

The Impact of Biophilic Design on Cognitive Map Performance: A Case Study on Girls Primary Public Schools in Bahrain

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Abstract

Previous studies have demonstrated a positive relationship between biophilic design strategies and cognitive function. However, similar effects on primary schools, the main space influencing children's spatial perception, have yet to be explored. The study adopts qualitative and quantitative approaches to investigate the impact of biophilic design attributes on children's cognitive performance, aiming to improve wayfinding strategies in primary schools in Bahrain. While the interviews with boys and girls from different schools assisted in defining the study area and children's gender, an expert in school design shed light on wayfinding parameters used in Bahrain. The cognitive map drawings collected from 67 girls between 9 and 11 allowed the study to determine the characteristics that influence girls' spatial perception. The study findings demonstrate the potential of each biophilic design attribute as an opportunity to design future primary schools in Bahrain that provide healthy and sustainable spaces for children to thrive and develop.

Keywords: Biophilic Design; Cognitive Development; Cognitive Map, Primary School; Wayfinding; Bahrain.

1. Introduction

People often struggle to navigate within complex indoor environments, which may leave them feeling lost and disoriented. This maze-like environment can cause stress and have negative implications for individuals' cognitive development, leading to inefficient wayfinding (Jiang et al., 2022). In this context, "cognitive" refers to the mental processes involved in acquiring and manipulating knowledge, serving as an insightful reflection of the human mind. Meanwhile, "development" denotes alterations in the structure or function of an individual over time (Bjorklund, 2022). According to Piaget's cognitive development theory, disorientation among children is especially crucial, as their cognitive maps are still forming and developing at that age, especially when young children overestimate their navigational abilities, which increases their risk of being lost (Piaget, 2005).

There are various factors that influence children's cognitive development, including social context, knowledge, and how information is presented (Bjorklund, 2022). Given that children spend a significant portion of their day in school, educational institutions have become one of the most significant influences on future generations (Nagy & Sayed, 2020; Watchman et al., 2022). However, there have been few studies exploring the connection between cognitive function and school wayfinding performance. Although high learning expectations can lead to pressure and stress in children, negatively impacting their cognitive function (Asim & Shree, 2019), inefficient wayfinding performance in poorly designed buildings can also cause additional stress (Jiang et al., 2022).

Children's anxiety and stress might not be completely eliminated. Still, exposure to nature has been proven to significantly improve their experience in school and enhance their attention, memory, mental abilities, and cognitive function (Browning & Ryan, 2020). Biophilia, which refers to the innate human connection to nature, is crucial for engaging children with the natural environment and promoting their cognitive development and wayfinding performance (Fidan et al. 2021). However, this approach is rarely implemented in schools despite the benefits (Almusaed et al., 2022; Watchman et al., 2021; Yaseen & Mustafa, 2023). The concept of 'learning from nature' has been a recurring theme throughout history, but using nature as a setting for school design is a relatively new idea (Browning & Ryan, 2020). Unfortunately, many educational institutions fail to connect nature with the classrooms, which can have negative consequences for students' behavior (Nagy & Sayed, 2020). While Figure 1 demonstrates the connection between biophilic design and children, further research in primary schools is required to determine how biophilic design affects children's spatial awareness.

In addition to the restorative benefits of biophilic design, providing efficient wayfinding in primary schools offers an environment that is safe and navigable for students, teachers, and visitors. It ensures that navigation is accessible to all individuals regardless of their physical or sensory abilities. It reduces the time to arrive at the desired destinations without disruptions to teaching and learning. Therefore, this study employed a descriptive and analytical approach to explore the potential of biophilic design elements to enhance cognitive maps among primary school children in Bahrain (Figure 2). This study aims to evaluate the biophilic design's potential to improve children's cognitive performance in primary schools in Bahrain by investigating the following objectives:

- 1) Identify the influence of biophilic design elements on children's cognitive maps based on individual differences.
- 2) Identify the wayfinding parameters used in schools in Bahrain.
- 3) Assess the impact of biophilic design and cognitive performance in children.

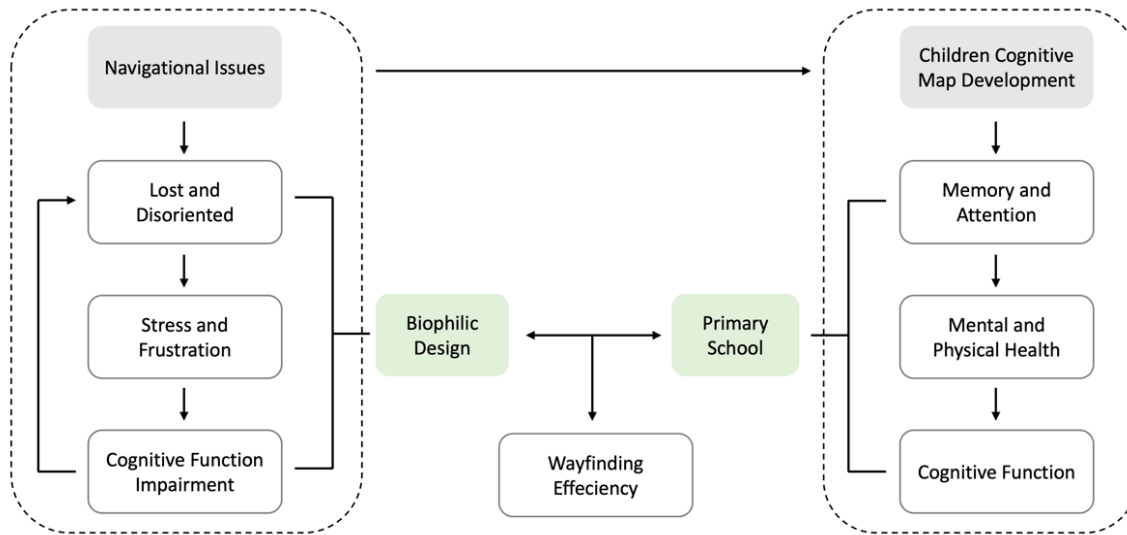


Figure 1. Identifying the research problem (Developed by Author).

