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Evaluating Biophilic Design Characteristics in Lincoln Public Schools

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EVALUATING BIOPHILIC DESIGN CHARACTERISTICS IN LINCOLN PUBLIC
SCHOOLS

by

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EVALUATING BIOPHILIC DESIGN CHARACTERISTICS IN LINCOLN PUBLIC SCHOOLS

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A mixed qualitative-quantitative study was conducted in Lincoln, Nebraska to observe and evaluate the biophilic design characteristics in Lincoln Public Schools (LPS). There is a significant lack of nature in urban environments, especially in older buildings and schools, therefore incorporating natural elements in school buildings can promote the success of students and contribute to improved well-being. The research question this study aims to address is: How and to what degree are Lincoln Public Schools integrating biophilic design characteristics in their high school buildings? Four high schools were toured utilizing an evaluation form with 10 biophilic design characteristics and a 5-point presence rating scale. Findings reveal an increased presence of biophilic design characteristics in the newer high school buildings and an evolution of the design between the older and newer schools. LPS has improved with the integration of biophilic design characteristics in their high school buildings in recent years. This is most prominently represented by the spaciousness, use of natural materials, abundance of natural sunlight, large windows, gardens, and landscaping. School D incorporates the most biophilic design characteristics and students at the school are expected to have the best academic performance, classroom experience, attention levels, and well-being overall compared to the other three schools due to the abundance of natural light, nature views, large windows, and landscaping.

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Introduction

Biophilic design is a concept that focuses on connecting humans and nature by incorporating natural elements into the built environment. The purpose of this thesis project is to observe and evaluate the biophilic design characteristics in Lincoln Public Schools (LPS). The significance of the study is to generate new knowledge about the presence of biophilic design characteristics, specifically in LPS high schools. The goal is to educate school officials and the local community about the benefits of incorporating biophilic design characteristics in schools and possibly encourage future use of biophilic design in schools. This study attempts to address the need for an evaluation of the current use of biophilic design characteristics in Lincoln Public Schools. Evaluating current applications of biophilic design will provide baseline knowledge for future improvements in sustainability efforts within the school system. Implications of biophilic design in schools, including improved student performance, reduced stress, and increased mood and well-being, will be discussed.

Significance of the Study

Biophilic design can improve mental, physical, and psychological health by incorporating natural elements into built environments. Children spend most of their day at school therefore the physical environment of the school building and classrooms influence students' learning and academic performance (Kelz et. al., 2015). In addition, students are often stressed due to assignments, homework, and exams. Studies have revealed that students experience many benefits from contact with nature such as reduced stress, increased well-being, positive classroom experiences, and better grades. In fact, research shows that humans prefer natural environments rather than built ones (Van den Berg et al., 2003), but there is a significant lack of nature in urban environments, especially in older buildings and schools. Merging indoor and outdoor spaces could lead to a greater appreciation for nature, beautiful and energizing spaces, and mental health benefits. Furthermore, incorporating nature into schools is a great way to promote the success of students and contribute to improved well-being. School districts and planners have the power to design schools with biophilia in mind which can benefit students' academic performance and well-being.

Research Question and Objectives

The research question for this study is: *How and to what degree are Lincoln Public Schools integrating biophilic design characteristics in their high school buildings?* The biophilic design characteristics that will be evaluated are indoor plants, quality views of nature, natural light, color choices, landscaping, natural forms, artwork depicting nature, natural materials, gardens, and spaciousness. In total, there are eight LPS high school buildings. Four of the high

schools were built before 2000 and four were built after 2000, two of which opened in the last two years (2022 and 2023).

The objectives of this study are as follows:

- Create an evaluation tool to assess the presence of biophilic design characteristics in LPS high schools.
- Provide a baseline understanding of the degree to which LPS high schools integrate biophilic design characteristics into their school buildings.

The assumptions for this study are that the recently built schools and renovated areas will contain more biophilic design characteristics such as large windows for ample sunlight and nature views, bright open spaces, earth-tone colors, a garden, and landscaping. The schools built in the 1900s and areas that haven't been renovated are expected to comprise less biophilic characteristics such as small windows, minimal sunlight and nature views, few open spaces, and lack an outdoor garden and landscaping. If older schools have undergone renovations then it is assumed that those spaces will incorporate more biophilic design characteristics. Lastly, it is expected that there was significant consideration of biophilic design when building the newer high schools due to recent studies and research revealing the benefits of biophilic design, and the prediction that LPS may have adopted new building design requirements. Some potential limitations to this study may be gaining access to tour schools and classrooms due to needing assistance to conduct tours or scheduling issues.

Literature Review

Background about Biophilic Design

Biophilic design is based on the concept of biophilia which Edward O. Wilson defines as “the innate tendency to focus on life and lifelike processes” (Wilson, 1984). Correspondingly, the biophilia hypothesis states that humans possess an inherent desire to connect with nature to satisfy our physical, aesthetic, intellectual, cognitive, and spiritual needs (Keller et al., 1995). In other words, humans and nature share a deep connection and studies have shown that nature has the capacity to restore energy, improve mental health, and increase well-being. In essence, biophilic design incorporates plants and other natural elements into indoor spaces. Designs include vertical plant walls, large windows for ample natural sunlight, wood/stone floors and walls, and indoor plants. Two popular theories related to biophilic design are the attention restoration theory (ART) and the psychological–evolutionary theory (PET).

Theories

Stephen Kaplan's attention restoration theory (ART) is one of the two major theories associated with the benefits of nature and biophilic design. Restoration is defined as "the process of renewing diminished functional resources and capabilities" (Kelz et al., 2015). Basically, the theory suggests that nature can restore depleted attention levels. In addition, the attention restoration theory suggests that exposure to nature can improve concentration as well as cognitive, prosocial, emotional, and physical energy (Kaplan, 1995) (Klotz et al., 2021). Humans use directed attention to focus and accomplish tasks, but have a limited attention span that depletes after extended use. At this point, individuals begin experiencing attention fatigue resulting in decreased efficiency and capability (Hartig et al., 1991). Fortunately, humans can restore depleted attention and recover from mental fatigue by spending time in restorative environments, which contain natural elements (Kaplan et al., 1998). Examples include a forest, lake, backyard, or indoor space with plants. The most restorative biophilic designs are ones that feel natural, not built, and fit with the character of the individuals occupying the space (Klotz et al., 2021). Specific examples include mountain views, an indoor creek, a forest surrounding the building, and using reclaimed materials. According to Kaplan, there are four features of restorative environments: being away, extent, fascination, and compatibility (Kaplan, 1995).

