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ENHANCING ENERGY EFFICIENCY AND VISUAL COMFORT: THE ROLE OF PASSIVE DAYLIGHTING IN PUBLIC HIGHER EDUCATIONAL BUILDINGS

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Abstract
This comprehensive research investigates the implementation of passive daylighting strategies in public higher educational buildings, addressing the critical challenges of energy efficiency and visual comfort in modern educational environments. With the continuous expansion of educational institutions worldwide and the subsequent surge in energy consumption, particularly in lighting, there is an urgent need for sustainable design solutions that can meet both environmental and functional requirements. The study examines how passive daylighting techniques can effectively reduce dependency on artificial lighting. The research systematically examines various daylighting strategies, implementation methods, and performance outcomes across different educational contexts through a rigorous qualitative methodology, incorporating an extensive literature review and detailed thematic analysis of academic papers from established databases. The findings reveal that passive daylighting strategies, including light shelves, window, skylights, louvres, and overhangs, can significantly enhance energy efficiency when adequately implemented in educational settings. Specifically, light shelves demonstrate remarkable potential, reducing lighting energy consumption by up to 60%, while carefully calculated 40-60% window-to-wall ratios provide balanced natural lighting. The research emphasises the significance of considering local climate conditions, building orientation, and seamless integration with other building systems for successful implementation. These comprehensive findings provide valuable insights for architects, educational administrators, and facility managers seeking to incorporate sustainable daylighting in educational facilities. The study concludes that effective passive daylighting strategies are essential tools for creating sustainable and comfortable educational spaces.

Keywords: passive daylighting, higher education, lighting

1. INTRODUCTION

Public Higher Education Institutions (PHEI) have seen rapid growth and urbanisation, leading to increased energy consumption, especially in lighting. Othman (2024) reveals that educational buildings constitute a significant portion of global energy use, with artificial lighting primarily contributing to electricity demand. As climate change and sustainability concerns grow, incorporating energy-efficient design strategies has become crucial for modern educational facilities (Viriezky et al., 2023). Passive daylighting is a strategy that uses natural light to illuminate indoor spaces, reducing artificial lighting needs while improving indoor environmental quality (Othman et al., 2017). This approach employs various techniques, including optimised window placement, light shelves, and reflective surfaces, proven to enhance energy efficiency and occupant well-being.

However, many PHEI buildings still struggle with poor daylight integration. This results

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in excess energy use and poor visual comfort (Othman, 2024). Poor daylighting design creates problems like glare and uneven light distribution, forcing unnecessary reliance on artificial lighting even during daylight hours (Othman, 2024). Many buildings also lack proper shading systems, leading to excess heat gain and higher cooling needs, undermining the energy savings that daylighting should provide (Sharp et al., 2014). These implementation challenges raise questions about how daylight can effectively be used in PHEI settings. This research, therefore, aims to examine how passive daylighting strategies can be better utilised in PHEI buildings.

2. LITERATURE REVIEW

Research on passive daylighting strategies in PHEI buildings has grown significantly, as these approaches promise enhanced energy efficiency, visual comfort, and occupant well-being. Recent studies have thoroughly examined various daylighting techniques, analysing their energy impacts and architectural implications. Studies demonstrate that effective daylighting strategies significantly reduce artificial lighting needs. Viriezky et al., (2023) found that optimised daylighting systems can reduce lighting energy demand by up to 50%, depending on factors like building orientation and window design.

Visual comfort significantly impacts student outcomes (Othman, 2024). The field study examined daylight distribution effects on student performance, daylighting enhances visual comfort and cognitive function. While the combined field measurements and user surveys provided valuable insights. This highlights the need to integrate user feedback and energy data when developing daylighting strategies (Othman, 2024). Building orientation and façade design significantly impact daylighting. Wagdy et al., (2017) found that north- and south-facing windows provide optimal daylight, while east- and west-facing windows increase glare.

3. METHODOLOGY

This research adopts a qualitative methodology through a comprehensive literature review of existing studies on passive daylighting in educational buildings. The study systematically analyses academic papers, research articles, and case studies sourced from established databases, including Scopus, Science Direct, and Google Scholar. Using thematic analysis as the primary analytical tool, the research examines recurring patterns and relationships in the literature, focusing on daylighting strategies, implementation methods, performance outcomes, and challenges. This methodological approach enables the systematic categorisation of findings into coherent themes, facilitating a deeper understanding of passive daylighting implementation in PHEI.