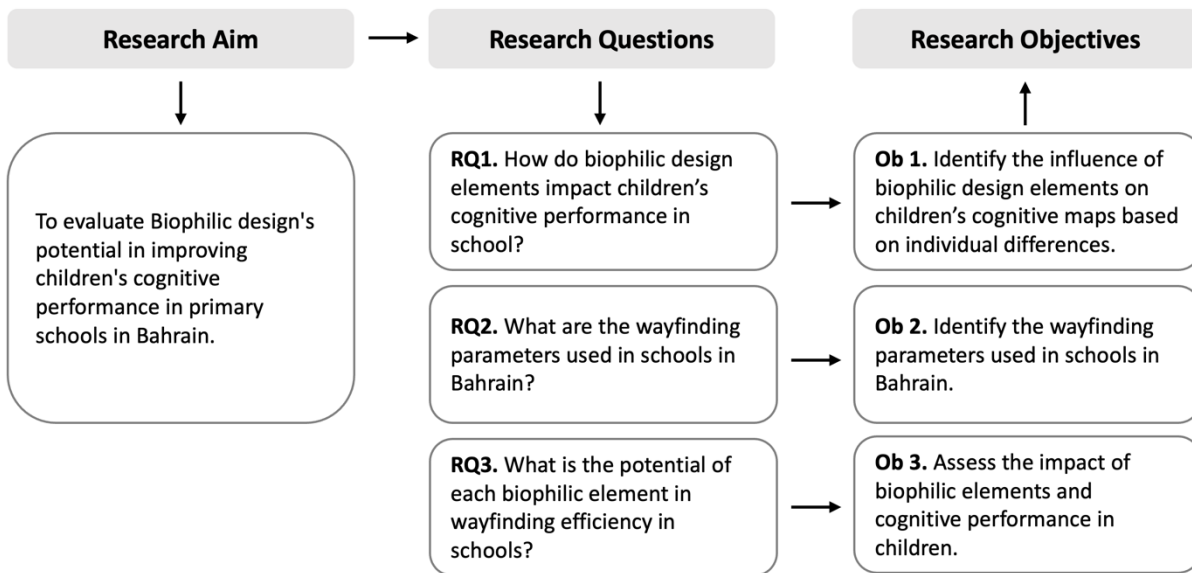


Figure 2. The connection between the research aim, questions, and objectives (Developed by Author).

To achieve these objectives, the literature on cognitive map development and biophilic design theories are examined in the second section. This section takes a qualitative approach to review the impact, importance, and association between cognitive maps and biophilic design in primary schools. The third section will discuss the practical methodologies used in the study, including qualitative and quantitative data collection and analysis. The fourth and fifth sections review and discuss the results obtained from the selected case study through a descriptive and analytical approach using interviews and cognitive map activities with children. The study concludes by determining the relationship between each biophilic element and cognitive function in children in primary schools in Bahrain.

2. Literature Review:

Cognitive mapping refers to cognitive ability in navigation and wayfinding. Tolman first defined it in 1948 as the ability to orient and navigate within a space and assist individuals in reaching their desired destination by gathering mental information from their surroundings (Tolman, 1948). Biologically, cognitive maps are composed of different cell combinations located in the brain that are activated in response to various stimulants perceived from the environment and interpreted as an abstract representation of the surroundings (Bond, 2020).

While many neurological studies have focused on comprehending this cognitive map in adults (Burles et al., 2019), psychologist Jean Piaget in 1967 explored the development of this theory in young children, suggesting that spatial knowledge evolves throughout a person's life. Spatial knowledge among children differs based on age, gender, and mental representation (mental image) of their surroundings (Arnold et al., 2013), which is necessary to achieve a practical cognitive map. This mental image is also referred to as "imageability," which is the degree to which physical elements evoke images in an observer's mind (Lynch, 1960). When the quality of the objects is strong in evoking images, the space becomes easily comprehended and understandable (legible). Although Lynch examined environmental imageability and legibility in relation to urban and city scales, legibility is also required for indoor navigation and wayfinding processes (Fidan et al., 2021). Thus, environmental legibility is essential for effectively utilizing spatial knowledge to achieve a positive cognitive map performance.

At an early age, children lack the necessary spatial perception to grasp the concept of spatial perception; however, this perception evolves and adapts with age. To understand navigational behaviors, it is crucial to consider children's cognitive capacities at various physical and mental developmental stages (Liapae et al., 2020; Türel & Ayşe Gür, 2019). Jean Piaget, who studied the constructive approach to how kids perceived the environment in 1960, analyzed child cognitive development based on age and defined it in four stages: Sensorimotor, Preoperational, Concrete Operational, and Formal Operational (Piaget, 2005). These stage-based mental development stages result from children's interaction and experimentation with their environment. However, Burles et al.'s study, which tested children's cognitive map in a virtual reality setting, defined the age of 9 as the milestone for cognitive development in children (Burles et al., 2019). Other studies on cognitive map drawings suggest that children ages 6 to 8 have the tendency to employ symbols in their drawings. Nonetheless, children can comprehend views of aerial images by the age of 9. By the time they are 11 years old, they can read navigational maps, identify significant elements, and produce accurate perceptual maps (Catling, 1979).