- **Being Away:** escaping the task that requires directed attention by moving to a restorative environment or shifting one's gaze.
- **Fascination:** requires no mental effort and is experienced by observing or experiencing nature. Examples include clouds, sunsets, birds chirping, or walking outside. These sights/sounds/activities are restoring because one's mind can wander.
- **Extent:** an environment that feels like a whole other world and is stimulating and engaging. One must be able to see, experience, and think about the environment.
- **Compatibility:** an environment that aligns with one's current and future goals.

Roger Ulrich's psychological–evolutionary theory (PET) is the other major theory. The difference between PET and ART is that PET is concerned with stress restoration rather than attention restoration (Hartig et al., 1991). PET also known as the stress reduction theory suggests that natural environments help us with stress recovery by stimulating involuntary attention, evoking a positive emotional response, and reducing heart rate and blood pressure (Ulrich et al., 1991). In a situation that is harmful, threatening, or challenging, people will experience stress and negative emotions which consumes energy, leading to fatigue (Brannon & Feist, 1997; Ulrich et al., 1991). Stress restoration means mentally and emotionally recovering as well as recharging the energy lost due to stress (Han et al., 2009). When humans are exposed to restorative environments such as landscapes and natural settings, they can experience more positive thoughts and emotions leading to regaining their cognitive functioning (Parsons, 1991; Ulrich, 1993).

Certification Programs

Biophilic design is a building concept that is referenced in green building certification programs such as LEED and WELL. LEED stands for Leadership in Energy and Environmental Design and is “the world’s most widely used green building rating system” (USGBC, 2023). In LEED v4, the most recent version, there is a pilot credit for biophilic design with the intent “To support and improve human health, well-being, and productivity by providing and incorporating elements of nature in the indoor environment” (USGBC, 2023). LEED also developed two rating systems specifically for K-12 schools, one for building design and construction and the other for operations and maintenance. The LEED for Schools programs were created to help school buildings become healthier for students, staff, and the environment as well as improve learning. The certification process focuses on several sustainability topics, including energy, water, health and human experience, innovation, and more (USGBC, 2017).

Furthermore, the WELL Building Standard v2, a similar program to LEED v4, is defined as “a vehicle for buildings and organizations to deliver more thoughtful and intentional spaces that enhance human health and well-being” (WELL, 2020). WELL also directly and indirectly refers to biophilic design in its standards.

Biophilic design is becoming a design standard to achieve sustainability goals and improve human health and well-being (Architect, 2012). Therefore, biophilic design is an important concept for architects, interior designers, and business owners to consider incorporating more frequently into projects due to the health and sustainability of the design such as air purification, using cheaper natural materials, and requiring less heating and cooling as well as less electrical lighting (Jiang et al., 2022).

Biophilia in Schools

Research related to the effects of incorporating biophilic design elements in schools mainly tends to focus on characteristics such as sunlight, windows, indoor plants, and playgrounds.

Sunlight

In a study conducted in 2000, Heschong investigated the connection between daylight and the academic performance of students at elementary schools in California, Washington, and Colorado. The results in all three states showed a strong connection between daylight, from windows or skylights, and improved exam scores (Heschong, 2000). Moreover, results show that in classrooms with the most natural light, students progressed faster on tests and achieved better test results compared to the classrooms with the least amount of natural light. Classrooms were evaluated based on “the size and tint of windows, the presence and type of any sky lighting, and the overall amount of daylight expected” (Heschong, 2000). In summary, there is a positive effect of daylight in classrooms on students’ academic performance.

Windows with Natural Views

A study conducted in 2015 by Benfield et al, provides insight into the impact of natural views on undergraduate college students. All of the students were enrolled in the same course but in different sections. Some of the classrooms had windows facing a concrete wall and the other classrooms had windows facing a grassy area with blooming trees. All other factors remained the same such as room layout, type and time of course, etc. The students were given a questionnaire at the beginning and end of the semester to rate their experience in the class. The results of the study show that students placed in a classroom with natural views rated the course curriculum and classroom resources higher or more positively than the students exposed to no natural view (Benfield et al., 2015). In addition, final course grades for students with the natural view were higher. This study doesn't explain why the natural views are linked to more positive ratings and grades but it is assumed that it is due to lower stress and improved mood (Benfield et al., 2015). All in all, the results of the study reveal that natural views positively impacted the student's grades and classroom experience.

Plants in Classrooms

Han et al found in their 2009 study involving eighth-grade students at a Taiwanese school that when plants were placed in the back of the classroom students experienced "significantly stronger feelings of preference, comfort, and friendliness" (Han et. al., 2009). There were six cinnamon trees characterized by dense foliage and shiny green leaves. Each tree was about 4.5 feet tall and 2.5 feet wide occupying 6% of the floor space and they were lined up in a row against the back wall of the classroom (Han et. al., 2009). The students had limited visibility of the plants although the greenery was able to positively influence the student's perceptions of the classroom.

Playground

Kelz et al conducted a study in 2015 that revealed the benefits of creating a more natural and interactive playground at schools. Researchers redesigned an Austrian middle school playground by adding greenery, seating, and sports opportunities. They found that the renovation impacted students by reducing stress and increasing well-being (Kelz et. al., 2015). The renovated schoolyard included shrubs, potted plants, trees, wooden chairs and tables, wooden benches, seating pillows, ping pong tables, a volleyball net and field, a soccer field, and a drinking fountain. Based on Kaplan's features of restorative environments, results from the study showed that students experienced an increase in fascination and compatibility after the redesign indicating that there was partial perceived restoration from mental fatigue. In essence, this study shows the significance of landscaping and interactive outdoor spaces for students.

Short Research Studies

There are a few other noteworthy research studies that reveal additional benefits from human interaction with nature. Walking in nature or simply viewing pictures of nature can improve directed attention abilities and short-term memory, thus validating the attention-restoration theory (Berman et al., 2008). Nature improves cognitive functioning and restores directed attention because it is a peaceful environment and requires limited directed attention. Whereas urban environments are overly stimulating, require directed attention, and are much less restorative than nature (Berman et al., 2008).

Shifting the focus, studies have shown that schools were originally designed to be windowless to reduce distractions, outside noise, and HVAC costs as well as provide more space for learning materials (Edwards & Torcellini, 2002). However new research has shown that windowless classrooms may be linked to decreased academic performance, therefore windows are actually beneficial for the success of students (Küller & Lindsten, 1992). Recent studies have revealed that students experience increased stimulation, decreased boredom, and perform better on tasks requiring focus and attention when learning in a classroom with natural views compared to a classroom without natural views (Eberhard, 2009; Kelz et al., 2015). Similarly, another study found that in elementary classrooms, large windows with interesting views such as nature, human activity, and long-range views were associated with better academic performance from students (Aumann, 2004). Lastly, Taiwanese kindergarten students were observed, and found that students experienced increased attention and reduced distraction when vegetation was present in the classroom (Han et. al., 2009; Hung and Chang, 2002).

