




## Evaluating Natural Lighting as a Criterion for Healthy Spaces in Early Childhood Buildings



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### ABSTRACT

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*natural lighting, healthy spaces, childhood, nursery buildings, design for children, daylight simulation, Velux Daylight Visualizer*

Natural lighting is a crucial design criterion in architectural spaces, and studies have demonstrated its vital importance in the early stages of child development. This study aims to evaluate the efficiency of natural lighting in buildings dedicated to early childhood, using the University of Mosul Nursery (Children's Laboratory) as a case study. This nursery serves children aged between one month and four years. The study methodology consists of two parts: an analytical approach to derive design criteria for healthy spaces for children, and a computer-aided experimental approach using AutoCAD and Velux Daylight Visualizer to evaluate the performance of lighting in bedrooms, learning spaces, and dining rooms. The evaluation focuses on the adequacy and distribution of natural light to ensure a healthy and stimulating environment for this age group. The study concluded that rectangular windows with a width-to-height ratio of 24% to 40% provide sufficient daylight, while curved windows with a width-to-height ratio of 7% to 14% showed insufficient lighting. The study also presented a set of solutions to improve the quality of the indoor environment and promote the concept of a healthy space.

## 1. INTRODUCTION

The early childhood stages represent an important starting point in children's lives, physically, health-wise, and psychologically, as the child begins to learn about the world around him and the environment in which he lives. Therefore, it is very important that the environment around him is healthy, safe, and sustainable. The design of the built environment, including residential and educational buildings and outdoor spaces, will have a direct impact on the child's life in a way that can support the child's physical, mental, and psychological development, thus improving his chances of future growth [1]. Recent studies have proven the necessity of ensuring that the spaces in which children are present, whether playing, sleeping, or otherwise, are healthy spaces in terms of ventilation and lighting, which is the subject of the paper. They all emphasized the importance of natural lighting for a child's healthy and behavioral development, as it is related to regulating the melatonin hormone, sleep and wake patterns in children, and the secretion of dopamine in the eyes, which affects vision, in addition to its positive effects on the social, emotional, cognitive, and physical aspects of children [2]. The impact of natural lighting on infants under one year is focused on the fact that a balanced lighting system is very important at this stage in regulating sleep and daily activity, and is a very important factor in the development of the child's growth in the first months [3]. From the above, we can say that the effect of lighting on the child's health is to improve growth in the

early stages through its effect on biological functions - biological rhythm and balance between sleep and wakefulness, vision, psychological health, behavioral, and cognitive development.

## 2. HEALTH SPACES FOR CHILDREN

A healthy space is defined as a space that promotes healthy behavior, provides health support to people, and takes into consideration the health needs of sensitive groups, such as children and the elderly, and the individual's circadian rhythm, especially through the design of thoughtful natural lighting [4]. It is a supportive space for improving the quality of life, reducing stress, and enhancing mood, given that natural lighting is one of the most important health needs of its users [5]. Therefore, natural lighting is an important and primary indicator in assessing the aesthetics of architectural spaces. It has been included in LEED, WELL, and BREEAM ratings as an important indicator of health [6]. It provides physical and mental support, enhances comfort, and increases children's focus during daily activities. It also improves children's visual perception [7]. We can say that a healthy space for children is an architectural space designated for children that has sufficient natural lighting that supports the child's physical, mental, and behavioral development.

### 3. PREVIOUS LITERATURE

Many studies have highlighted the importance of providing natural lighting in spaces designed for children, particularly during the various stages of a child's life, particularly early childhood, as discussed in the previous paragraphs. These studies include its role in regulating and improving children's sleep and developing children's cognitive and physical performance [2]. Jaušovec and Gabrovec [5]'s study highlighted the importance of natural lighting as a fundamental criterion for achieving "environmental comfort," which must be present in the design of healthy spaces, including nursery spaces. This is due to its role in achieving biological balance through the design of openings, the orientation of the building, and the duration of exposure to sunlight. From an applied design perspective, many studies have considered focusing on natural lighting in the design process to ensure the appropriate distribution of natural light and improve vision and biological rhythms [8]. A recent study conducted on a group of nursery buildings to evaluate daylighting in nursery spaces recommended the importance of providing natural lighting by regulating the window-to-floor ratio to ensure proper light distribution [9]. Given the importance of providing natural light in this type of building, the WELL Building Standards state that to enhance the access of natural light to spaces where children spend their time, the following should be considered:

- Ensure that  $\geq 55\%$  of these spaces receive  $\geq 300$  lux of daylight for sufficient hours, preferably 75% for maximum scores.
- The distance from any occupied area to the nearest window should not exceed 7.5 m (and 5.5 m if possible).
- The percentage of glazed openings (Window-to-Wall Ratio) in walls should be between 20% and 60%, and above 40% should only be with external shading or adaptive glazing [10].