In the context of individual differences, the results of an experimental study on the spatial cognitive maps of 11-year-old children of both genders showed that boys had a stronger spatial structure in their cognitive maps compared to girls (Canakcioglu, 2015). In contrast, Sigurjónsson et al. (2020) have found minimal or no differences in how boys and girls perform a wayfinding task. However, boys tend to solve the wayfinding task more quickly than girls. It is worth noting that both boys and girls perform better as they age, and this development is equal in both genders (Sigurjónsson et al., 2020). Despite these distinctions, it is essential to recognize three key variables: cognitive map, primary schools, and biophilic design. A comprehensive understanding of these variables will be explored in the following subsections.

2.1. Cognitive Maps in Primary Schools

In most cases, children attend school for over one-third of the day (Liapae et al., 2020), and elementary schools have become the primary setting to achieve positive cognitive map development. Although a school might seem like an educational facility block, it represents a mini-city that offers shared benefits between the city itself (school) and its population (students) (Türel & Ayşe Gür, 2019). The structural and physical elements of the school are the primary factors that influence children's spatial perception and ability to construct mental images. While Türel and Ayşe Gür (2019) examined the physical traits of different schools and how they influence children at various stages of their cognitive development, Liapae et al. (2020) focused on students' interactions with physical characteristics and how different elements evoke their mental images depending on their perception. Both studies evaluated students' drawings of maps that visualized their spatial perception from a point to a destination and suggested that children's spatial abilities are improved by "visual stimulants" such as texture, colors, abstract symbols, and scale change. However, Türel and Ayşe Gür's results also revealed that rarely visited locations had little involvement in their perception that flexible, open, and adaptive settings impact both behavior and spatial perception, and students primarily rely on reference points as a navigational strategy.

In contrast, Liapae et al. (2020) determined the most significant navigation signals in schools based on the age groups of children. Playgrounds are believed to have the most significant impact on children's mental images between the ages of seven and eight, green spaces impact children between nine and ten, and navigational signage influences children between the ages of 11 and 12. Perhaps due to their emotional attachment to playtime in the youngest age group and natural attachment for children aged 9 to 10, those aged between 11 and 12 are beginning to form an understanding of the wayfinding concept.

2.2. Cognitive Maps Through Biophilic Design

Although many environmental elements help provoke mental images, nature provides an appreciative setting for cognitive performance and development. Research on the human-nature connection has concentrated on psychological effects, such as stress and cognitive response, as well as physical effects, such as heart rate and blood pressure (Browning & Ryan, 2020). Eventually, this relationship with nature-inspired restoration theory proposes that cognitive function and performance are improved (Kaplan & Kaplan, 1989), which suggests a biological link between people and nature and how they interact with nature within the built environment (Wilson, 1984). In addition to restoring the relationship between humans and nature, it will also contribute to the development of sustainable architecture, building quality, and psychological and physiological benefits, such as mental health, overall well-being, and cognitive performance (Zhong et al., 2023).

Asim and Shree (2019) proposed that understanding the effect of "Biophilic Variables" on "Perceived Restorativeness" and "Emotional Stability" can shed light on essential natural psychological aspects. They proposed that design should mediate between students and nature rather than a "containment" for students (Asim & Shree, 2019). Researchers investigating the correlation between students' emotional stability and biophilic environmental variables found that these variables strongly support the creation of restorative environments. Accordingly, Asim and Shree suggested that the effect of the variables can be increased through proper design solutions to improve students' ability to perceive their surroundings as restorative. Moreover, for the restorative biophilic environmental elements to be part of children's perception of their environment, the study suggests that exposing children to natural settings supports their mental health and improves their functional and spatial cognitive performance.

Various studies have also supported the findings concerning the relationship between natural elements and humans. Aristizabal et al. (2021) suggested that biophilic design strategies improve functional and spatial cognitive performances (Aristizabal et al., 2021). These strategies allow users to have fewer stops to observe signage, shorter walking distances and reduced time consumption due to the correct selection of a more efficient route during the experiment (Jiang et al., 2022). Moreover, biophilic design is seen to enhance students' academic performance and lower stress levels than students in a "non-biophilic" classroom (Determan et al., 2019).

2.3. Biophilic Design in Primary Schools

While many schools seek to provide a high-quality learning experience that satisfies both present and future requirements, the lack of thorough awareness of biophilic design strategies and comprehensive guidelines on how to apply them has resulted in inefficiency and inadequacy of integration of nature in schools (Watchman et al., 2022; Yaseen & Mustafa, 2023). To avoid interfering with the learning process and avoid subjective results solely based on participants' perceptions and self-reported evaluations, their study proposed an evaluation instrument that measures the existing school's architectural features to examine the biophilic attributes needed. Before conducting an in-depth review and site inspection, this tool seeks to discover the potential biophilic aspects of buildings in the initial renovation phase. It also provides a preliminary assessment of various educational institutions.

A study investigating the relationship between children and nature in schools implemented direct experiences with nature's biophilic attributes in classrooms, such as natural materials and colors, natural shapes and forms, light, air, animals, plants, and water, as intervention measures (Miller, 2018). Similarly, Watchman et al. (2022), who studied how humans and nature integrate from the perspective of "direct sensory experience" from architectural drawings, suggested that architectural drawings can be used to demonstrate issues and quantify architectural information related to biophilia. Beyond physical and psychological improvements, this study allows school administrators to debate building certification requirements. It provides designers with quick access to comparative design options, rapid diagnosis of biophilic issues in existing schools, and design recommendations to be applied during the renovation.