Synopsis

All in all, this study focuses on observing and evaluating the biophilic design characteristics in Lincoln Public Schools in order to provide baseline knowledge for future improvements in sustainability efforts within the school system. The goal is to educate school officials and the local community about the benefits of incorporating biophilic design characteristics in schools. In conclusion, research has shown that biophilic design in schools can improve students' academic performance, reduce stress, and increase mood and well-being.

Methods

Research Design and Approach

The research for this study was conducted using a mixed quantitative-qualitative design. In 2021, Jose et al. conducted a similar study using description and comparison methods to evaluate the biophilic design elements in different school buildings at a University, leading to useful results. For this study, the quantitative part consists of the assigned scores for each school

on a 5-point scale. Conversely, the qualitative part focuses on the description of the biophilic design characteristics present at each school and the photos taken. The rationale for using mixed methods was to obtain multiple perspectives and validate findings. Specifically for this study, mixed methods helped build a comprehensive understanding of biophilic design, develop better-contextualized measures of high school site information, and track the process of the implementation of biophilic design elements. The use of both quantitative and qualitative methods of data collection also helped corroborate findings through triangulation.

Methodology

For this research study, a convenience sample was used to select the schools and case studies were used to evaluate the data collected at each school. High schools were chosen for this study rather than elementary or middle schools due to the number of buildings and the range in years the buildings were constructed. The year each of the LPS high schools opened follows: 1915, 1941, 1955, 1967, 2002, 2003, 2022, and 2023. LPS consists of only eight high schools, whereas, there are 13 middle schools and 51 elementary schools (Lincoln Public Schools, 2023). Furthermore, high schools were chosen since there have been two new high schools built in Lincoln in the last two years as well as schools built in the early 1900s, which provides a significant range of building dates.

Originally the plan was to tour all eight of the high schools but due to the short time frame for this project, the scope of research was limited. Four of the LPS high schools were toured, including the oldest and the second newest built school. The schools that were chosen provided the most variety in building designs, as some of the schools have the same design plan. Touring only four of the high schools allowed for more detailed data to be collected and analyzed.

An evaluation form was used to record the biophilic design characteristics present in each school. Furthermore, to standardize the tours, the evaluation form included specific options to select for each characteristic, which allowed for detailed data to be collected and compared. The tours involved observing the main entrance, cafeteria, library, gymnasium, auditorium, classrooms, hallways, gardens, and the landscaping around the building. During the tours, descriptions of each element were documented and photos were taken.

The two newly built LPS high school buildings, one in 2022 and one in 2023, should reflect LPS' current building design guidelines and the level of consideration regarding biophilic design characteristics. In contrast, the other high school buildings that were built in the early and mid-1900s or the early 2000s should indicate LPS' older building design standards. Due to the wide range of years between the opening date of each of the high schools, there may be notable changes in the biophilic design characteristics between schools.

The methods of data collection for this study were modified based on a previous study that evaluated the biophilic design elements at a university (Jose et al., 2021). The evaluation form used in this study was created based on the six biophilic design elements and 75 attributes

defined by Kellert et al. in 2011, listed below and shown in Figure 1 created by The Sheward Partnership in 2019. Moreover, the characteristics were determined based on previous research studies and the most common biophilic design elements that are incorporated into schools.

Biophilic design elements (Kellert et al., 2011)

- **Environmental features:** well-recognized characteristics of the natural world
- **Natural shapes and forms:** representations and simulations of the natural world
- **Natural patterns and processes:** properties found in nature
- **Light and space:** qualities of light and spatial relationships
- **Place-based relationships:** refers to the connection of people to places
- **Evolved human-nature relationships:** fundamental aspects of the inherent human relationship to nature

Environmental Features	Natural Shapes and Forms	Natural Patterns and Processes
Color	Botanical motifs	Sensory variability
Water	Tree and columnar supports	Information richness
Air	Animal (mainly vertebrate) motifs	Age, change, and the patina of time
Sunlight	Shells and spirals	Growth and efflorescence
Plants	Egg, oval, and tubular forms	Central focal point
Animals	Arches, vaults, domes	Patterned wholes
Natural materials	Shapes resisting straight lines and right angles	Bounded spaces
Views and vistas	Simulation of natural features	Transitional spaces
Facade greening	Biomorphy	Linked series and chains
Geology and landscape	Geomorphology	Integration of parts to wholes
Habitats and ecosystems	Biomimicry	Complementary contrasts
		Dynamic balance and tension
		Fractals
		Hierarchically organized ratios and scales
Light and Space	Place-Based Relationships	Evolved Human-Nature Relationships
Natural light	Geographic connection to place	Prospect and refuge
Filtered and diffused light	Historic connection to place	Order and complexity
Light and shadow	Ecological connection to place	Curiosity and enticement
Reflected light	Cultural connection to place	Change and metamorphosis
Light pools	Indigenous materials	Security and protection
Warm light	Landscape orientation	Mastery and control
Light as shape and form	Landscape features that define building form	Affection and attachment
Spaciousness	Landscape ecology	Attraction and beauty
Spatial variability	Integration of culture and ecology	Exploration and discovery
Space as shape and form	Spirit of place	Information and cognition
Spatial harmony	Avoiding placelessness	Fear and awe
Inside-outside spaces		Reverence and spirituality

Figure 1 - Biophilic Design Attributes (Kellert et al., 2011; The Sheward Partnership, 2019)

After the tours were completed, each biophilic design characteristic was assigned a score based on a 5-point scale, used to evaluate the presence of the characteristic.

5-point presence rating scale

- 1 = *absence* of the element
- 2 = minimal
- 3 = moderate
- 4 = high
- 5 = *very high* presence of the element

The evaluation form includes 10 biophilic design characteristics that were observed on the interior and exterior of the school buildings. Table 1 lists the biophilic design characteristics that were evaluated in each school. The blank boxes were utilized to fill in the presence rating score for each of the characteristics, and then the total and mean scores were calculated at the bottom.

Table 1 - Biophilic Design Characteristics for Tours

<u>Characteristic & Description</u>	A	B	C	D
Indoor plants - amount, type, placement				
Views - nature, vegetation, far				
Natural Light - large windows, skylights				
Color - earth tones (brown, green, yellow, blue)				
Natural materials - brick, wood, stone				
Natural shapes/forms - arches, organic shapes				
Nature photos/posters/art				
Spaciousness - open spaces				
Gardens				
Landscaping - trees, plant varieties				
Total				
Mean Score				

Figure 2 below shows the format of the actual evaluation form that was used during the tours. The form includes the 5-point presence rating scale, a checklist of the different areas toured, specific options under each characteristic to be circled as observed, and a section for notes. During the tours, short descriptions were written about the specific biophilic characteristics at each school and photos were taken for reference.

