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PLANT PHOTOTROPISM AS THE BASIS FOR DESIGNING INCLUSIVE LIGHTING IN SPACES FOR THE DEAF

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ABSTRAK

Artikel ini mengeksplorasi pendekatan biomimikri arsitektur, dengan menggunakan konsep fototropisme tanaman sebagai dasar konseptual dalam merancang pencahayaan ruang yang inklusif bagi penyandang tunarungu. Melalui pemahaman bahwa tunarungu mengandalkan penglihatan sebagai media komunikasi utama, penelitian ini mengadopsi perilaku tanaman yang bergerak mengikuti arah cahaya (fototropisme) sebagai analogi terhadap cara pengguna tunarungu berinteraksi dengan lingkungan bercahaya. Pendekatan ini diperkuat dengan teori multisensori dalam arsitektur (Spence, 2020) yang menegaskan bahwa persepsi ruang tidak hanya bersifat visual, tetapi hasil integrasi berbagai indera. Dengan menggunakan pendekatan kualitatif dan eksperimen konseptual terhadap arah pertumbuhan tanaman, penelitian ini menghasilkan prinsip rancangan pencahayaan yang merata, adaptif, dan responsif terhadap kebutuhan komunikasi visual. Prinsip tersebut diterjemahkan menjadi strategi arsitektural seperti orientasi ruang terhadap sumber cahaya alami, penyebaran iluminasi buatan yang seimbang, serta pemanfaatan reflektansi material. Dengan demikian, fototropisme dapat dijadikan dasar biomimetik dalam pengembangan DeafSpace yang tidak hanya fungsional, tetapi juga memperkaya pengalaman inderawi pengguna.

Kata Kunci: biomimikri; deafspace; desain inklusif; fototropisme; tunarungu.

ABSTRACT

This article explores a biomimetic architectural approach that applies the concept of plant phototropism as a conceptual foundation for designing inclusive lighting environments for individuals who are deaf or hard of hearing. Recognizing that deaf users rely on visual perception as their primary medium of communication, this study draws an analogy between the way plants move toward light and the way deaf individuals orient themselves within illuminated spaces. Supported by the multisensory theory in architecture (Spence, 2020), which asserts that spatial perception arises from the integration of multiple senses, this research employs qualitative and conceptual experimentation based on plant growth direction to develop lighting design principles that are even, adaptive, and responsive to visual communication needs. These principles are translated into architectural strategies such as the orientation of spaces toward natural light, the balanced distribution of artificial illumination, and the use of material reflectance, positioning phototropism as a biomimetic foundation for DeafSpace development that enhances both functionality and sensory experience.

Keywords: *biomimicry; deafspace; inclusive design; phototropism.*

INTRODUCTION

Biomimicry is a scientific approach that studies nature's models and then imitates or takes inspiration from these designs and processes to solve human problems. It provides innovative solutions to contemporary environmental challenges by drawing from nature's strategies to enhance sustainability, such as optimizing energy consumption and improving indoor environmental quality (IEQ). In architecture, biomimicry is recognized as a sustainable design method that seeks harmony between natural systems and human needs (Ibrahim & Nasreldin, 2025). Plants, in particular, serve as one of the most common sources of inspiration for biomimicry applications due to their remarkable adaptability and growth capability in diverse environments (Bijari, Aflaki, & Esfandiari, 2025).

According to Kahlen et al. (2008), phototropism refers to the growth movement

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of plants toward a light source, which serves as an ecological adaptation to optimize energy absorption. This process is regulated by the distribution of auxin hormones, which control the direction of growth based on variations in light intensity.

This phenomenon can be interpreted analogously within the context of Inclusive Design for the Deaf (DeafSpace). Edwards and Harold (2014) explain that DeafSpace is not merely a form of functional adaptation, but rather a manifestation of the visual cultural identity of the Deaf community. Spatial design must therefore facilitate visual-based communication by considering body orientation, sightlines, and light distribution that support facial expression and hand movements as key components of interaction.

One significant application of this is found in the concept of DeafSpace, a design philosophy developed at Gallaudet University that responds to the lived experiences and communication patterns of the Deaf community. DeafSpace emphasizes the visual and spatial qualities of architecture such as light, color, and spatial openness to facilitate visual communication and social interaction (Bauman, 2010; Harahap et al., 2020). This approach aligns with the understanding that built environments should be both physically and perceptually inclusive, enabling users to orient, navigate, and communicate effectively through visual means (Zahrah & Gamal, 2018; Wijaya, 2021).