2.4. Cognitive Maps Through Biophilic Design in Primary Schools

Based on the previous literature, the three variables (children, cognitive maps, and biophilic design elements) are crucial to wayfinding efficiency in schools. Although finding a comprehensive relationship between them is rare in the literature realm, Fidan et al. (2021) explored biophilic elements in an elementary school as a wayfinding strategy. This study proposes merging Lynch's elements of imageability with biophilic elements in a school setting (Fidan et al., 2021). These elements were suggested for children to use in cognitive map drawings to measure their spatial perception of their school. The study found that 80% of the students who participated in this experiment were lost during the cognitive-mapping process. However, biophilic edges and landmarks were seen as the most important features that enabled children to transition between the defined spaces. Most importantly, Fidan et al. (2021) found that biophilic design elements improve wayfinding performance in elementary schools. In summary, the literature review explores the potential of biophilic design in enhancing children's learning environments and spatial cognition. It aims to reduce the stress caused by navigational problems or navigational problems caused by stress. These studies used varied methodologies, including technological, psychological, and spatial approaches. Cognitive drawing methods were used to understand the psychological aspects of cognitive performance. In contrast, building and technical drawing analysis tools were used to analyze the effect of spatial and physical characteristics on cognitive performance. In conclusion, biophilic design strategies are essential for wayfinding in primary schools. They connect students with nature, provide a healthy environment, reduce stress, contribute to their well-being, and bring back some of the qualities fading within a busy educational environment (Figure 1).

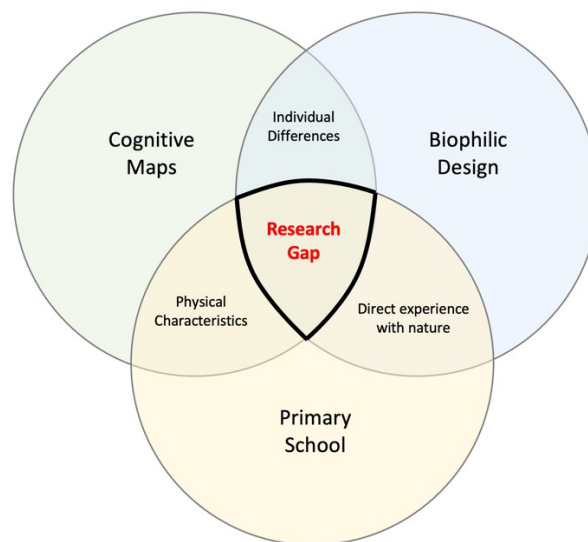


Figure 3. Wayfinding efficiency through biophilic design strategies in primary schools (Developed by Author).

3. Methodology

Although biophilic design strategies have been shown to improve cognitive performance, prioritizing cognitive development strategies in public schools in Bahrain is a subject of debate. The purpose of this study is to evaluate Biophilic design's potential to improve children's cognitive performance in primary schools in Bahrain. To guide the study design and methodology selection, common themes emerged from the literature review: individual differences, physical characteristics, and direct experience with nature. These themes informed the development of a three-stage study.

The common themes were aligned to the study's objectives throughout the three stages. The first stage focused on examining the impact of biophilic design elements on children's cognitive maps based on gender and school type. This was done through a qualitative data collection and analysis approach, including cognitive map activity with children. The second stage focused on schools' wayfinding parameters and physical characteristics used in Bahrain through semi-structured interview with school design expert as a descriptive analysis approach. The third stage, with an analytical approach, focused on a non-intervention observation study, which aims to quantify and qualify the impact of biophilic elements and cognitive performance in children (Figure 4). The study's three-stage qualitative and quantitative innovative approach allowed the study to address the main question of whether biophilic design elements affect children's cognitive performance in primary schools in Bahrain. The following subsections will discuss the study's theoretical framework, data collection and analysis methods, methodology integration with the study's design, and ethical considerations in relation to children.

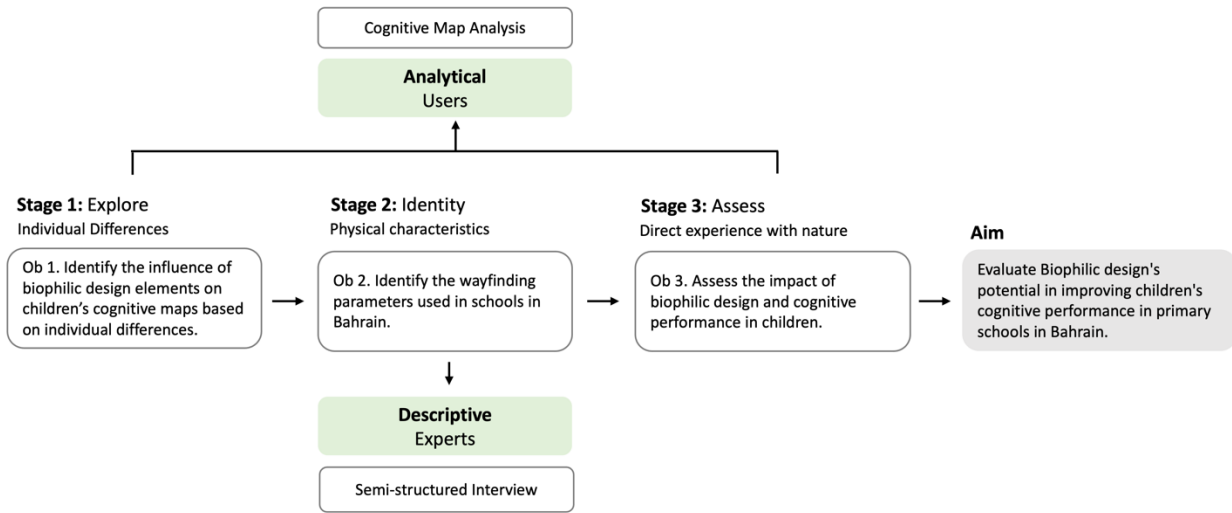


Figure 4. An analytical and descriptive study design shows the objective’s integration with the study’s three stages (Developed by Author).

