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Assessing Daylighting Efficacy Of Academic Buildings Through Post-Occupancy Evaluation

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Abstract: ***This research study investigates the impact of daylighting on indoor environments within academic buildings, focusing on the School of Management and Information Technology (SMIT) complex. The study employs a post-occupancy evaluation to assess the efficacy of daylighting strategies in enhancing indoor lighting quality, occupant comfort, and task performance. Questionnaires were distributed to occupants, including students and staff, to gather their perceptions and experiences related to lighting conditions.***

The findings reveal a strong preference for good lighting, with natural light being highly desired. However, a significant number of occupants reported inadequately lit work areas. The study highlights the importance of effective daylighting in creating pleasant workspaces and enhancing user satisfaction. The results provide insights into user preferences, the significance of windows, and the impact of lighting on overall impressions of spaces.

The study contributes to the understanding of how daylighting influences occupant well-being and performance in academic settings.

Keywords: Daylighting, Post-Occupancy Evaluation, Academic Buildings, Natural Light

I. INTRODUCTION

Daylighting is a significant aspect of modern architecture, and its insufficiency or excess can negatively impact visual perception, productivity, human health, and energy conservation. Within an academic environment, students' productivity is influenced by individual motivation, psychological conditions, intelligence, and external factors affecting both students and the overall learning environment (Abdelatia, 2010).

"Daylighting is a process that makes use of daylight to achieve some expected lighting effects in buildings, such as lighting up a task area, highlighting some objects while obscuring others, or even totally avoiding its contribution under particular circumstances " (Costanzo, Marletta, & Evola, 2017). The adequacy of lighting for a task area is subjective and varies according to user perception, with each task having distinct lighting requirements. It is crucial that individuals can comfortably perform tasks with complete reliance on daylight, without experiencing strain or discomfort. The incorporation of daylighting strategies leads to reduced electrical energy consumption in buildings. Interest and research into daylight as an effective means to mitigate energy usage in buildings are increasing. In academic buildings where productivity is of utmost importance, daylighting plays a pivotal role in establishing an ideal learning environment.

"For daylighting strategies to be effective, the great majority of time that teachers and students are in the particular space, the daylighting strategy must be superior to the electrical lighting" (Innovative Design, 2004).

This research aims to assess the efficacy of daylight within the School of Management and Information Technology (SMIT) complex through a post-occupancy evaluation. The extent to which daylight is utilized to illuminate the interior spaces of the academic building and its alignment with occupants' needs is of significant concern.

The main research question for this research is: How does the efficacy of daylight within an academic building impact the quality of indoor lighting, occupant comfort, and task performance, and how do these factors interact within the School of Management and Information Technology (SMIT) complex? This research question encompasses the fundamental aspects of the study, focusing on evaluating the efficacy of daylight, its impact on indoor lighting quality, occupant comfort, and task performance in academic buildings.

These findings offer insights into the challenges associated with natural lighting in the SMIT complex as perceived by its occupants. The results of this research project will aid designers in better formulating daylighting strategies during the design phase or for already operational structures. Additionally, the inconsistent nature of the Nigerian electricity grid impedes reliance on artificial lighting in the specific building, thereby the relevance of this research is not only for the studied building but also for numerous others facing similar circumstances.

II. LITERATURE REVIEW

A. DAYLIGHTING IN SCHOOLS

PRIOR TO 1930

Due to the absence of electricity, daylight served as the primary source of illumination for classrooms until the 1930s. Consequently, classrooms were planned and positioned to maximize daylight intake throughout the day. The popular notion was that light should originate from above the left shoulder of students. “Apparently this view was based on the assumption that students should write with their right hand, and thus light coming over their right shoulder would be blocked by their arm” (Baker, 2010). The guiding principle suggested a window-to-floor ratio of 20% for classrooms lit from the sides

School buildings were standardized during this era to ensure sufficient daylight for classrooms and other task-oriented spaces. However, this often resulted in an excessive influx of sunlight, leading to increased glare and higher classroom temperatures. This highlights the fact that daylighting is more than merely providing daylight; it also involves mitigating the undesirable characteristics that accompany it.