For individuals who are deaf or hard of hearing, light functions as the primary medium of communication. Visual cues including facial expressions, gestures, and body movements depend greatly on adequate lighting. As a result, lighting design becomes a crucial element in enabling visual communication and orientation. In poorly illuminated environments, visual interaction can be hindered, reducing both spatial awareness and the ability to engage socially (Rout & Cloete, 2022). Harahap et al. (2020) emphasize that understanding within DeafSpace arises through visual perception, meaning that light quality and distribution are integral to functional and emotional comfort. In this way, light acts not only as a physical phenomenon but also as a social enabler that shapes the experience of space for Deaf users.

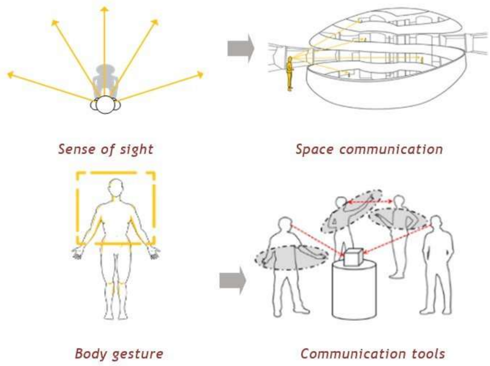

Figure 1. Visual Communication and Spatial Interaction in DeafSpace (Harahap et al., 2020)

This centrality of light in DeafSpace can be conceptually compared to how plants interact with light in nature. Plants depend on sunlight for photosynthesis, a process through which they convert light energy into chemical energy that sustains growth and reproduction. In addition to photosynthesis, plants exhibit phototropism, a behavioral response that allows them to move or grow toward a light source to maximize exposure (Christie & Murphy, 2013). This adaptive response is regulated by the hormone auxin, which redistributes itself to promote growth toward light, thereby optimizing orientation for survival. Even in extreme environments such as the deep sea, certain organisms like the bacterium *GSB1* are capable of synthesizing energy from geothermal light sources at the ocean floor (Beatty et al., 2005). These biological phenomena demonstrate that light fundamentally determines the vitality and behavior of living organisms.

The concept of phototropism provides a meaningful natural analogy for DeafSpace design. Both plants and Deaf individuals depend on light as a vital medium of interaction: plants for photosynthetic survival, and Deaf users for visual communication and spatial orientation. This research identifies a symbolic relationship between the behavioral responses of plants to light and the sensory adaptations of Deaf individuals in architectural space (Christie & Murphy, 2013; Harahap et al., 2020; Devansari & Rachmawati, 2017; Bauman, 2010). In both contexts, light governs movement, awareness, and engagement with the surrounding environment. The similarities between these two can be summarized in the table bellow.

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Table 1. Analogy between Plant Phototropic Behavior and DeafSpace Lighting Principles

Plants (Experimental Object)	Deaf Users (Design Object)	Analogical/ Architectural Design Principle	Conceptual Explanation (Non-Technical Meaning)	Supporting References
Depend heavily on light for photosynthesis and phototropism	Depend on light for seeing, reading facial expressions, and visual communication	Light as a system of navigation and communication	Light becomes the essential medium for both survival and social interaction — for plants and deaf users alike	(Christie & Murphy, 2013); (Hohm et al., 2013); (Devansari & Rachmawati, 2017); (Bauman, 2010)
Move toward light sources (phototropism)	Use light direction to read lips and sign language	Optimal lighting enables "seeing to hear" functions	Natural lighting supports effective communication for the deaf, just as light supports plant growth	(Beatty et al., 2005); (Harahap et al., 2020)

Source: Author Conclusion, 2023

The plant experiment conducted in this study functions as a conceptual biomimetic simulation, serving as a metaphorical model for understanding how architectural space can respond to light similarly to how humans with hearing differences utilize light for navigation and communication. The purpose of this simulation is not to equate human and plant behavior but rather to extract principles of light responsiveness that can inform inclusive spatial design. This conceptual approach provides a foundation for developing a biomimetic framework for DeafSpace lighting design, where natural strategies of adaptation are translated into architectural principles that enhance inclusivity.