3.1. Theoretical Framework

While Tolman’s theory in 1932 stated that a cognitive map is when individuals collect cues from the environment and could use these to build a mental image of their environments (Tolman, 1948), other studies defined cognitive maps as the representation of people’s knowledge, which depends on the spatial and environmental relation to the surrounding space (Kitchin, 2015). Furthermore, Jean Piaget, who studied the constructive approach to how kids perceived the environment in 1960, analyzed child cognitive development based on age and defined them in four stages: Sensorimotor, Preoperational, Concrete Operational, and Formal Operational (Piaget, 2005). These fast-based mental development stages result from children’s interaction and experimentation with their environment. However, Burles et al.’s study, which tested children’s cognitive map in a virtual reality setting, defined the age of 9 as the milestone for cognitive development in children (Burles et al., 2019).

On the other hand, the analysis of an experimental study on children of both genders at the age of 11 demonstrated that boys’ spatial structure of their cognitive maps is stronger than girls’ mental maps (Canakcioglu, 2015), implying that the result could be due to cultural and societal influences as girls could be raised in a more inward-focused manner than boys, which could have limited their cognitive development from a young age. Other studies on cognitive map drawings suggest that children ages 6 to 8 have the tendency to employ symbols in their drawings. Nonetheless, children can comprehend views of aerial images by the age of 9. By the time they are 11 years old, they can read navigational maps, identify significant elements, and produce accurate perceptual maps (Catling, 1979).

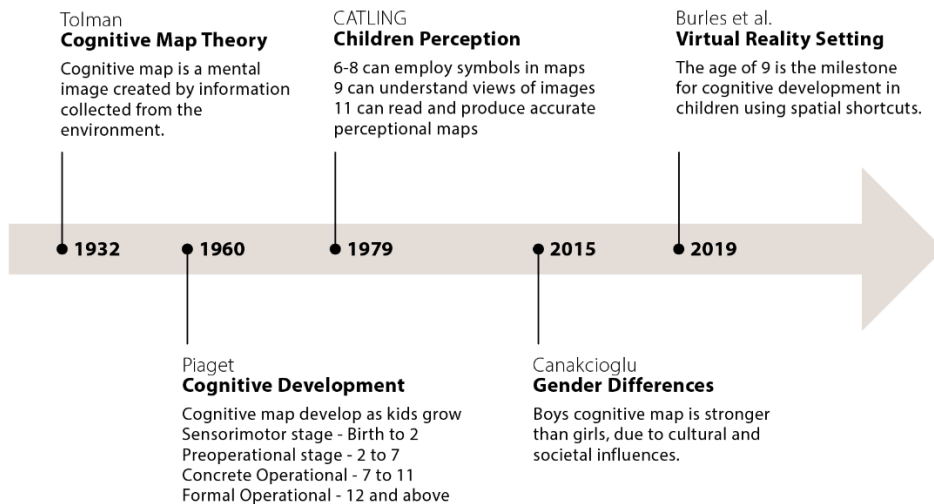


Figure 5. Theoretical Framework adopted in the study methodology (Developed by Author).

Based on the above review summarized in Figure 5, this research will conduct cognitive map analysis through constructivist epistemology as a critique to qualify how the mind is perceived as a "passive system" that gathers its contents from its environment (Balbi, J., 2008). The constructivist approach allowed the study to deconstruct the problem into essential cognitive map variables, such as age group and gender. Although primary schools in Bahrain include children aged 6 to 12, this study will approach students between 9 to 11 years old through their school's administrators. At this age, children can understand vires of images, read and produce accurate perceptual maps, able to use spatial shortcuts. This is considered the most crucial period of cognitive map development. Meanwhile, gender was identified after cognitive map data collection and analysis in stage 1.

3.2. Methodological Planning and Data Collection

This study adopted descriptive and observational approaches as it aimed to assess the influence of biophilic design interventions on children's cognitive maps. To define the school type and gender to be used in this study, stage one focused on children's spatial perception of their school through a drawing activity with four children between 9 and 11: two boys and two girls from public and private schools. The study focused on determining the existence of Epstein et al.'s three elements of the cognitive map: spatial coding, landmark anchoring, and route planning (Epstein et al., 2017). These elements will enable the study to identify and analyze specific aspects of the drawings based on individual differences, in this case, gender.

The second stage of the study aimed to gather information concerning the role of designers and decision-makers in ensuring positive educational experiences for children. It also aimed to investigate and identify the strategies employed in prioritizing wayfinding within schools in Bahrain. To achieve these objectives, a semi-structured interview was conducted with the Chief of the Building Design Section and the Acting Director of the Construction Projects Directorate from the Ministry of Work. The collected data from the interview were then analyzed through a deductive approach to categorize information and extract the main wayfinding parameters.

After identifying the gender and wayfinding parameters from stage one and two, stage three focused on collecting drawn sketches from children between 9 and 11. These sketches represent children's understanding of spatial relations and how to go from one place to another when designing a cognitive map (Fidan et al., 2021). The drawings were qualitatively and quantitatively analyzed through MAXQDA software to gain accurate data concerning children's cognitive map strategies. Although a randomized controlled trial can examine the extent of biophilic design interventions on children's cognitive performance, this approach is time-consuming and challenging without interfering with the education flow. Therefore, an observational approach depending on drawing analysis was adopted.