1930-1980

In the 1940s, many schools began incorporating fluorescent lighting in addition to natural light from windows. This transition prompted considerations regarding how classrooms should be illuminated. “School designs during the 1940s and 1950s tended to provide ample natural light along with the newly added artificial light” (Baker, 2010). Paradoxically, artificial lighting exacerbated issues of visual comfort, potentially intensifying glare. Another issue emerged while using slide projectors as a learning tool; the inability to screen out natural light. There’s little evidence to confirm if blinds and curtains were commonplace in classrooms during the 1950s (Baker, 2010). Moreover, there is limited evidence to ascertain whether the teachers and students preferred natural or artificial light. Nevertheless, there was an increasing interest in using both light sources to optimize the visual environment (Baker, 2010).

The 1960s and 1970s witnessed a surge in the use of artificial lighting. The energy crisis raised architectural speculation on whether windows were a necessity in classrooms. As cited in (Baker, 2010), research conducted in the early 1970s showed that windowless classrooms had no discernable negative impact on student learning, even though teachers and students did complain about the conditions being unpleasant (Collins, 1975; Wienstein, 1979, as cited in Baker, 2010). Some theories argue that windows are a distraction to many students (Costanzo, Marletta, & Evola, 2017).

1980-Today

The early 1980s marked a shift toward climate-sensitive school architecture, favoring south-facing windows to optimize solar gain (Costanzo, Marletta, & Evola, 2017).

“Although illumination standards for classrooms have largely leveled off in recent years, there is still some disagreement about even the most basic question of how much illumination is necessary in classrooms” (Baker, 2010). The primary point of contention revolves around proper light distribution, quality, and challenges inherent in daylighting design. As noted by Baker (2010), significant debate surrounds the suitable metrics for daylighting, particularly as the industry re-embraces the value of naturally lit spaces (Mardaljevic et al., 2009, Baker, 2010).

A survey conducted by the Heschong Mahone Group in US elementary schools revealed that daylight improved visibility due to superior light quality compared to artificial lighting. This improvement stemmed from better light distribution, as artificial light predominantly falls directly above workspaces, leaving vertical surfaces less illuminated. Daylight also boasts better spectral distribution, rendering all colors more accurately. Moreover, daylight has an absence of flicker, a common occurrence with alternating current, and has been associated with complaints of headaches, eye strain, and distraction (Heschong, 1999/08/20). The study also reported enhanced academic performance among students with sufficient daylight in classrooms. Those in classrooms with greater window area or daylighting achieved 7% to 18% higher scores on standardized tests than those with less window area or daylighting. Furthermore, improvements in mental stimulation, mood, behavior, and well-being were observed.

With no standardized metrics to specify daylighting performance levels, recent decades have witnessed the construction of numerous schools with abundant natural light, yet plagued by conflicting issues of visual comfort (Baker, 2010). Nevertheless, researchers and designers possess a comprehensive understanding of what constitutes a favorable visual environment.

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B. THE RATIONALE OF POST-OCCUPANCY EVALUATION

Today, people expect more from their buildings than just protection from rain, wind, surroundings, and so forth. They want buildings to function as intended, be safe, comfortable, and adaptable to new situations (Tookalooa & Smith, 2015). The global focus on sustainability has made the topic of Building performance more relevant for both developers and building owners. There are many theories and tools in practice today to determine Building performance, Post Occupancy Evaluation is one.