By exploring the phototropic response as an analogy for human interaction with light, this study aims to derive conceptual insights that enhance visual communication, spatial awareness, and sensory inclusivity for Deaf users. Furthermore, Spence (2020) emphasizes that human spatial perception is inherently multisensory; the dominance of visual elements in modern architecture often neglects the potential of other senses such as touch, hearing, and proprioception. Therefore, this research proposes an integration between biomimicry (natural mechanisms) and multisensory perception (human experiential responses) in designing spaces that are inclusive for deaf users. Through this approach, the study contributes to the formulation of inclusive lighting principles based on plant phototropism as a biomimetic conceptual model that supports visual communication within DeafSpace.

RESEARCH METHODS

The research employs a qualitative experimental approach through a simulation of plant phototropism as an analogical model of human spatial behavior. The study aimed not to verify biological relationships between plants and humans but to develop a biomimetic conceptual model illustrating how architectural spaces can respond to light in ways that are inclusive for Deaf users. Through this analogical framework, the study sought to interpret natural behavioral responses to light and translate them into architectural principles that support visual communication and orientation. The qualitative method was chosen because it allows flexibility in exploring symbolic and behavioral meanings, emphasizing interpretation over measurement. As Creswell (2014) explains, qualitative research provides an understanding of phenomena through reflective analysis, focusing on the "why" and "how" behind behavioral patterns. Within this framework, the study interprets how living organisms demonstrate responsive behavior toward light and how such natural phenomena can inform lighting design in DeafSpace, where vision and light are central to communication.

The experimental observation was conducted to simulate how living organisms respond to light. The experiment lasted for 40 days, during which plants were placed inside a closed wooden box with several light openings serving as variables for illumination sources. The direction of plant growth was recorded daily through photographs to observe their responses to varying light intensities. The box contained several ventilation openings on selected sides that acted as controlled light sources, resembling windows or skylights in a building. This arrangement allowed the observation of how plants orient their growth according to the

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direction and intensity of light entering through the openings. The primary objective was to understand how the plant's behavior toward light could serve as an analogy for human spatial behavior, particularly among Deaf users who rely on visual stimuli. The experiment was therefore not intended as a biological study of plant growth, but as a conceptual simulation to explore the relationship between light, orientation, and environmental response.

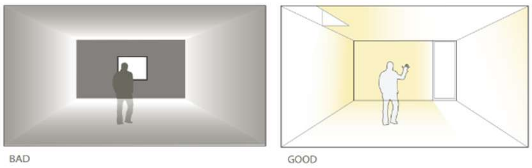

Figure 2. Theillustration of the needs of light towards deaf people in
Source: DeafSpace Design Guidelines (Bauman, 2010)

The experiment was designed to observe the plants' response to different light intensities within a confined environment. Plants were placed inside a wooden box with small openings that allowed light to enter from particular directions. These openings functioned as variables that determined how the plants would orient themselves toward available light. By observing this process, the study identified how living organisms naturally adapt to visual stimuli and how such adaptation can inform architectural strategies that enhance inclusivity. The gradual movement of the plant stems toward light sources provided valuable insight into the principle of phototropism, a natural mechanism through which plants optimize their exposure to light.

The conceptual connection between the experiment and DeafSpace lies in their shared dependency on light. For Deaf individuals, vision serves as the primary medium of communication. Adequate lighting allows them to perceive facial expressions, hand gestures, and spatial cues that are essential for interaction and orientation. Poorly lit environments, on the other hand, hinder visibility and obstruct communication. Similarly, plants depend on light for photosynthesis and movement. Their ability to grow toward light sources through phototropism (Christie & Murphy, 2013) mirrors the way Deaf users orient themselves within visually accessible spaces. This behavioral similarity forms the basis for interpreting how spatial design can metaphorically "move toward" light to enhance inclusivity.

The process of data collection included daily observation, photographic documentation, and measurement of the plant's growth direction over time. The data were analyzed using architectural interpretation rather than biological metrics. The analysis consisted of three stages. The first stage involved observing the plants' physical responses to light, focusing on how the stems adapted to directional light changes. The second stage translated these responses into conceptual principles of light behavior, emphasizing directionality, balance, and intensity as they relate to human visual orientation. The final stage applied these principles to formulate inclusive lighting strategies for DeafSpace design. Through this process, the experiment functioned as a metaphorical model of spatial awareness, revealing how light can guide movement, perception, and interaction.