<p>High School: _____</p> <p>5-point scale</p> <ul style="list-style-type: none"> ● 1 = absence of the element ● 2 = minimal ● 3 = moderate ● 4 = high ● 5 = very high presence of the element <p>Areas</p> <p><input type="checkbox"/> Main entrance and hallways</p> <p><input type="checkbox"/> Cafeteria</p> <p><input type="checkbox"/> Library</p> <p><input type="checkbox"/> Gymnasium</p> <p><input type="checkbox"/> Classrooms # _____</p> <p><input type="checkbox"/> Outdoor spaces (garden, landscaping, etc.)</p>
<p><i>Biophilic Design Characteristics</i></p> <p>Natural Light</p> <p>Presence Rating: 1 2 3 4 5</p> <p>Window sizes: small medium large</p> <p>Primary light source: daylight LED light bulbs/overhead</p> <p>Color: yellow white Overall building lighting: light dark</p> <p>Notes: _____</p>

Figure 2 - Evaluation Form

Data Collection

The materials used were a pen, clipboard, printed evaluation forms, and an iPhone for photos. During the tours, the form was filled out and many photos were taken. The areas observed in every school were the main entrance, hallways, cafeteria, library, gymnasium, auditorium, classrooms, outdoor garden, and the landscaping around the building. After all the tours were complete, the presence ratings for each characteristic at each school were determined by comparing notes and photos.

Data Analysis

Once the presence ratings for each characteristic at each school were assigned on the evaluation form, Table 2 was created to input the data. The total and mean scores were calculated for each of the high schools and also added to Table 2. Then the scores, along with the notes on the evaluation form and photos, were compared between the schools. The scores were used to identify the biophilic design characteristics that had a moderate to very high presence (3-5) in most of the schools and the characteristics that were absent to minimally present (1-2) in most schools. Graphics were created in Excel based on the data in Table 2 to help visualize and compare the presence of the biophilic design characteristics at each school. For each school, the completed evaluation form and photos were reviewed to provide an overall understanding of the school building design. Based on the data gathered, detailed notes and themes were synthesized.

Results

Table 2 below provides a solid baseline understanding of the presence of biophilic design characteristics in LPS high school buildings. The biophilic design characteristics that are moderately to very highly present (score 3-5) across three out of four of the schools are nature views, natural light, natural materials, natural shapes, and landscaping. The only biophilic design characteristic that is moderately to very highly present (score 3-5) across all schools is spaciousness. The biophilic design characteristics that are absent to minimally present (score 1-2) across three out of four of the schools are indoor plants and nature artwork. Color is the only element that is minimally to moderately present (score 2-3) across the schools.

Table 2 - Biophilic Design Characteristic Presence Ratings for the Schools

Characteristic & Description	A	B	C	D	Total
Indoor plants - amount, type, placement	2	3	2	2	9
Nature views - vegetation	1	3	3	5	12
Natural Light - large windows	2	3	4	5	14
Color - earth tones (brown, green, yellow, blue)	2	2	3	3	10
Natural materials - wood, stone	4	2	3	5	14
Natural shapes - arches, organic shapes	3	2	3	3	11
Nature artwork - visuals, posters	2	2	2	2	8
Spaciousness - open spaces	3	3	4	5	15
Gardens	1	4	2	4	11

Landscaping - trees, plant varieties	2	3	3	5	13
Total	22	27	29	39	
Mean Score	2.2	2.7	2.9	3.9	

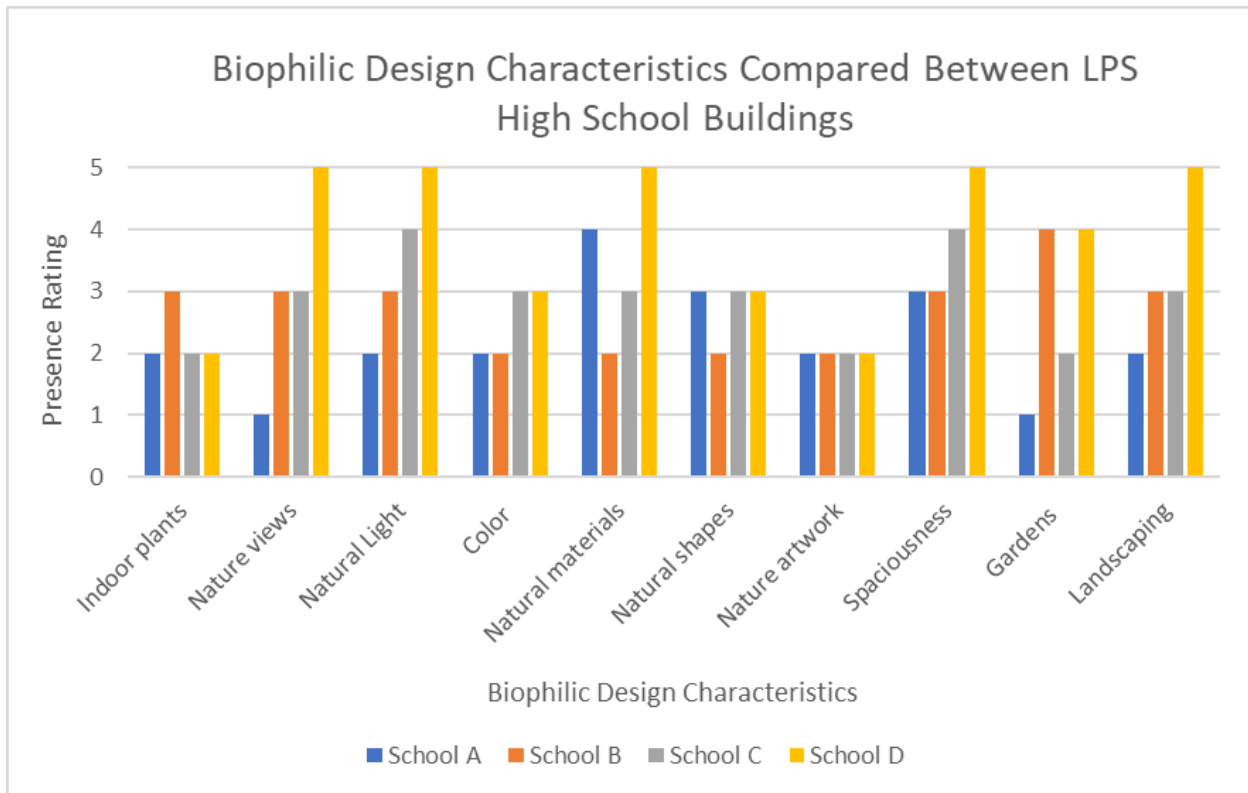


Figure 3 - Biophilic Design Characteristics Presence Across Schools

Figure 3 provides a comparison of the presence of the biophilic design characteristics between the four high schools. The ranking list below is for the biophilic design characteristics that are most to least present across all the schools. The score for each characteristic at each school was summed together. The ranking with two characteristics indicates that the scores were tied.