In 1967, Van der Ryn and Murray Silverstein published "Dorms at Berkeley: An Environmental Analysis," one of the earliest formal assessments of a building (Hosey, 2019). "Post Occupancy Evaluation (POE) is the process of gathering feedback on a building's performance after it has been constructed and occupied. POE encompasses information collection on building use, energy consumption, and user satisfaction" (Royal Institute of British Architects (Royal Institute of British Architects (RIBA), 2020). A POE aims to ascertain whether the building functions as intended and whether occupants are content. Dissatisfied users are likely to seek solutions to alleviate discomfort within the spaces. POE systematically assesses performance, aiming to better comprehend occupants' perceptions and attitudes toward indoor spaces. Its purpose is to determine if the building's performance matches the intended level established during the design phase. It can be applied to analyze nearly all aspects of a building's physical indoor environment. This process provides a deeper understanding of prevailing daylighting issues that may require refinement, identification of elements to avoid, recognition of features for future implementation, and revelation of aspects necessitating further research and exploration (Hygge & Löfberg, 1999).

Post Occupancy Evaluation of educational environments has evolved over nearly fifty years (Tookalooa & Smith, 2015). It is particularly concerned with how a building supports educational adequacy by evaluating the physical environment it accommodates. The assessment's methodology aligns with that of a traditional POE, emphasizing user experience, needs, and value. The study and evaluation of academic institutions have propelled the advancement of POEs. Since the 1960s, universities have actively participated in POE exercises facilitated by design practitioners (Tookalooa & Smith, 2015).

Like any evaluation method, POEs have their drawbacks. As participants in a POE are human, finding a universally appreciated system is unlikely, and responses are subjective to user experiences. Consequently, the questions adopted must bear these differences in mind, and accommodate for the varying responses.

III. METHODOLOGY

A. CASE STUDY

The School of Management and Information Technology (SMIT) complex is an academic building situated within Modibbo Adama University of Technology, Yola. Constructed in 2002 as an Education Trust Fund (ETF) project by Madugu Construction Company, it was officially commissioned in 2006. The building accommodates educational activities for various departments, including Accountancy, Economics, Management Technology, and Information Technology. Comprising two stories, the complex features twin lecture halls, classrooms, offices, libraries, restrooms, and a spacious central courtyard.

A walkthrough of the building was conducted to validate the prevailing complaints voiced by its occupants. The feedback received, along with observations and reactions, predominantly revolved around daylight conditions and inadequate ventilation within the premises. This tour also facilitated the identification of pertinent focus areas for the Post Occupancy Evaluation. The lecture theaters were excluded from the study due to their infrequent usage by student occupants.

The POEs were executed for the eight classrooms in the building, each covering an area of 62.6 m². Four classrooms are situated on each floor, oriented towards the northeast and northwest. These evaluations were distributed among full-time students of the respective faculty, those who frequently utilized these classrooms throughout the academic year.

Additionally, POEs were conducted for twelve out of the thirty-two office spaces, each occupying an area of 23 m². This selection was made because many office spaces either remained unoccupied or were not utilized as originally intended. Nevertheless, the distribution of POEs remained equitable, considering that the arrangement of converted office spaces was similar, serving the various departments in the faculty. Sixteen offices are located on each floor, oriented along the southwest, south, and southeast directions. The participants in these evaluations were full-time staff members who worked during regular office hours in their designated offices.