3.3. Integration with Study Design

The selected data collection methods will assist in investigating the research objectives through the study design adopted. The first stage allowed the study to identify the age group and school type, shown in Table 1. The descriptive study approach through semi-structured interviews allowed the study to investigate the current wayfinding parameters used in school designs in Bahrain. Furthermore, the observational analysis, as part of the analytical approach, through cognitive map drawings with the children, which guided the study to assess the biophilic elements affecting children's cognitive performance. Investigating these areas ultimately assessed in answering the research question.

Table 1. Integration of data collection method with study design to investigate the research objectives.

Study Stage	Study Approach	Population	Data Collection	Data Analysis	Study Objectives
Stage 1: Spatial Perception	Analytical	9-11 years old Two boys & Two girls Public & private schools	Interview & cognitive map drawings	- Spatial coding - Landmark anchoring - Route planning	Identify the influence of biophilic design elements on children's cognitive maps based on individual differences.
Stage 2: Wayfinding Parameters	Descriptive	The Chief of the Building Design Section & the Acting Director of the Construction Projects Directorate. Bahrain Ministry of Work	Semi-structured Interview	Categorizing information through a deductive approach	Identify the wayfinding parameters used in schools in Bahrain.
Stage 3: Cognitive Map	Analytical	9-11 years old Girls from a public school *	Cognitive map drawings	MAXQDA software	Assess the impact of biophilic elements and cognitive performance in children.

* Gender and school were identified after the analysis of stage 1

Familiarization with the data collection method is a crucial factor for this study. To achieve the intended outcome within the timeframe, the study explored various techniques in conducting case study analysis, including clarifying

the key elements which will be focused on, such as layout, nature exposure, and indoor wayfinding strategies. Additionally, as cognitive map drawings by children can be unpredictable and challenging to understand without experts and psychological analysis, the study will focus on determining Epstein et al.'s three elements of cognitive map only: spatial coding, landmark anchoring, and route planning. This will enable the study to identify and analyze specific aspects of the drawings (Epstein et al., 2017).

While the qualitative and quantitative methods will be assessed in meeting the research objectives, this innovative study design and its methods contribute to advancing their usage in future studies. From the descriptive approach, the case study provides a first-hand observation from experts in the Ministry of Works regarding public school designs. While the analytical approach will shed light on the students' cognitive mapping and wayfinding abilities, bridging the gap between the design and its users. Reviewing student's cognitive maps, in addition to retrieval of information from the Ministry of Works experts through conducting leader interviews and reviewing public schools' technical drawings, will bridge the gap between the decision-makers and students, paving the way for a user-based approach in concern to the wayfinding performance. The methodology in this research will significantly contribute to raising awareness surrounding cognitive mapping and wayfinding in Bahrain, a country lacking in naturally green sceneries due to its climate. Additionally, reviewing all the collected data allowed the study to assess each biophilic design element and its relation to children's cognitive performance.

3.4. Ethical Considerations

Ethical matters were considered in this study, including permission from the school administration to enter the school and speak with the children, voluntary participation, avoidance of improper language, and privacy of the respondents during the data collection process. The name of the selected school will remain anonymous, as requested by the administrators.

4. Results

The study aimed to enhance children's cognitive map and wayfinding performance in primary schools in Bahrain through biophilic design strategies, emphasizing the current elements affecting children's wayfinding strategies and the role of stakeholders and decision-makers in ensuring a positive spatial experience in Bahrain. The study questioned the role of biophilic elements in children's cognitive maps in schools in Bahrain. According to Piaget's theory of cognitive map development, the study was conducted with the 9–11 age group, representing the period of tangible operations. Many studies focused on children's cognitive map differences based on gender. However, no studies were found focusing on one gender. Therefore, this study used three data collection stages to establish the gap in schools in Bahrain. This section will focus on the results obtained from the three stages.

Stage 1: Spatial Perception

The first study objective was approached by conducting a cognitive map drawing activity with four children between 9 and 11. Two boys and two girls from public and private schools in Bahrain to evaluate their spatial perception of their school. In addition to descriptive drawings, the study first focused on determining and quantifying the existence of Epstein et al.'s three elements of the cognitive map: spatial coding, landmark anchoring, and route planning. These elements enabled the study to identify and analyze specific aspects of the drawings (Epstein et al., 2017).

Although spatial coding allows individuals to create mental images of their surrounding environment, it also involves locations, distance, position, and orientation of spaces and the relation between them. Children from private schools showed lower accuracy of dimensions and distance; most classrooms were indicated as a flush door on a wall rather than a 3-dimensional volume. However, the route planning in public school children's drawings suggests a level of orientation and distance awareness (Table 2).

Stage 2: Wayfinding Parameters

The study conducted an interview with the Chief of the Building Design Section and the Acting Director of the Construction Projects Directorate from the Ministry of Work. The Directorate has been working on public school designs in Bahrain since 2006, indicating that public school designs in Bahrain depend on regulations from multiple authorities. For instance, Urban Planning and Development Authority regulations are used for land specification, the Ministry of Municipalities regulations for property boundaries and heights, safety regulations from Bahrain Civil Defense, and EWA for water and electricity regulations. However, the school design depends primarily on experiences with the Ministry of Education regarding requirements and spatial layout, such as classrooms and school utilities.