Biophilic Design Characteristics - Ranking of Most Present to Least Present

1. Spaciousness
2. Natural Materials & Natural Light
3. Landscaping
4. Nature views
5. Natural shapes & Gardens
6. Color
7. Indoor Plants
8. Nature Artwork

The photos below exemplify a quality example of each of the biophilic characteristics observed at the high schools.

Biophilic Design Characteristic - Photo Examples

Photo 1 - Spaciousness



Photo 2 - Natural Light



Photo 3 - Nature Views



Photo 4 - Landscaping



Photo 5 - Natural Shapes



Photo 6 - Nature Artwork



Photo 7 - Gardens



Photo 8 - Indoor Plants



Photo 9 - Color



Photo 10 - Natural Materials



Case Study 1: School A

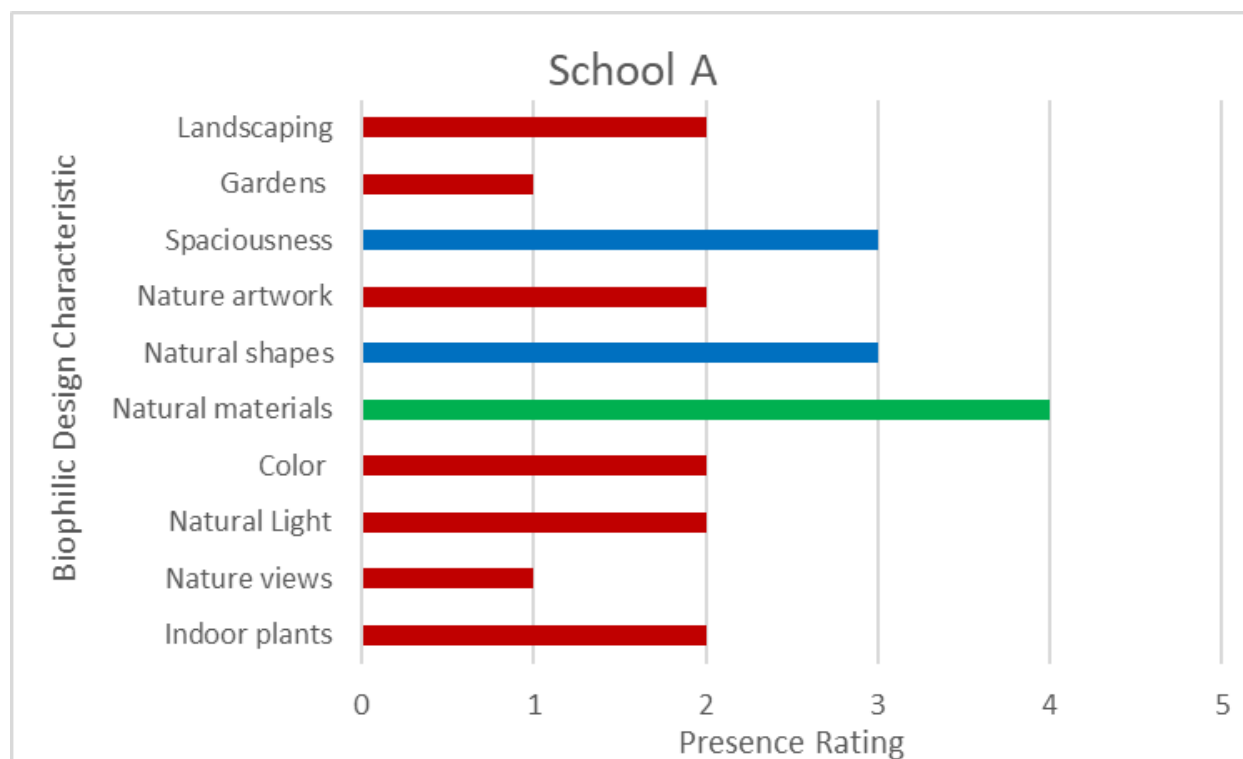


Figure 4 - Biophilic Design Characteristic Ratings for School A

School A was originally built in 1915, although sections have been added to the building over time to increase the size. The most notable characteristics are the colors used, natural materials, and artificial lighting. Cream is the prominent base color and the school colors, red and black, are incorporated throughout most of the building. There is a high use of natural materials used such as brick, marble, and tile. Overhead white LED lighting is present in all areas of the school. There is minimal natural lighting in the building and sunlight is most often only visible at the end of hallways. There are few windows in common areas, none in the library, and not many windows in classrooms. Where windows are present, there is an absence of views of nature, vegetation, or landscapes, instead, windows reveal views of brick walls, the roof, or the parking lots and streets surrounding the building.

The school is moderately spacious with mostly wide hallways with arched entrances, large common areas, and high ceilings. There were no real plants in any common areas although some plants were observed in a few of the classrooms including an aloe and spider plant. There were fake plants in the library and a small colored ceramic tile depiction of a mountain, located on a wall in a hallway. There is no garden and only minimal landscaping including trees around the school and turf grass.