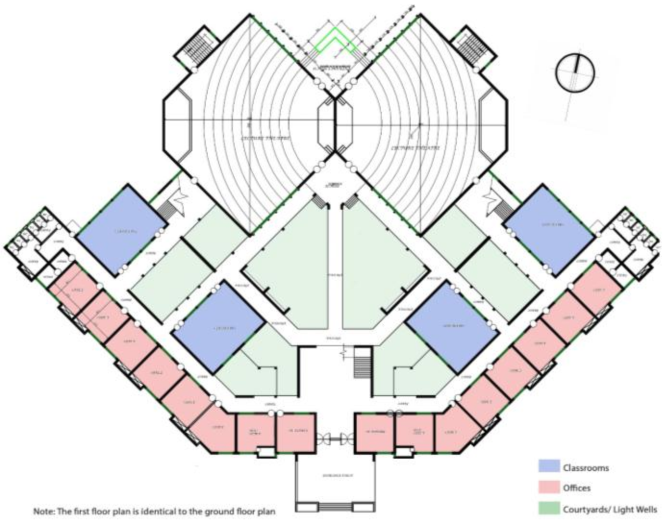

Figure 3.1: Ground floor plan of the SMIT complex

Figure 3.2: Exterior view of the SMIT complex

Figure 3.3: View toward the entrance with visible dark spaces

Figure 3.4: View of SMIT comples's biggest courtyard

B. DATA COLLECTION

The Hygge & Löfberg (1997) adaptation of the POE titled *"Lighting Conditions Survey"*, originally devised by Elder, Turner, & Rubin (1979), was employed to assess the daylight conditions within the SMIT complex. The former approach is specifically tailored to lighting conditions. The initial questionnaire encompasses inquiries spanning user perceptions of the entire building, workstations, lighting, privacy, as well as thermal and acoustic conditions.

Questionnaires were randomly distributed among two participant groups: staff and students working within their respective areas (offices or classrooms). The POE assessment took place from June 10th to June 14th, 2021, based on the availability of participants who volunteered to participate. A total of 70 questionnaires were distributed (50 to students and 20 to staff), and the POE questionnaires were completed by 65 participants (50 students and 15 staff).

C. DATA ANALYSIS

The collected data from the POE questionnaire were subjected to thorough analysis on the Statistical Package for the Social Sciences (SPSS) software. Utilizing SPSS ensures transparency and reproducibility of the analysis through its well-documented environment.

Descriptive statistics, including mean, percentage, and frequency distributions, were generated to summarize the characteristics of the numerical and categorical variables.

D. LIMITATIONS

While the chosen methodology and data collection techniques provide valuable insights into the effectiveness of daylighting within the SMIT complex, there are certain limitations that should be acknowledged.

- ✓ In accordance with the standard categories identified by Hygge & Löfberg (1999), this POE exercise is classified as a "field study - few subjects case". This classification is chosen when a real-world building is selected for evaluation, and limited alterations to lighting conditions can be executed, involving only a small number of participants. While this classification does not result in a in-depth POE, it does provide valuable insights, particularly if certain aspects of the building are highly pronounced, as evident in the less-than-desirable daylight conditions complaints from occupants.
- ✓ The study was conducted within the confines of a single academic building, the School of Management and Information Technology (SMIT) complex.
- ✓ The research was conducted within a specific time frame, from June 10th to June 14th, 2021. This limited time scope might not capture potential variations in lighting conditions, occupant experiences, or other factors that could occur at different times of the year or under different circumstances.

Despite these limitations, the chosen approach offers a comprehensive understanding of the subject within the constraints of the study.

IV. RESULTS

A. DEMOGRAPHIC VARIABLES OF THE PARTICIPANTS

		Number of participants (N)	Percentage (%)
Gender of Respondants	Male	33	50.8%
	Female	32	49.2%
In general terms, what kind of job do you have?	Staff	15	23.1%
	Student	50	76.9%

Table 4.1: Gender of participants and job title

The gender distribution and job type data table in *Table 4.1* show that there is a slightly higher percentage of men, while the majority of participants are students.

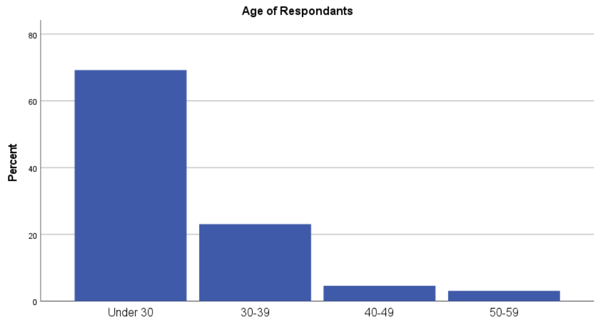

Figure 4.1: Age groups in the building.