This methodological framework refers to the principles of Functional Structural Plant Modelling (FSPM) as described by Kahlen et al. (2008), in which the direction of leaf and stem growth follows the red to far-red light spectrum ratio (R:FR ratio). Conceptually, this model is relevant for understanding how humans, particularly deaf, adjust their body orientation and gaze direction toward light sources in order to maximize visual communication.

The experiment serves as a representation of how architecture can behave like a living organism, adapting and orienting itself toward light to meet the needs of its users. By observing how plants respond to light, the study derives insights into how spatial configurations can enhance visual accessibility and communication for Deaf individuals. The observational data were then interpreted using a conceptual biomimetic framework, rather than a biological one, to identify architectural principles that could be applied in design practice. This interpretive approach follows the perspectives of Creswell (2014) and Spence (2020), who emphasize understanding phenomena through the reflection of sensory behavior and spatial perception. The findings contribute to the development of lighting design principles that are both biologically inspired and socially meaningful, ensuring that architectural spaces support inclusive human interaction and sensory experience.

RESULTS AND DISCUSSION

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The experiment was divided into three observation stages: pre-growth, growth, and post-growth. The process continued until the desired outcome was achieved, which was the plants growing through the openings or exhibiting behaviors consistent with the theory of phototropism. The experimental results showed that the plants consistently oriented themselves toward the primary light source. This observable pattern became the foundation for developing an analogy in designing spaces that support visual orientation for Deaf users. The following discussion elaborates on each stage and interprets the findings in the context of inclusive lighting design.

The research results are observed and discussed in three stages: the pre-growth stage, the growth stage, and the post-growth stage.

1. Pre-Growth Stage

The research begins with the creation of plant samples, in this case, a plant is chosen as the experimental object and placed in a container. Some of the plants are partially covered with a spatial design that is intended to block most of sunlight, with opening holes placed on the sides. This is done to observe how the plants respond to the contrasting light conditions in the dark and bright areas of the space. A stem of the plant is separated and placed within the spatial design to observe its movement in the partially covered area.

Figure 3. 9 March 2023, The initial stage of placing the spatial beam.

Initially, the entire plant was open, and it was difficult to observe any differences or movements since no spatial design was provided. This spatial design is created as a simulation of the real-world environment designed for deaf individuals.

(a) (b)

Figure 4. Plant condition on 12 March 2023. (a) Hole on the main side ; (b) Hole on the second side

(a) (b)

(c)

Figure 5. Plant condition at different state of time (a) 13 March 2023; (b) 17 March 2023; (c) 19 March 2023

2. Growth Stage

This stage begins with understanding the needs of plants and proving that the requirement for light is essential for their development and the process of photosynthesis. Additionally, the plants react to the sun with the movement towards the light, known as phototropism, which allows them to maximize the sunlight they receive for optimal growth.

(a)

(b)

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Figure 6. Plant conditions at different states of time in the growth stage. (a) 17 April 2023; (b) 19 April 2023

After one month, the desired results from the experiment are obtained, confirming the theory of phototropism. The subject of study, the plant, emerges from the created openings hole in the pre-growth stage.

3. Post-Growth Stage

The post-growth stage is observed by removing the spatial beam or wooden box to observe the differences in the overall stem's development compared to the initial conditions. It is found that only the parts close to the light source develop and produce leaves as a result of their growth, while the other parts that are far from the reach of the hole remain in the same condition as before.

Figure 7. The condition of the stem after removing the spatial beam on April 25, 2023

Results Conclusions of The Experiment

The three stages of the experiment provide a comprehensive understanding of how living organisms respond to light intensity and direction. The plants' consistent movement toward light validates their dependence on illumination as a guide for orientation and survival. Translating this finding into architectural terms, spaces designed for Deaf users should also prioritize clear visual orientation by optimizing light distribution.

Just as plants adapt their direction of growth toward light to ensure survival, Deaf individuals orient their bodies toward light sources to enable face-to-face communication. This adaptation allows facial expressions and vital components of visual communication to remain visible. In dimly lit environments, this process is disrupted, hindering comprehension and interaction. Similarly, plants deprived of light become weak and disoriented, struggling to maintain their growth direction.

This parallel demonstrates that inclusive lighting design should focus on the even distribution of both natural and artificial light, avoiding glare and maintaining clear sightlines between users. By ensuring that light acts as both a spatial and communicative medium, architecture can support the visual comfort and social engagement of Deaf individuals. The principles derived from the plant experiment thus serve as a biomimetic foundation for formulating lighting strategies that enhance visual communication, orientation, and inclusivity in built environments.