As for the UNICEF guidelines for children, they have provided guidelines that include: Providing natural lighting through walls that are not less than 20% of the wall area. Providing natural lighting for a period of 2-3 hours to provide a healthy environment for the child's growth. Directing the openings towards the south or east, with the possibility of using shading methods for areas with a hot climate [11]. Recent studies confirm the child's innate inclination towards spaces with natural light [12]. And reducing the level of pain or discomfort in the child improves the mood [13]. Therefore, it is linked to improving the overall quality of the indoor environment [14]. In study [15], Deng et al. pointed out the importance of the child's space in kindergartens, being an environment that provides natural light and connection with nature.

### 4. METHODOLOGY

This study adopted a quantitative analytical approach to evaluate the efficiency of natural lighting in selected architectural spaces within early childhood environments. The research methodology combined architectural analysis with digital simulation techniques for natural lighting to assess its distribution and performance under different design conditions.

Architectural plans were prepared using AutoCAD software and then analyzed using Velux Daylight Visualizer software

to simulate the performance of natural lighting [16]. The simulation studied the effect of window sizes, depth of space, and seasonal changes on light distribution within interior spaces, comparing them to the health standards of the theoretical framework. This led to the classification of spaces and lighting quality in the study building sample, along with proposed design treatments and solutions. This is due to the importance of window design, shape, and dimensions in the space, as well as the glass's transparency and its performance in providing natural light within the space [17].

### 5. SIMULATION SETTINGS INCLUDED

Location: Mosul, Iraq

Sky Model: Coherent Infrared Energy Clear Sky

Room Height: 3.2 m

Work-plane Height: 0.75 m

Wall Reflectance: 40%

Ceiling Reflectance: 81%

Floor Reflectance: 20%

Glazing Transmittance: 80% (the adopted glazing transmittance value (80%) corresponds to the performance range of standard clear architectural glazing reported in daylighting literature and technical glazing specifications) [18].

### 6. PRACTICAL STUDY

The University of Mosul Nursery building was established in 1978 within the university campus; it welcomes children of university staff. It was renovated and reopened with support from the United Nations (UNDP). It receives children of university staff, with a capacity of 180-200 children, and this number can be increased along with the staff who care for them (Figure 1) [19].

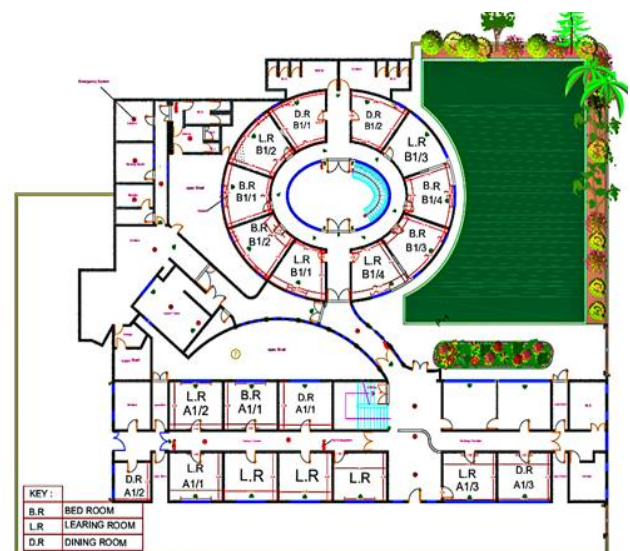


Figure 1. Building plan, ground floor

The children's time at the nursery is distributed from 8:30 for breakfast to 9:30, then recreational time and lessons begin at 10, then at 11 a second meal, and the sleep period is at 11:30 or 12 noon.

The building comprises two sections:

- The oval section of the building is for children aged one month to one and a half years. Each bedroom accommodates 13-15 children, and the beds measure 1 meter by 70 centimeters.
- The rectangular section of the building houses the kindergarten and nursery. Each bedroom accommodates 25 children. The beds in the bedrooms are typically bunk beds measuring 180 meters by 90 centimeters.