The age distribution in *Figure 4.1* shows that the highest fraction of participants are under 30 years of age, while the lowest fraction falls within the 50-59 age range.

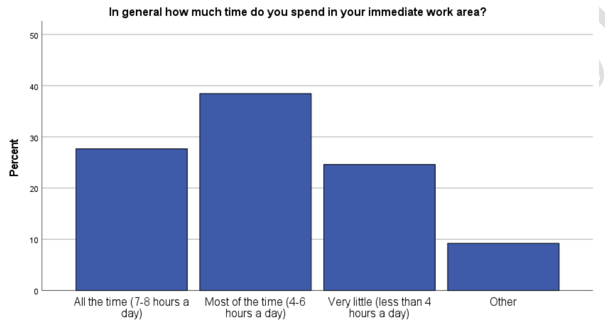

Figure 4.2: Time spent in immediate work area

Figure 4.2 shows that the highest percentage of occupants spend most of their time (4-6 hours a day) in their immediate work area.

B. WHAT DO THE OCCUPANTS WANT FROM THEIR INDOOR ENVIRONMENT?

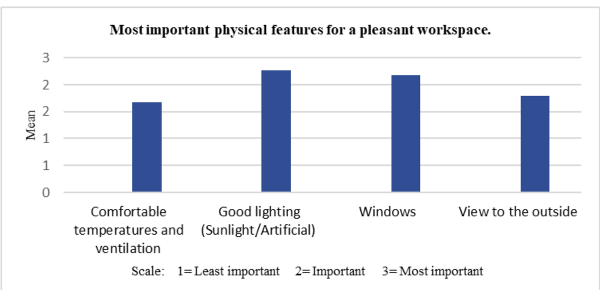

Figure 4.3: Mean importance rating or physical features

Figure 4.3 shows the mean importance ratings of different aspects of the workplace. The question asked occupants to rank the three most important physical features necessary to create a pleasant workspace. They were given four alternatives to rank: comfortable temperatures and ventilation, good lighting (sunlight/artificial), windows, and a view to the outside. The responses to this question were considered indicators of the occupants' preferences, not necessarily reflecting their current conditions.

Among the options, good lighting emerges as the most desired feature by the occupants, followed by windows at a close second.

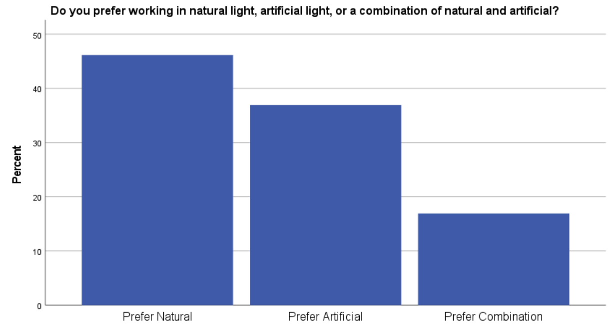

Figure 4.4: Light preference for work

Figure 4.4 shows the light preference of the occupants. Natural light gained a higher rating compared to artificial light, with fewer than 20% favoring a combination of both.

		Window in work area Yes	No
Impotance of window in work area	Very Important	69.2%	10.8%
	Moderately Important	7.7%	12.3%
	Not Important	0.0%	0.0%
Total		N= 50	N= 15

Table 4.2: Rated importance of window and presence of windows

Table 4.2 shows the relationship between the rated importance of having a window and actually having one in a work area. The purpose of this question is to ascertain whether high importance ratings of a feature correlate with its availability. A significant correlation is observed between having a window in the work area and assigning it a high importance rating. Notably, none of the occupants marked 'not important,' regardless of whether they had a window in their room or work area.