The conclusion of the experiments summarized in forms of a table below.

Table 2. Results conclusions of the experiment

Stage	Indicator	Results Conclusions	Previous Researcher(s)	Observation Keywords
Pre-Growth	Light	Different parts of the box receive varying amounts of sunlight, causing differences in brightness levels within the box.	-	Placement
Growth	Light	In the growth stage, plants proven perform the phototropism process because of the hole that lead the plant outwards the box	(Christie & Murphy, 2013)	Light Source
	Movement			
Post Growth	Light	A different part of the box has another effect towards the plant.	(Christie & Murphy, 2013; Chen et al., 2019)	Placement
	Movement	Branch that near the hole of the box grow outward as part of the process of phototropism and produce leaf	(Christie & Murphy, 2013; Hohm, Preuten, & Fankhauser, 2013)	Light Source and Placement
		Branch that far from the hole of the box do not grow any kind of plants activity		

Source: Author Conclusion, 2023

The table simplified the conclusion in terms of keywords to understand the main result of observation in creating a space for deaf people. The placement and light source

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play a significant role in creating a better environment for communication to deaf people.

Analogy Between Phototropism and the Visual Response of Deaf Users

Plants exhibit growth patterns directed toward light sources to optimize photosynthesis. In this experiment, the stems and leaves were observed to bend toward openings with higher light intensity. This phenomenon mirrors the visual orientation behavior of Deaf individuals, who naturally position themselves to clearly see the facial expressions and body movements of their interlocutors (Edwards & Harold, 2014). Both phenomena demonstrate an innate tendency to orient toward sources of visual information, for plants, this serves the purpose of energy acquisition, while for humans, it facilitates visual communication.

Integration of Multisensory Principles in Spatial Design

According to Spence (2020), architectural experience does not result from a single sensory modality but rather from the integration between light, color, temperature, and sound. In the context of DeafSpace, this means that lighting should not stand alone; it must be supported by the texture, materiality, and acoustics of the space to create a balanced sensory environment. Thus, the application of phototropism principles is not solely about the direction of light, but also about how light interacts with surfaces, reflects, and shapes a visual atmosphere that is both comfortable and informative.

Biomimetic Implications for DeafSpace Design

The principles derived from the plant experiment are translated into architectural design strategies as follows:

1. Spatial orientation toward natural light sources, such as the placement of large windows in directions that allow for an even distribution of daylight.
2. Adaptive artificial illumination, which adjusts light intensity and direction according to the needs of group communication.
3. Avoidance of glare and harsh shadows, which may interfere with the perception of hand movements and facial expressions.
4. Controlled reflectivity of wall and floor materials to enhance light diffusion without causing excessive reflection.

These strategies align with the essence of DeafSpace (Bauman, 2010), which emphasizes visual, spatial, and social dimensions in supporting interaction within the Deaf community.

Phototropism as a Model of Spatial Adaptation

The model proposed by Kahlen et al. (2008) demonstrates that a plant's response to light gradients represents a form of adaptation to dynamic environmental conditions. In architecture, this concept can be interpreted as human spatial adaptation to lighting conditions, for instance, through the implementation of intelligent lighting systems that respond to user presence (adaptive lighting). Thus, inclusive design is not static but capable of reacting dynamically to the visual needs of users in real time.

Design Solutions

Drawing inspiration from the principle of phototropism, architectural design can be directed to "follow the light," just as Deaf individuals depend on optimal lighting for communication and spatial awareness. The plant experiment provided valuable insight into how light governs the behavior and movement of living organisms. Similarly, for Deaf users, light dictates how they interact, communicate, and navigate within space. Therefore, the experimental findings serve as a biomimetic model for designing spaces that metaphorically "move toward the light" to create inclusive and visually accessible environments.

The analogy between plants and Deaf individuals lies in their shared dependency on light for orientation and functionality. Plants grow toward light sources to sustain life through photosynthesis, while Deaf individuals orient themselves toward well-lit areas to perceive visual cues essential for communication. In both cases, light acts as a guiding element that shapes behavior and defines the quality of experience. This understanding underpins the development of architectural strategies that translate biological behavior into spatial design principles.