Case Study 2: School B

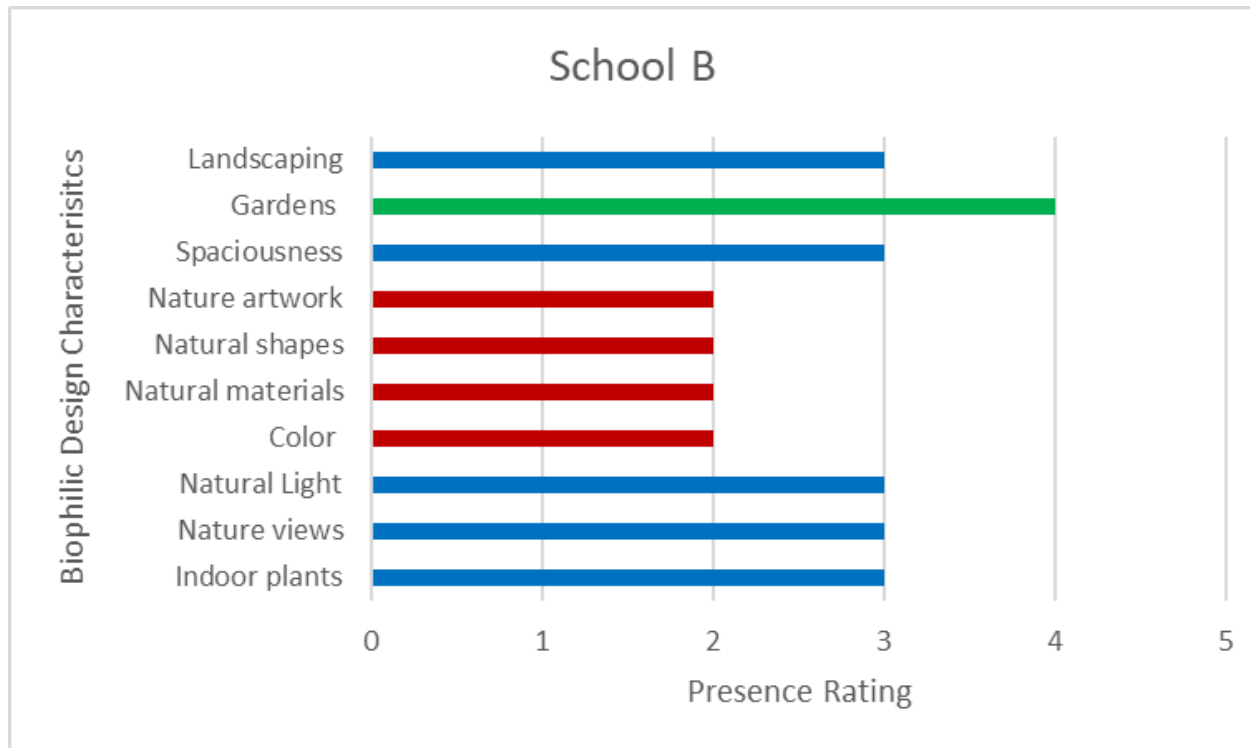


Figure 5 - Biophilic Design Characteristic Ratings for School B

School B was originally built in 1941. The main color theme is white, cream, and tan revealed in the walls, flooring, and lockers. Brick and wood are the primary natural materials used in the design of the building. The exterior of the school building is mainly red brick and there is tan brick used as part of the interior wall design. Classrooms have old wooden cabinets and small wooden desks attached to chairs. There are many colorful and random posters hung on the walls around the school promoting events, ideas, or artwork.

The school is moderately spacious portrayed by the size of the library and cafeteria as well as the wide hallways. Hallways are primarily lit with LED lights but there are a few pyramid-shaped skylights incorporated in some hallways that provide minimal sunlight. The lower floor has minimal windows, a high use of LED lighting, low ceilings, and a mix of tan and brown colored materials. The cafeteria contains a living tree, has high ceilings, and there is a high presence of natural light due to the large windows. The library, which was renovated, also has a high presence of natural lighting, a variety of real plants near the windows, light gray painted walls, and organically shaped furniture. The third floor has the most natural light due to the high presence of windows. Most of the windows in the school provide natural views of the landscaping and neighborhood surrounding the building. The landscaping includes some large trees, shrubs, and green turf. In addition, the school has established a community garden with

multiple raised garden beds, flowers for pollinators, a bird feeder, trellises, a compost bin, and a watering hose.

Case Study 3: School C

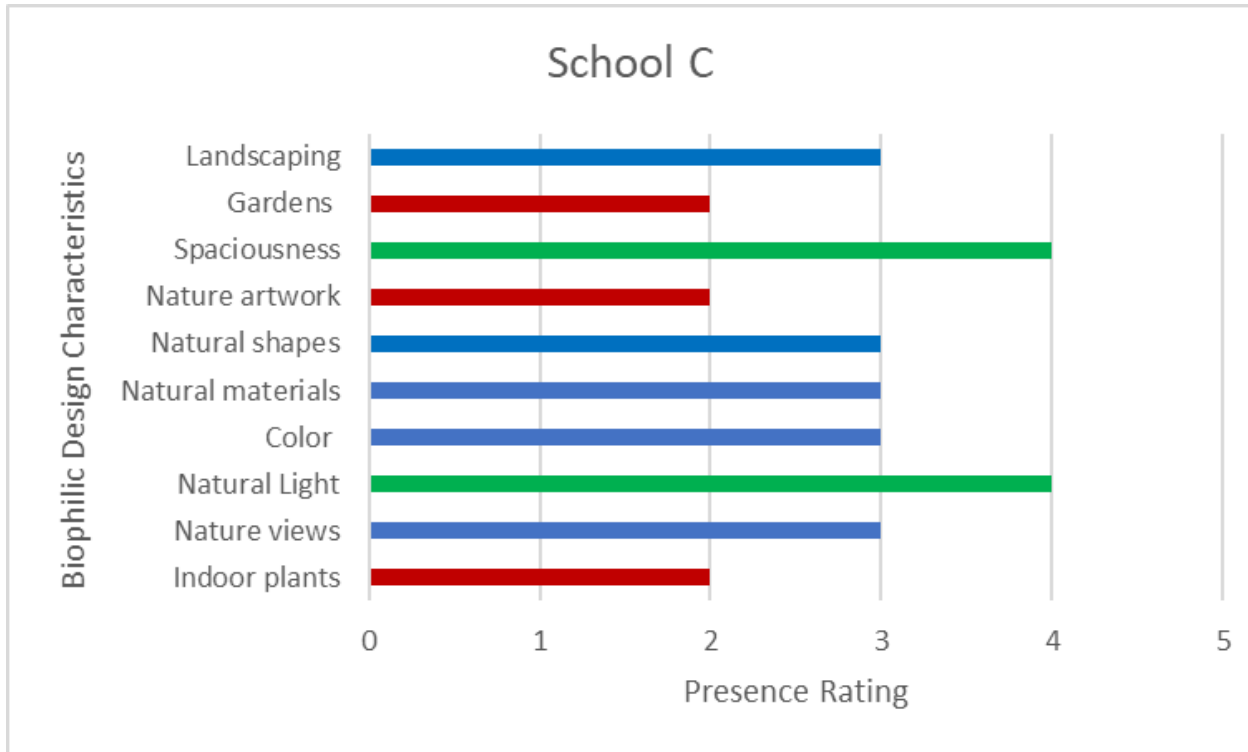


Figure 6 - Biophilic Design Characteristic Ratings for School C

School C was built in 2003. The building has a simple layout and all the common areas are spacious and located on the first floor. The entrance and cafeteria are very open and spacious and there is lots of natural light due to the large windows and high ceilings. Hallways are wide and contain LED lights. In the library, there are large windows with views of the cafeteria or hallways and there are some depictions of nature in the decor and patterned furniture. The gym is lit with LED lights and the space is partially open at the top. There is a skylight in the main stairwell and on the second floor which provides some natural light and brightens up the spaces.