The research relied on coding the building's constituent spaces according to function and effectiveness within each space. Please note that the analysis will be limited to the ground floor only, as shown in Table 1. These spaces included sleeping areas, learning spaces, and dining areas. Each of these spaces was subsequently analyzed and its details clarified in detailed tables that included the shape of the space, the number of spaces on each floor, the area of the space, the orientation of the space, and the length and number of windows in the space. The research also relied on an analysis of the architectural spaces (bedrooms, learning spaces, and dining rooms) in terms of area, orientation, and lighting and ventilation openings, as follows:

1. Bedrooms (B.R)

The bedrooms are distributed across three floors with consistent sizes but varying orientations:

Area: Each bedroom measures 23.3625 m<sup>2</sup>.

Ground Floor:

Model (A1/1) faces north with a 3-meter window opening onto the light well.

Model (B1/1) faces west with a 2-meter window opening onto the light well.

Models (B1/3) and (B1/4) feature southeast and east orientations, respectively, with windows ranging from 0.9 to 2

meters wide and overlooking the outside.

First and Second Floors: Each floor contains four rooms of Model (A1/1) with a consistent north orientation.

2. Learning/Living spaces (L.R)

The tables demonstrate the flexibility in using these spaces, sometimes referred to as living rooms and sometimes as learning spaces:

Standard Area: 23.362 m<sup>2</sup>

Ground Floor Layout:

There are 4 units of the model (A1/1) facing south with a 3-meter window and a view to the outside.

There are 2 units of the model (A1/2) facing north with a view of the light well.

Model (A1/3) features an extra-large window, up to 5.1 meters wide, and a south-facing view to the outside.

Corner Models (B1): These are distributed in northwest-facing directions with a view to the light well, northeast-facing directions to the outside, and southwest-facing directions with various window openings to the light well.

Repeated Floors: These include 4 units distributed between north and south-facing directions to ensure cross-ventilation or different lighting options.

3. Dining rooms (D.R.)

The dining rooms were designed with a focus on their relationship to the exterior spaces or skylights:

Area: 23.3625 m<sup>2</sup>


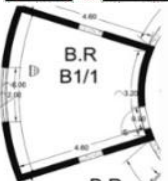
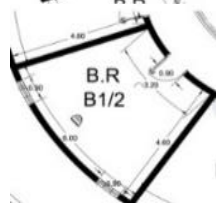

Ventilation Elements:

Model (A1/1) overlooks an open shaft to the north.



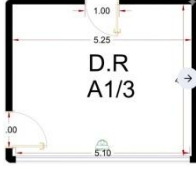
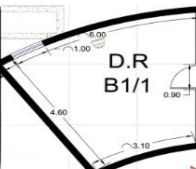

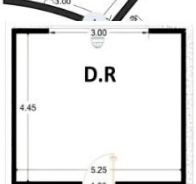
Models (A1/2) and (A1/3) overlook directly to the outside (south) with windows up to 5.1 m.

Repeated Floors: The dining rooms continue to have north-facing (via the shaft) and south-facing (outside) orientations (Table 1).

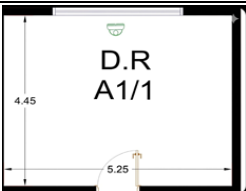



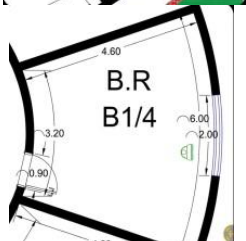

**Table 1.** Details of the different spaces in the building

Floors	Shape	Bedroom			
		Number of Units	Area (m <sup>2</sup> )	Orientation	Window Width (m)
Ground floor/fl Type		1	23.3625 m <sup>2</sup>	North/shaft	3 m
A1		1	23.3625 m <sup>2</sup>	West/ shaft	One window 2 m
B1		1	23.3625 m <sup>2</sup>	Southwest/ shaft	Two windows 0.9 m
B1/3		1	23.3625 m <sup>2</sup>	Southeast/out	Two Windows 0.9 m