The design solutions proposed in this study are derived directly from the experimental observations and conceptual analysis. The findings reveal that openness to light within enclosed environments is a critical factor that promotes growth, interaction, and inclusivity. Applying this to architecture, spaces intended for Deaf users should integrate both natural and artificial lighting systems that ensure consistent and balanced illumination. The following solutions were formulated as practical applications of these principles:

1. **Use of Windows as Natural Light Openings**
   Windows serve as primary elements that introduce daylight into interior spaces, providing a natural source of illumination that supports visual orientation. The placement and size of windows should be carefully designed to distribute light evenly, reduce shadow zones, and enhance visual clarity between occupants.
2. **Use of Artificial Lighting as a Complementary System**
   Artificial lighting, including ceiling lamps and wall fixtures, should complement natural light by maintaining visual balance throughout the day. Adjustable light intensity and color temperature can help adapt to different communication needs and times of day, ensuring that visibility is maintained even under varying environmental conditions.
3. **Strategic Placement of Light Sources**
   Both windows and lamps must be positioned to avoid glare, prevent backlighting during communication, and maintain clear sightlines. Proper placement ensures that facial expressions and hand gestures to remain visible and comfortable to observe.

Through these strategies, architectural design mirrors the biological logic observed in plants responding to light for growth and connection. A dark or poorly lit space challenges both organisms: plants struggle to thrive, while Deaf individuals find it difficult to perceive and communicate effectively. Accessible light, therefore, becomes a universal enabler of vitality and inclusion.

This relationship shows that inclusivity extends beyond physical accessibility to encompass visual accessibility within architectural space. The more accessible a space is, the more inclusive it becomes (Zahrah, Rizky, & Egidia, 2023, p. 6152). Ensuring that light is evenly distributed and visually accessible is not only a biological or technical concern but also a social imperative that fosters natural communication and equal participation.

By integrating these principles, architecture transforms from a static construct into a responsive system that behaves like a living organism guided by light. Such spaces do not merely accommodate Deaf users; they celebrate and enhance their perception, reinforcing harmony between natural processes and human-centered design.

Design Example

The following design examples illustrate the implementation of various design solutions and their possible variations. The placement of these design elements within the building can be observed in the floor plan (Figure 8). The building functions as a learning center for elderly individuals, including those with partial or complete hearing loss. It is divided into two main zones: a healthcare area and a social gathering area, which accommodates multipurpose functions such as seminars, study spaces, and temporary resting zones.

The design adopts the DeafSpace approach with the concept of “Eyes that Hear.” This concept emphasizes the importance of visual clarity and spatial awareness for deaf individuals, who rely primarily on sight to communicate and navigate their surroundings. In developing this architectural approach, the behavior of plants, particularly the phenomenon of phototropis, becomes a relevant biomimetic analogy. Phototropism refers to a plant’s natural tendency to move or grow toward light sources, enabling it to perform photosynthesis effectively and sustain its life processes. Similarly, for individuals whose hard of hearing, light acts as a vital guide that stimulates spatial orientation, communication, and movement within the built environment.

By drawing from this biological principle, the building design integrates light vessels, architectural openings that act as conduits for natural light penetration. These vessels are not merely functional apertures but serve as stimuli for movement and interaction, directing users along naturally illuminated pathways and creating a sense of rhythm within the spatial experience. Just as light guides plant growth and response, these light vessels orchestrate human movement, fostering a visual and spatial dialogue

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between the users and their environment. The resulting design transforms light into a dynamic architectural medium that enhances visibility, comfort, and emotional well-being, allowing deaf users to experience space through illumination and visual connection rather than sound.