For color, ceilings and walls are white and the flooring is tan with white and blue accents. Brick is used throughout the building on the exterior and interior. In classrooms, there are wooden cabinets and desks and some nature artwork in or near specific classrooms. Most classrooms only have one window which provides minimal natural light and is often located by the teacher's desk, therefore not viewable to students. More windows are present in the classrooms at the ends of the school but not in the middle. There are views of trees around the building but some windows look to the roof or brick wall. Large windows are located in the side stairwells which produce lots of natural light and provide views of the trees outside. By the

entrance of the building, there are many trees and some shrubs, but other green spaces and plants are minimal. There are two overgrown garden beds outside the cooking classroom and no real or fake plants in the common areas, only some real plants were observed in classrooms.

Case Study 4: School D

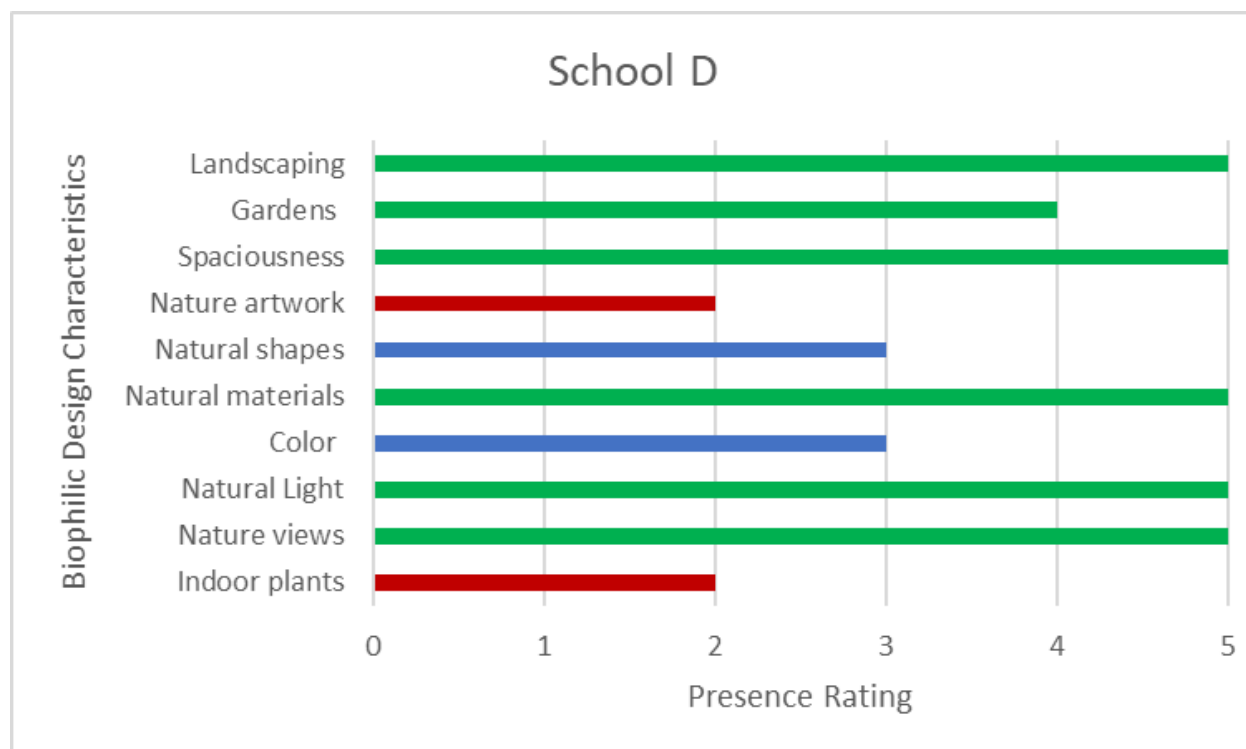


Figure 7 - Biophilic Design Characteristic Ratings for School D

School D was built in 2022. The school has a very high presence of spaciousness, natural light, natural materials, landscaping, and nature views. At the entrance to the building, there are metal circle bike racks and various grasses and turf. Most of the areas in the building are connected and open to each other. The main colors incorporated are white and light to dark gray with accents of bright purple, which is the school color. There is a mixture of natural materials utilized throughout the school, including wood, brick, tile, and marble. Brick is used on the exterior of the building, and on the interior, textured walls, wood doors, and stone tiling are incorporated. Wood paneling is used often and incorporated in the entrance of the school, on the swimming pool room ceiling, walls, and throughout many other areas.

Every classroom that was observed had large windows for natural light or at a minimum windows allowed views of the hallways. All common areas, including the gym, provided natural lighting. When LED lighting was present, it was illuminated by thin long light strips in the ceilings. Large windows in common areas and classrooms provide near and distant landscape views of the surrounding fields and landscaping, including turf patches, trees, various grasses,

and a rain garden created at the entrance by the parking lot. Another feature is a rooftop garden that is accessible by two classrooms consisting of planter boxes, a cistern for rainwater harvesting, tiled paths, and nature views.

There is a moderate presence of bright colors and natural forms and a minimal presence of nature artwork and plants. Pops of colors such as blue, orange, pink, and purple are used in the small open areas near classrooms shown on the carpet and wall paint. Natural forms are depicted by the organic table shapes in the library, cylindrical lights, curved walking paths outside, and the abstract layout of the school. There is one painting of dandelions in the library and some posters created by students that reference nature. The only plants observed were a medium-sized montesera in the school office and some small plants in a classroom. No plants were observed in any common areas.

Discussion

There is an increased presence of biophilic design elements in the newer high schools. Furthermore, there is a notable evolution of the design between the older and newer schools. The older schools, School A and B, are mainly cream-colored, have minimal natural lighting, utilize mostly LED lighting, and have a complex layout. The newer schools, School C and D, are mainly gray and white, utilize a combination of natural and LED lighting, and have a more simple and navigable layout. Overall, School D incorporates the most biophilic design characteristics and exemplifies the LPS building design guidelines.

The LPS' Design Guidelines were developed in 2020 and document the school building design and construction standards for all LPS projects (LPS, 2020). In section DG 01 35 00 - Sustainable Building Design, LPS states that "New facilities will be designed to meet LEED for Schools v4 New Construction GOLD standard." Moreover, LPS explains the LEED certification will not be pursued but that LEED for Schools will be utilized as a "guideline and a monitoring mechanism to accomplish the desired higher-performing school facilities" (DG 01 35 00 - 2). LPS specifies that "Projects will be designed with emphasis given to Energy & Atmosphere, Water Efficiency, Materials and Resources, and Indoor Environmental Quality" (DG 01 35 00 - 4).