The main aim of this stage is to Identify the wayfinding parameters used in schools in Bahrain. The interview was analyzed through a deductive approach to defining students' needs and considerations during the school design process. These considerations were then grouped into four categories: Safety and security, Comfort, Spatial Planning, integration of sustainability, technology, and creativity (Figure 4). Spatial planning is categorized into three main approaches, including open spaces, indoor spaces, and circulation. All three aspects were selected as current strategies for wayfinding in public schools' design to be explored and evaluated in stage 3.

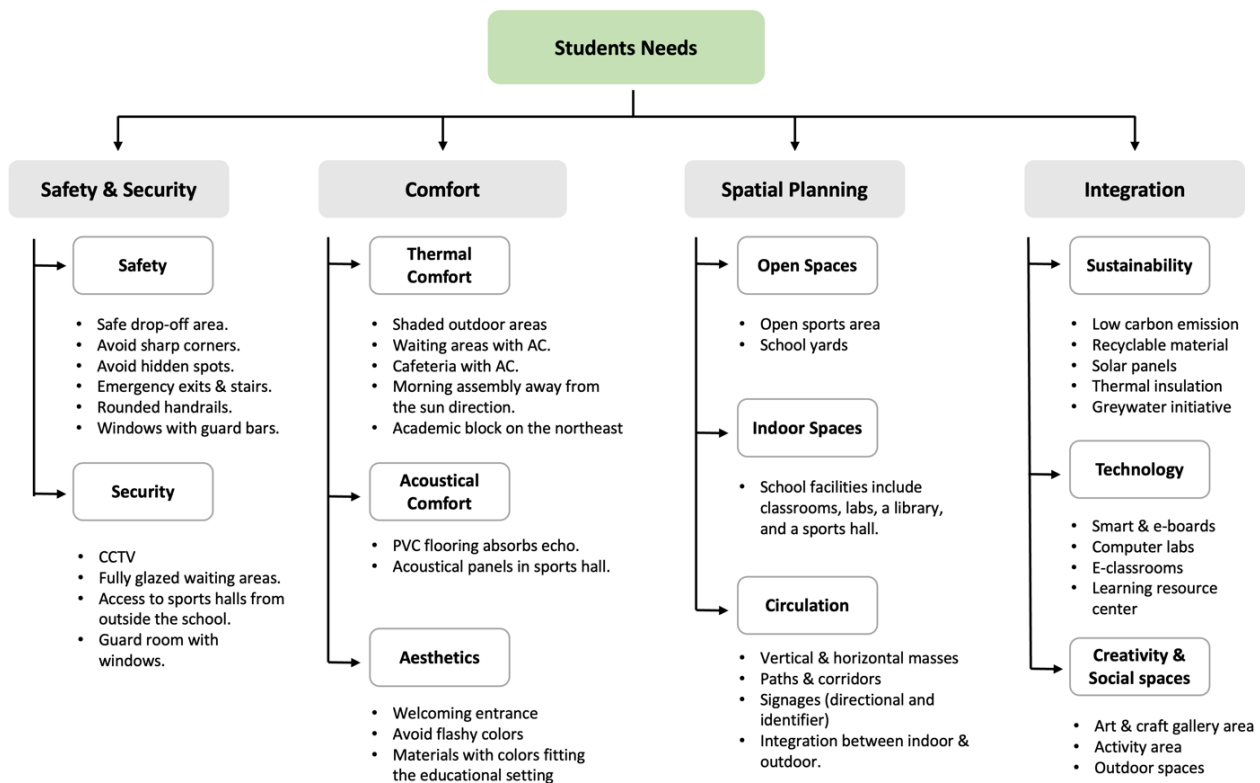

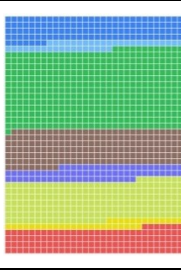

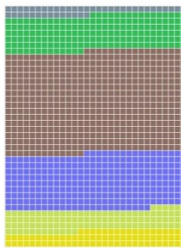

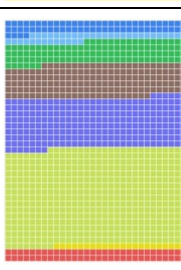


Figure 7: Student Needs in Public Schools in Bahrain (Developed by Author).

Stage 3: Cognitive Map

This stage focused on assessing the impact of biophilic elements and cognitive performance in children. The study analyzed 67 sketches through MAXQDA software to determine the coverage percentage of these parameters in the drawings. Based on the findings from the drawings, nine segments and characteristics were identified as children's cognitive map strategies. These segments include school entrances, classrooms, labs, facilities, offices, yards, natural elements, corridors, and stairs (Table 3). A strong connection is found when comparing these segments to spatial planning strategies extracted from stage 2.

Table 3. Example of cognitive map drawings analyzed by MAXQDA.

Sketch	Age	Description	Coverage (%)	Visual Analysis
	9yrs	Dark Blue: Labs Green: Nature Yellow: Stairs Light Blue: Offices Yellow: Corridors Brown: Entrance Brown: Yard Purple: Classrooms Red: Facilities	8.82% 36.51% 1.15% 2.25% 8.40% 0.49% 17.05% 1.98% 12.20%	
	10yrs	Brown: Yard Purple: Classrooms Yellow: Stairs Brown: Entrance Yellow: Corridors Green: Nature	6.80% 6.09% 1.36% 0.67% 3.00% 5.59%	
	11yrs	Brown: Entrance Dark Blue: Labs Red: Facilities Purple: Classrooms Yellow: Stairs Yellow: Corridors Brown: Yard Green: Nature Light Blue: Offices	2.34% 4.77% 3.61% 23.48% 0.46% 14.00% 3.36% 6.58% 3.47%	

5. Discussion

The analysis of the sketches shows that for children between the ages of 9 and 11 are demonstrate in Figure 8a. The frequency of classrooms being drawn in children’s sketches reached (24%), suggesting that it is the most critical and larger segment in their cognitive map. Followed by corridors, which covered (20.5%) of the children’s drawings. Schoolyard and natural elements were recorded as children's third most frequent cognitive elements used in the drawings, reaching (13.5%) and (10.6%), suggesting a moderate impact of natural elements on children’s cognitive map. The least used element by the children is the school facilities, which barely covered (5.8%) of the children's drawings. This could be due to low frequency of children using these facilities compared to other schools’ functions.