Dining Room					
Floors	Shape	Number of Units	Area(m <sup>2</sup> )	Orientation	Window Width (m)
Ground floor/f1 Type					
A1/1		1	23.3625 m <sup>2</sup>	North/ Open shaft	One window 3 m
A1					
A1/2		1	3.3625 m <sup>2</sup>	South/ out	One window 3 m
A1/3		1	23.3625m <sup>2</sup>	South/ out	5.1 m
B1					
B1/1		1	23.3625 m <sup>2</sup>	Northwest/ out	One window 0.9 m
B1/2		1	23.3625 m <sup>2</sup>	Northeast/ out	One window 0.9 m
First floor/f2 Second floor/f3		1	23.3625 m <sup>2</sup>	North/ Open shaft South/ out	One window 3 m

**Table 2.** Shapes and dimensions of the opening

Plane	Shape the Space
	
	
	

From Table 2, two types of architectural window configurations can be observed:

Regular configuration (Block A): Shown in space (D.R A1/1), which is a 3 m × 1.5 m floor plan.

Organic/curved configuration (Block B): Shown in models (B1/3) and (B1/4), where the windows take on a trapezoidal or arched shape with an area of 1.5 m × 0.9 m, or a circular shape with an area of 2 m × 1.5 m, overlooking green spaces or skylights.

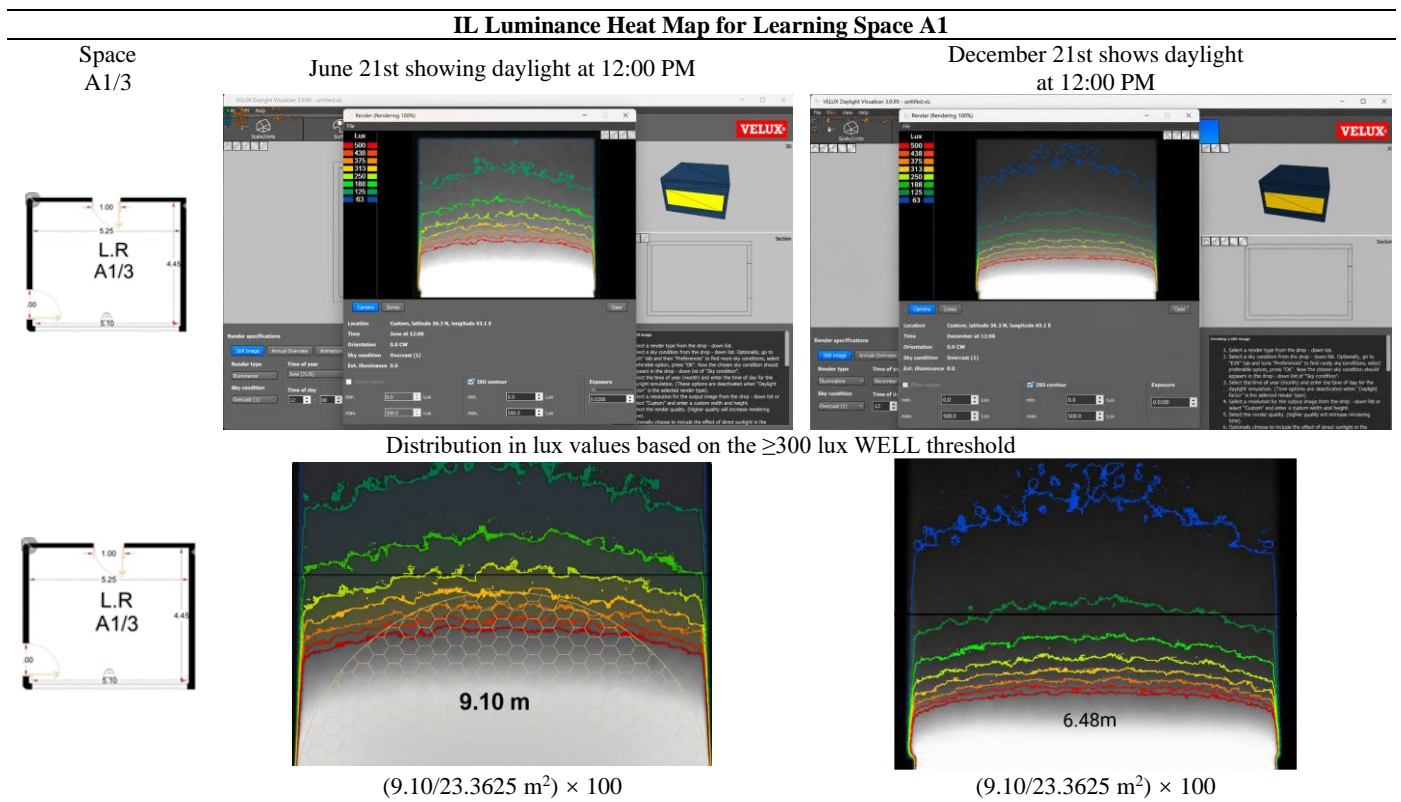
Architectural note: The design is based on a nearly constant unit of area (module) for all uses, with the "sheath shape" and solar orientation varying according to the room's location in the building. The window shapes, which vary between rectangular, sectional, and circular, are illustrated as shown in Table 2.