C. HOW DO THE OCCUPANTS RATE THEIR INDOOR ENVIRONMENT?

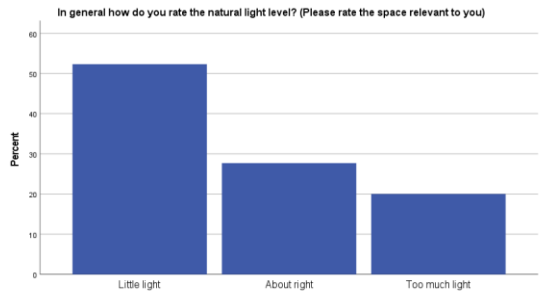

Figure 4.5: Ratings of natural light

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Figure 4.5 shows the rating of natural light levels by occupants in their respective work areas. A majority of occupants, over 50%, assessed their work area as having little light overall. Slightly under 30% rated the lighting in their work area as 'about right'. Only 20% of occupants indicated that their work area had excessive light levels.

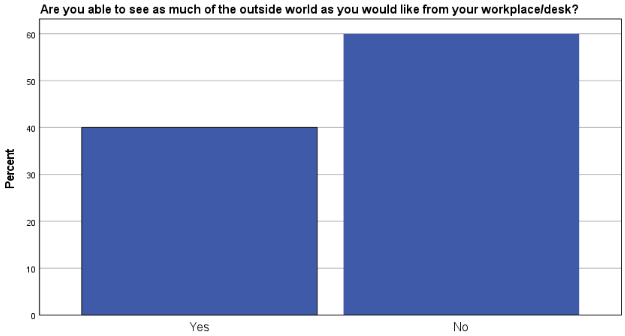

Figure 4.6: Outside world from workplace/desk

Figure 4.6 shows that 60% of occupants do not see as much of the outside world as they would like from their workplace or desk.

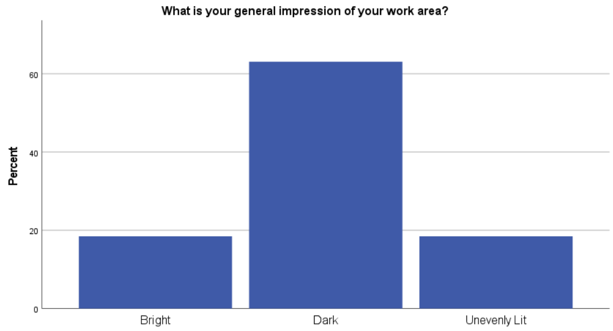

Figure 4.6: General impression of work area

Figure 4.6 shows the overall impression of occupants' work areas. More than 60% of occupants rated their work area as dark. Fewer than 20% described their work area as bright, and less than 20% found their work area to be unevenly lit. Overall, light levels were deemed unsatisfactory by the majority of occupants in the building.

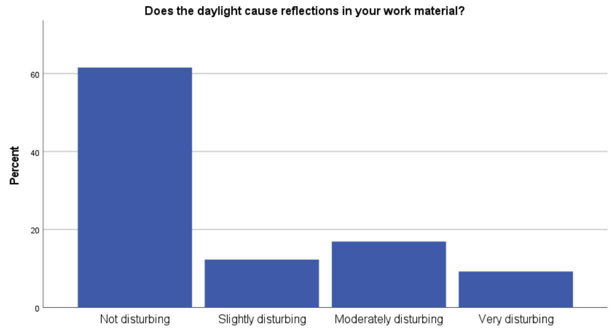

Figure 4.7: Reflection in work material

Figure 4.7 shows the ratings of reflection on occupants' work materials. More than 60% of occupants find reflections from natural light not problematic while working. In each of the subsequent categories, fewer than 20% of occupants indicated that reflections were slightly disturbing, moderately disturbing, or very disturbing.