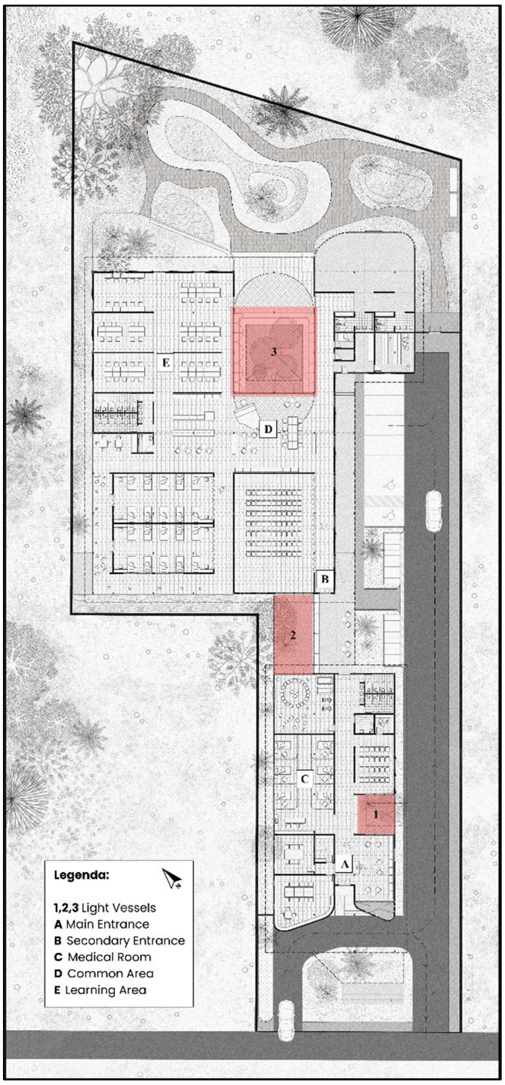

Figure 8. Ground Plan of the learning centre.

Figure 8 shows the ground floor plan, where rectangular openings such as indoor gardens and windows are strategically placed along the corridors. These openings serve as visual and spatial stimuli, guiding movement while allowing natural light to penetrate the interior. This spatial arrangement facilitates communication among users by ensuring that visual cues remain unobstructed.

Figure 9. Simulation of the light and activity in the lobby and corridor

Furthermore, Figure 9 illustrates a lighting simulation that demonstrates how natural light functions as a spatial stimulus or "activator." The use of brick wall materials filters incoming light, reducing glare and creating a comfortable visual environment. This material selection not only controls light quality but also enhances the sensory comfort of deaf occupants who rely heavily on visual information.

Figure 10. The common area and learning area of the building.

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The main activity area of the building is centered around a courtyard, surrounded by functional spaces such as reading rooms and learning areas (Figure 10). The use of glass partitions between these spaces enhances visual connectivity, enabling users to maintain eye contact and visual awareness across distances, an essential aspect of communication in DeafSpace design.

Through the application of these architectural strategies, the design accommodates the spatial and perceptual needs of deaf users, promoting movement, comfort, and safety within the building (Devansari & Rachmawati, 2017). The integration of the "Eyes that Hear" concept also aligns with the principles of universal design, a design philosophy that aims to make environments and products understandable and usable by everyone, to the greatest extent possible, without requiring specialized adaptations. Universal Design ensures comfort, accessibility, usability, safety, and independence for all users (Wijaya, 2021; Sukamto & Hetyorini, 2013).

CONCLUSIONS

This research demonstrates that the principle of phototropism in plants can serve as a conceptual foundation for designing inclusive lighting environments for Deaf users. The simple plant experiment confirmed that the presence and direction of light play a crucial role in determining orientation and movement behavior. This natural phenomenon provides a clear analogy: Deaf individuals, who rely on vision as their primary means of communication, require lighting conditions that are evenly distributed, non-glaring, and supportive of visual orientation among users.

By applying the concept of "moving toward the light," architectural design can create environments that are not only functional but also inclusive where Deaf users can interact and communicate optimally. The phototropism principle thus evolves from a biological response into an architectural strategy, shaping how built environments respond to human sensory diversity.

In relation to the previous discussion, the design strategies derived from this research embody this phototropic logic. Just as plants orient themselves toward light to sustain growth, spatial design for Deaf users should guide and enhance visual connection through ` lighting. In this way, the biomimetic approach transforms a natural behavior into a design philosophy that bridges biological adaptation and human-centered architecture.

Through the biomimicry approach and the theory of multisensory perception, it was found that the adaptive behavior of plants toward light aligns with the visual needs of Deaf users in facilitating communication. The integration of Spence's (2020) multisensory theory, Kahlen et al.'s (2008) biological model, and the DeafSpace paradigm (Edwards & Harold, 2014) produces a design framework that emphasizes:

1. Light as a medium for orientation and communication;
2. Space as a responsive system that adapts to visual needs;
3. Inclusive design that combines sensory experience with natural principles.

Thus, biomimetic architecture based on phototropism can serve as a conceptual model for designing spaces that are not only ecologically efficient but also empathetic to human sensory diversity.

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