4. FINDING AND DISCUSSION

Research on implementing daylighting strategies in PHEI buildings is necessary. These strategies are crucial for improving energy efficiency and creating sustainable environments (Sharp et al., 2014). Effective daylighting design integrates passive strategies to reduce lighting energy use without increasing cooling loads, beginning with proper building site selection. Five main passive daylight strategies are adopted

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in PHEI building as presented in Figure 1.

Figure 1. Passive Daylighting Strategy in Public Higher Education Buildings

4.1 Light Shelf

Light shelf daylighting strategies are innovative architectural solutions that enhance lighting quality and energy efficiency in PHEI buildings. These horizontal, light-reflecting overhangs serve multiple purposes: improving daylight penetration, minimising glare, and creating a more comfortable visual environment. When installed on south-facing facades, light shelves effectively distribute natural light. By integrating these systems, institutions can maximise energy savings and create optimal learning environments. Light shelves significantly benefit educational facilities, reducing lighting energy consumption by up to 60% through optimised natural light use (Viriezky et al., 2023). The systems enhance visual comfort by creating uniform light distribution and reducing the contrast between window-adjacent areas and interior zones (Sabbagh et al., 2022).

4.2 Window

Windows are fundamental to daylighting strategies in PHEI buildings, serving as the primary means of natural light integration. When properly implemented, they enhance visual comfort, reduce energy consumption, and create environments supporting academic achievement and student health. Research shows that strategic window placement, particularly north-south alignments, optimises daylight while controlling glare, with studies indicating an optimal window-to-wall ratio of 40-60% for balanced natural lighting (Dewi et al., 2022). The successful implementation of window daylighting requires careful attention to multiple factors. Natural light utilisation significantly reduces electrical lighting demands while creating environments that enhance student focus and reduce visual strain (Al-Mowallad et al., 2024). In addition, effective light management through appropriate shading systems and thoughtful material selection is crucial, as both glazing and interior surfaces significantly impact daylight distribution and overall performance.

4.3 Skylight

Skylights are essential to daylighting strategies in PHEI buildings, enhancing aesthetics and functionality. Channeling natural light into interior spaces improves occupant well-being, reduces energy consumption, and enhances learning outcomes. Skylights offer significant advantages in educational environments. Natural daylight from skylights has been shown to improve student performance, especially in mathematics and reading. They reduce dependence on artificial lighting, leading to substantial energy savings. While well-designed skylights enhance visual clarity and thermal comfort, their effectiveness depends on proper implementation. Crucial design factors include orientation and shape, which affect daylight distribution. Proper glare control through overhangs and shading devices is essential; without these measures, excessive sunlight can disrupt the learning environment (Othman et al., 2017).

4.4 Louvres

Louvers are effective daylighting and shading devices that significantly enhance building performance. These adjustable slats or panels are integrated into building façades to control natural light penetration and distribution. Modern systems can be automated to maintain optimal daylight levels throughout the day (Jung et al., 2022). Properly implemented louvres have multiple benefits, including enhanced thermal comfort, reduced energy costs, and improved indoor environmental quality. By blocking direct solar radiation, louvres provide one of the most effective methods for managing solar heat gain while maintaining pleasant daylight conditions (Qiuhua et al., 2017). The effectiveness of louvres adapts to different climate zones.

4.5 Overhangs

Overhangs are passive shading systems that regulate daylight entering a building. Installed above windows, they shield direct sunlight, preventing excessive heat gain and glare while maintaining exterior views (Sghiouri et al., 2018). The effectiveness of overhangs depends on their width, reflectance, and geometry characteristics that influence daylight penetration. These features make overhangs particularly effective in tropical climates (Sghiouri et al., 2018). In studio spaces, overhangs effectively control direct sunlight, provide essential shade, and reducing daylight intensity. Sghiouri et al. (2018) also added the additional benefits include (i) improved occupant comfort and thermal performance and (ii) enhanced visual comfort and energy savings.

5. CONCLUSION

This research demonstrates that effective passive daylighting strategies - including light shelves, windows, skylights, louvres, and overhangs, can significantly improve energy efficiency and occupant comfort in PHEI buildings. When properly implemented, these strategies reduce electricity consumption while creating better learning environments through improved visual comfort and natural lighting. For successful adoption, careful consideration must be given to local climate conditions, building orientation, and integration with other building systems. These findings provide practical guidance for architects and administrators looking to implement sustainable daylighting solutions in educational facilities.

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