The analysis relied on the ground floor (first floor) and measured the lighting percentage, excluding the upper floors, because natural light increases on the upper floors. The AutoCAD and Flex programs were used, following these steps: Each selected nursery space was drawn using AutoCAD 3D, and the space was entered into the Flex program to measure the natural lighting. Lighting levels varied, and each space was measured at 12:00 PM. The selection of the base measurement and simulation point was based on climatic and functional considerations related to the local context of Mosul. Solar radiation intensity and daylight availability usually peak at midday. In addition, children are mainly present in the building during the morning and afternoon hours only. The chosen time represents the most suitable occupancy period,

during which children are exposed to the highest level of daylight inside the building. Once on December 21st and once

on June 21st, as shown in Table 3, for measuring some of the spaces.

**Table 3.** Analysis of the efficiency of natural lighting in the studied architectural spaces using the program Velux Daylight



## 7. STUDY RESULTS

### 7.1 Lighting quality by illuminated space size

- Group one (Sleeping Spaces): Spaces in categories A1, B1, and B4 showed good lighting in summer and average lighting in winter. This is attributed to the size and orientation of the windows. Spaces B2 and B3, however, had poor lighting in both winter and summer, despite their good orientation.
- Group two (Learning Spaces): The results showed that spaces in categories A1, A5, A3, and B4, which are oriented north and south, had very good lighting. Spaces oriented west and east had poor lighting in both seasons.
- Group THREE (Dining Areas): Poor lighting prevailed

in all categories due to poorly planned window sizes and orientation.

### 7.2 Lighting quality by window-to-floor area ratio

Rectangular openings achieved a good percentage for the first group ( $1.6 \times 3$ ) at 24% and the second group ( $5.1 \times 1.6$ ) at 40%, which is a good choice for spaces. Circular openings achieved a percentage of 16%, while curved openings represented a poor choice for spaces, achieving a percentage of 7.2-14% even after increasing and repeating the window within the same space. Instead of focusing solely on the window's shape, consider these indicators for optimal natural lighting, which are shown in Tables 4 and 5.

The standard adopted is that any area achieving  $\geq 300$  lux is considered an illuminated area.





**Table 4.** Results of the lighting efficiency analysis in the studied architectural spaces

Bed Room Type	Time	Illuminated Area $\text{m}^2$	(Illuminated Area/ Total Area) $\times 100$	Lux Level	
				$>55$	$\leq 5$
A1	21/June	4.10	$(4.10/23.3625) \times 100$		●
	21/December	2.61	$(2.61/23.3625) \times 100$	○	
	21/June	2.81	$(2.81/23.3625) \times 100$		●
B1/1	21/December	1.80	$(1.80/23.3625) \times 100$	○	
	21/June	0.56, 0.42	$(0.56/23.3625) \times 100$ $(0.42/23.3625) \times 100$	○ ○	
B1/2	21/December	0.33, 0.25	$(0.33/23.3625) \times 100$ $(0.25/23.3625) \times 100$	○ ○	