The findings from this study support the initial assumptions. School D was built in 2022 and designed according to the 2020 LPS sustainable building design guidelines, therefore the school was built with more consideration for biophilic design which is revealed by the results. School D has more biophilic design characteristics such as large windows for ample sunlight and nature views, bright open spaces, a rooftop garden, and quality landscaping. The other older schools consist of less biophilic design characteristics, which was predicted, such as small or few windows, minimal sunlight and nature views, and basic landscaping. The library in School B was renovated and incorporates more biophilic design characteristics including indoor plants, large windows, natural light, spaciousness, and organic forms.

The research studies discussed in the literature review focus on the impact of one specific biophilic design characteristic on a student's academic performance and well-being whereas this study focuses on the presence of many biophilic design characteristics in high school buildings. It is important to note that the literature review lacks studies of the impact of biophilic design characteristics on high school students and research data is only available for kindergarten, elementary, middle, and undergraduate students. However, based on the results of the previously conducted research studies and the biophilic design characteristics observed in LPS high schools, some predictions can be made about the impact of the designs on LPS students.

Across the schools, there are a few main themes that were identified. First, the school buildings are moderately to very highly spacious. Second, some natural materials are incorporated into the exterior and interior, mainly brick, wood, and stone. Third, there are minimal indoor plants and nature artwork incorporated which was expected based on a comment made by the LPS Sustainability Coordinator. She mentioned that plants and artwork are not design features that are focused on at a school district level, instead, they are dependent upon school staff. Fourth, the landscaping consists mainly of trees and grass.

There are many areas where LPS incorporated biophilic design characteristics well, especially in School D, and some areas where there is room for improvement, especially in School A. Based on the results of many research studies, students at School D are expected to have the best academic performance overall compared to the other three schools due to the abundance of natural light, nature views, and large windows. There are classrooms with natural light in all of the schools but classrooms at School D provide the most natural light therefore students at School D should have the best academic performance (Heschong, 2000). Classrooms at School D have windows that provide natural views therefore the students should have higher exam scores and a more positive class experience than students at School A who have views of brick walls and the street (Benfield et al., 2015). In classrooms with natural views, like at School D, students should experience increased stimulation, decreased boredom, and better performance on tasks requiring focus and attention compared to learning in classrooms at School A without natural views (Eberhard, 2009; Kelz et al., 2015). There were the most natural views at School D, some at Schools C and B, and minimal at School A, therefore it is predicted that students will have better performance at School D and worse at School A. There are windows in most classrooms at School D which should benefit students academically and there are some classrooms with no windows at the other schools which may result in decreased academic performance (Küller & Lindsten, 1992). Furthermore, large windows with nature and long-range views are beneficial to academic performance which are present at School D and not at any of the other schools (Aumann, 2004).

At School D the use of native grasses, trees, and the creation of a rain garden and open green spaces may reduce student's stress and increase their well-being (Kelz et. al., 2015). Throughout the schools, there were some classrooms with indoor plants which may result in those students having a positive classroom experience as well as increased attention and reduced

distraction (Han et. al., 2009; Hung and Chang, 2002). Further research at LPS high schools and high schools in general would need to be conducted to confirm these predictions.

Limitations and recommendations

Limitations to the study are that only four of the LPS high schools were toured and not all areas were observed. Moreover, elementary or middle schools were not toured which could reveal different biophilic design characteristics, therefore tours of these schools are recommended. Additionally, the student's academic performance and well-being were not evaluated, therefore the impact of the biophilic design characteristics on the students is unknown. For follow-up or future studies, consider including interviews with LPS students and documentation of their grades to evaluate the impact of the school designs on their academic performance, mental health, and well-being. Moreover, surveys or questionnaires could also be distributed to students. Suggestions for further improvement for LPS schools include the addition of plants in classrooms, the cafeteria, and the library that require little water and management such as snake plants, pothos plants, and succulents. Moreover, nature artwork such as paintings, posters, or murals should be included in the schools, and the installation of windows where they are lacking, especially in classrooms, would be a beneficial improvement.

Overall, School D incorporates the most biophilic design characteristics and exemplifies the 2020 LPS building design guidelines. Based on the results of many research studies, students at School D are expected to have the best academic performance, classroom experience, attention levels, and well-being overall compared to the other three schools due to the abundance of natural light, nature views, large windows, and landscaping. This research is important because there is a lack of studies about biophilic design characteristics in high school buildings and the impact on high school students. Currently research data is only available for kindergarten, elementary, middle, and undergraduate students and schools.

Summary & Conclusions

Research has shown that biophilic design in schools can improve students' academic performance, reduce stress, and increase mood and well-being. Therefore, this study focuses on observing and evaluating the biophilic design characteristics in Lincoln Public Schools in order to provide baseline knowledge for future improvements in sustainability efforts within the school system. The goal of the study is to educate school officials and the local community about the benefits of incorporating biophilic design characteristics in schools. The study was conducted using a mixed qualitative-quantitative design consisting of a convenience sample to select the schools, case studies to evaluate the data collected at each school, and an evaluation form and 5-point scale used for the tours.

Findings reveal an increased presence of biophilic design elements in the newer high schools and an evolution of the design between the older and newer schools. Spaciousness,

natural materials, and natural light are the top three most present biophilic design characteristics across all four schools, and indoor plants and nature artwork are the two least present characteristics. School D incorporates the most biophilic design characteristics and exemplifies the 2020 LPS building design guidelines. Based on the results of many research studies, students at School D are expected to have the best academic performance, classroom experience, attention levels, and well-being overall compared to the other three schools due to the abundance of natural light, nature views, large windows, and landscaping. Overall, LPS has improved with the integration of biophilic design characteristics in their high school buildings in recent years. This is most prominently represented by the spaciousness, use of natural materials, abundance of natural sunlight, large windows, gardens, and landscaping.

Limitations to this study were that only four of the LPS high schools were toured and the student's academic performance and well-being were not evaluated. The impact of the biophilic design characteristics on the students is unknown therefore for future studies, interviews with LPS high school students should be conducted and their grades should be documented to evaluate the impact of the school designs on their academic performance, mental health, and well-being. This study helps fill a research gap about biophilic design in high schools, although further research should be conducted to support the results and confirm the potential beneficial impacts. A suggestion for LPS is to educate teachers about the mental health and academic benefits to students due to biophilic design. Moreover, LPS should encourage teachers to incorporate indoor plants and nature artwork in their classrooms.

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