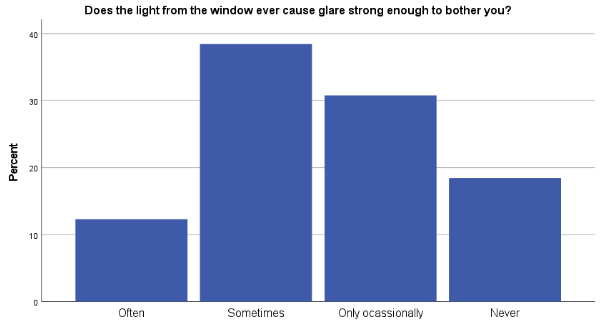

Figure 4.8: Glare disturbance from window

Figure 4.8 shows how occupants rate how strong enough glare is from the window to bother them. A little over 10% of occupants stated it often bothers them, less than 40% stated it sometimes bothers them, a little above 30% stated it only occasionally bothers them while less than 20% stated it never bothers them.

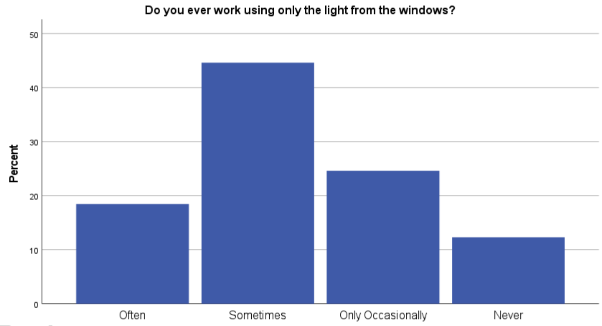

Figure 4.9: Working with only window light

Figure 4.9 shows how much the occupants depend on only the light from the window to carry out their tasks. A little less than 20% stated they often do, about 45% stated they sometimes do, 25% stated they only occasionally do, and a little above 10% said they never do.

V. DISCUSSION AND CONCLUSION

A. DISCUSSION

The findings of this study shed light on the critical role of daylighting within academic environments, particularly the School of Management and Information Technology (SMIT) complex. The research question sought to evaluate the efficacy of daylighting strategies and their impact on indoor lighting quality, occupant comfort, and task performance.

The analysis of occupants' responses indicated a strong preference for good lighting conditions, with natural light being the most desired feature. This aligns with previous research that emphasizes the positive effects of natural light on human well-being, productivity, and visual comfort (Heschong, 1999; Baker, 2010). The relationship between the rated importance of having a window and its actual presence further reinforces the significance of daylighting. Occupants rated having a window as very important and showed a preference for spaces with windows, indicating the role of windows in enhancing the overall indoor environment.

The data also revealed that while natural light was highly desired, a considerable percentage of occupants found their work areas to be inadequately lit. This discrepancy between preferences and reality highlights the challenges associated with implementing effective daylighting strategies.

Many occupants stated they only sometimes or occasionally depend on the light from the window to carry out their work, and less than 10% stated they often depend on it. This data reveals a general lack of reliance on light from windows for work in the building.

Furthermore, the study highlighted a disparity between occupants' desire for a connection to the outside world and having an actual view outside from their workplace. Over 60% of occupants expressed a lack of a better view, implying that the quality of views should be considered in the design and placement of work areas.

The participants' ratings of their general impression of work areas revealed that a significant portion of occupants perceived their spaces as dark, indicating a potential need for improved lighting design to address this concern.

B. CONCLUSION

This research project highlights the importance of effective daylighting strategies in enhancing the quality of indoor environments within academic buildings. The findings emphasize the need for holistic approaches that consider user preferences, visual comfort, and overall well-being. The insights gained from this study can guide designers, architects, and facility managers in optimizing lighting design and improving the indoor environment for occupants.

Further research is needed to dive into the specific design factors that contribute to successful daylighting strategies and explore innovative solutions that address the problems introduced. Additionally, long-term studies could further track the effects of daylighting on occupant satisfaction, productivity, and energy consumption.

This study serves as a valuable contribution to the ongoing discussion on sustainable and user-centered building design, bridging the gap between architectural theory and real-world performance.

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