B1/3	21/June	0.74, 0.78	$(0.74/23.3625) \times 100$ $(0.78/23.3625) \times 100$	○ ○	
	21/December	0.42, 0.45	$(0.42/23.3625) \times 100$ $(0.45/23.3625) \times 100$	○ ○	
B1/4	21/June	2.46	$(2.46/23.3625) \times 100$		●
	21/December	1.88	$(1.88/23.3625) \times 100$	○	
Learning Space Type	Time 12 Noon	Illuminated Area m <sup>2</sup>	(Illuminated Area/ Total Area) × 100	>55	≤5 5
A1/1	21/June	5.23	$(5.2/23.3625) \times 100$		●
	21/December	3.80	$(3.80/23.3625) \times 100$		●
A1/2	21/June	3.37	$(3.37/23.3625) \times 100$		●
	21/December	2.61	$(2.61/23.3625) \times 100$	○	
A1/3	21/June	9.10	$(9.10/23.3625) \times 100$		●
	21/December	6.48	$(6.48/23.3625) \times 100$		●
B1/1	21/June	0.45	$(0.45/23.3625) \times 100$	○ ○	
	21/December	0.37	$(0.37/23.3625) \times 100$	○ ○	
B1/2	21/June	0.21	$(0.21/23.3625) \times 100$	○ ○	
	21/December	0.1	$(0.1/23.3625) \times 100$	○ ○	
B1/3	21/June	0.74, 0.78	$(0.74/23.3625) \times 100$ $(0.78/23.3625) \times 100$	○ ○	
	21/December	0.42, 0.45	$(0.42/23.3625) \times 100$ $(0.45/23.3625) \times 100$	○ ○	
B1/4	21/June	2.46	$(2.46/23.3625) \times 100$		●
	21/December	1.88	$(1.88/23.3625) \times 100$	○	
Dining Room Type	Time 12 Noon	Illuminated Area m <sup>2</sup>	(Illuminated Area/ Total Area) × 100	>55	≤5 5
A1/1	21/June	5.23	$(5.2/23.3625) \times 100$		●
	21/December	3.80	$(3.80/23.3625) \times 100$	○	
A1/2	21/June	3.37	$(3.37/23.3625) \times 100$		●
	21/December	2.61	$(2.61/23.3625) \times 100$		●
A1/3	21/June	9.10	$(9.10/23.3625) \times 100$		●
	21/December	6.48	$(6.48/23.3625) \times 100$		●
B1/1	21/June	0.14	$(0.14/23.3625) \times 100$	○ ○	
	21/December	0.10	$(0.10/23.3625) \times 100$	○ ○	
B1/2	21/June	0.80	$(0.80/23.3625) \times 100$	○ ○	
	21/December	0.51	$(0.51/23.3625) \times 100$	○ ○	

●: Adequate daylight, ○: Moderate daylight, ○ ○: Insufficient daylight

**Table 5.** Results of the lighting efficiency analysis in the studied architectural spaces

Room, Learning Space, Dining Room			
Window Area	Percentage of Glass Openings	Picture	20%-60%
$3 \times 1.6 = 4.8$	$(4.8/20) \times 100 = 24\%$		●
$5.1 \times 1.6 = 8.1$	$(8.1/20) \times 100 = 40\%$		●
$2 \times 1.6 = 3.2$	$(3.2/20) \times 100 = 16\%$		○
$0.9 \times 1.6 = 1.44$ $1.44 \times 2 = 2.88$	$(2.88/20) \times 100 = 14\%$		○

$$0.9 \times 1.6 = 1.44$$

$$(1.44/20) \times 100 = 7.2\%$$



○

●: Adequate daylight, ○: Moderate daylight. Depending on the area and shape of the window, the percentage of glass openings = window area/wall area × 100%.

## 8. CONCLUSION

- Providing natural light is essential for creating a healthy and suitable environment for children. This depends not only on the quantity of natural light but also on its quality of distribution, glare control, and its compatibility with the needs of this age group.
- To achieve a healthy environment in nursery buildings, a combination of design strategies and architectural treatments is necessary. Diffused light is the true foundation for visual comfort and eye health in children in various spaces. And here's how, clearly and systematically:

The results from the study sample building showed that variations in the amount of light reaching the spaces necessitate architectural and design solutions, such as the need to use clear windows that receive light from above, rather than directly at eye level.

Also, spaces containing rectangular windows (24-40% window to wall ratio) achieved good lighting; circular windows (16%) achieved average lighting; curved windows (7-14%) achieved poor lighting.

- The possibility of using external shading devices to block direct light and allow only diffused light.

Redesigning spaces overlooking interior areas that have shown poor natural lighting, either due to small window sizes relative to the space or the orientation of the spaces and their views towards the interior, by using glass or semi-transparent partitions that allow light to pass between rooms while maintaining children's privacy. Alternatively, using relatively larger windows facing south with the addition of horizontal blinds and light-filled shelves, and using windows facing east to provide pleasant morning light for children.

The study suggests a future use of frosted or diffused glass in sensitive areas, especially in sleeping spaces. Adopting light, white paint colors for the spaces and minimizing their reflective properties.

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