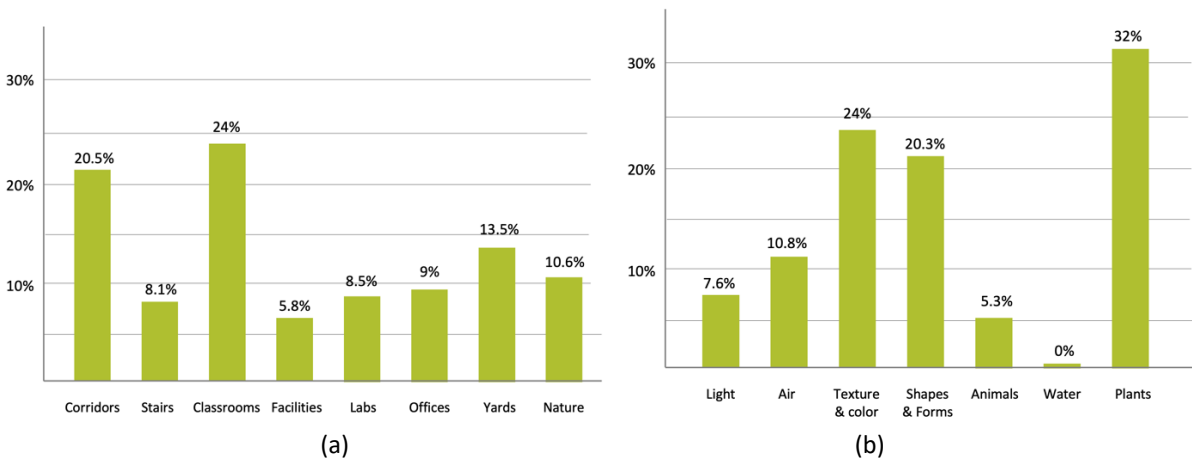


Figure 8: (a) Frequency of cognitive elements in children's mental map. (b) Frequency of biophilic design attributes in children's mental map. (Developed by Author).

The study showed that cognitive map analysis is an effective method for children to visualize their cognitive map and for researchers to analyze it. However, two limitations can be noted: the low number of samples obtained in this study due to time constraints and the difference in children's maps as their drawing abilities differ. Accordingly, the study statistically analyzed the received drawings by dividing them into percentages and occurrence frequency. Furthermore, sketches that did not have sufficient clarity for analysis were dismissed. Although ethical matters were considered in this study, including voluntary participation, avoidance of improper language, and privacy of the respondents during the data collection process, gaining access to the school to conduct the cognitive map activity with children was the main challenge. Obtaining early permission to access the school could improve the study by allowing for further exploration and observation of the school. Another improvement that can be made is adjusting the cognitive activity task to include a full image of the school instead of focusing on the journey from the school entrance to the classroom, which might eliminate other physical spaces not included in this journey.

6. Conclusion

In conclusion, this study aimed to evaluate biophilic design's potential in improving children's cognitive performance in primary schools in Bahrain. Through its qualitative and quantitative approaches, including interviews and children's cognitive map drawings activities, the study was able to answer the research objectives. Gender differences between children has not been recorded to change the influence of biophilic design elements on their cognitive maps in the first stage of the study. Instead, schools' biophilic physical characteristics, such as the connection between indoors and outdoors and the availability of greenery, are the main factors influencing children's cognitive maps.

These findings were supported by findings from the second stage, which focused on identifying wayfinding parameters in schools in Bahrain. Spatial planning, including outdoor space, indoor spaces, and circulation, were the strategies that experts and decision-makers approach to ensure a successful learning experience for students. Public schools in Bahrain have a strong integration of natural elements that enhance children's cognitive performance. Although the allocated budget for building public schools in Bahrain is limited, biophilic elements are unintentionally implemented. Plants, materials, and shapes are the most significant biophilic elements in impacting children's cognitive performance in Bahrain, followed by air and light. These findings allowed the study to address the third objective, which focuses on the impact of biophilic elements on children's cognitive performance. Integrating natural elements and biophilic attributes significantly affects children's cognitive development and well-being. It also offers students and teachers a safe, navigable, and accessible environment. Emphasizing the benefits of natural elements on children's physical and mental well-being can lead to incorporating them as requirements for public school building regulations.

One of the study limitations is utilizing one case study for this research. Comparing cognitive function from more than one school can improve the result's reliability and reduce the risk of subjectivity. Another limitation is the number of drawings samples obtained and analyzed in this study. A larger number of drawings can strengthen the data and the findings. The limited time allocated for the cognitive map activity for the children may have restricted the outcomes. Allowing children more time to emerge in their drawings could introduce more elements and colors and enhance the quality of their drawings. In a deserted country, such as Bahrain, biophilic elements could differ from elements in greenery-rich countries. Future studies can focus on the influence of culture, background, and school location on cognitive performance. Other directions could include a comparison between two case studies with the same or different genders or between public and private schools. Moreover, the degree of influence of each biophilic element could also be explored.

Acknowledgements

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Conflict of Interests

The Author (s) declare(s) that there is no conflict of interest.

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