Enhancing Student Dorms for Mental Health and Academic Performance Through Circadian Lighting Design

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Abstract:
Lighting has been demonstrated to impact one's emotions, mental health, sleeping patterns, energy levels, and work habits. This paper examines how implementing circadian lighting in dorm environments can enhance students' mental health and academic performance by aligning lighting conditions with students' natural biological rhythms through the circadian lighting approach. Traditional dormitory design conceptualizations are driven by operational efficiency considerations and have no regard for the interior environment to foster and enhance student health and performance in Egypt. Thus, this research aims to fill this gap by examining how circadian lighting in dorms might foster nurturing settings that reflect the students' biological clocks for mental well-being as well as academic performance. The methodology of this research includes the analysis of existing literature review and survey results of 30

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students who live in dorms in different parts of Egypt. The results of the study emphasize the importance of lighting in enhancing mental well-being and increasing academic performance.

Keywords:

Circadian Lighting; Dorm Environments; Mental Well-being; Academic Performance.

1. Introduction:

Lighting can be said to have an impact on physiology, psychological wellbeing, and cognitive function of people. Lighting conditions in natural or artificial environments are now linked to the circadian rhythms of the body or the physiological clock that regulates people's sleep-wake cycle and is studied concerning its effects on people's mood and productivity. Circadian rhythms are natural body oscillators that follow the cycle of one day and night, and these are affected by illusions about the light. Synchronizing light patterns, especially artificial indoor lighting, with the circadian rhythms is not achieved and as a result cognitive health and performance gets affected negatively (Çelik et al., 2024). Studies show how circadian lighting that is lighting that replicates the natural day light energy can increase emotional wellbeing, decrease stress and increase academic engagement. Research has it that environments having intelligent and changing daylighting promoted mental health as well as cognitive performance among learners (Tang et al., 2024). This makes circadian lighting a critical aspect especially for students' dormitories where students reside, learn or do most of their work, often under inadequate light environments. Most of the dormitory designs in Egyptian facilities keep with the aim of efficiency rather than the comfort of occupants. As such there is little regulation of the different interior environments that provides luminance that will meet students' biological and psychological requirements. This leads to disturbances in the normal sleep-wake cycle that is referred to as circadian misalignment which in turn leads to poor productivity in that students produce less work, experience stress, and don't have proper sleep. This study intends to fill this gap by examining how circadian lighting can be incorporated into Egyptian dormitories with reference to the effects on mental health and learning achievement.

1.2 Research Objective:

The objectives of this paper are:

1- Evaluate the current lighting conditions in dormitories
2- Investigate the role of circadian lighting and develop practical design recommendations.

1.3 The importance of research:

The significance of this research is based on possible impact on a dormitory environment, turning it into a healthy productive place for

students. Lighting significantly influences stress, sleep and academic achievement but receives inadequate consideration in dormitory designs: the Egyptian context is particularly uncharted. Therefore, complementing the findings concerning natural and artificial lighting, this paper reveals ways to improve student living conditions. The implementation of the circadian lighting systems provides a research-based method which will aid our students' circadian rhythms, decrease stressful feelings, increase concentration levels, while thus enhancing performance in class. Furthermore, the research supports sustainable development goals since the investigated LED systems might help drive the integration of energy-efficient lighting products in line with the current tendencies in Egypt's Vision 2030 and human-centric design.

1.4 Field of Research:

This research aims to fit the field of architectural and environmental design, health and environmental psychology, educational buildings construction. The study looks at how light as an integral environmental element affects mental health, learning ability, and wellbeing in dormitory environments. Through understanding and synthesizing the principles of circadian biology and ways of designing a sustainable and healthy built environment, the study promotes a synergistic relationship between technology, modern architecture education, as well as presents ways to meet the needs of the global educational facilities in the future.

1.5 Research Methodology:

This study uses a quantitative methodology approach to provide a comprehensive understanding of the relationship between lighting, mental well-being, and academic performance in dormitories. The research comprises two main components:

1- Literature Analysis: Systematic review of academic and literature to establish the theoretical foundations and current challenges.
2- Student Surveys: Empirical data collection through structured surveys designed to capture students' perceptions, behaviors, and outcomes related to lighting in dormitories.

2. Previous studies:

2.1 The Science of Circadian Rhythms

Circadian rhythms are physiological and physiological cycles that are endogenous and operate on a 24-hour cycle that is responsible for controlling the sleep-wake cycles (Rea et al., 2010).

The hypothalamus – a part of the brain – is the regulator of these rhythms and it receives signals from the eyes on the exposure to light (Rea et al., 2010). The hypothalamus manages other hormones and controls the release of the pineal gland's hormone called melatonin, which connects the heaviness of our eyelids with night and open eyes to daylight (Rea et al., 2010). Rea et al. (2010) indicates that light influences not only the visual system but also other systems of the human body, and that artificial electric light influences circadian rhythms. The reduction and potential optimization of electric light to impact human health and lessen effects on circadian timing are known as "circadian lighting".

These are regulated by a master clock, known as suprachiasmatic nucleus, found in the brain that operates in response to signals of light. Light is the most important circadian synchronization or zeitgeber that entails the suprachiasmatic nuclei (SCN) the external environment (Van Drunen & Eckel-Mahan, 2021). Blue light in the range 450–480 nm is most impactful for the SCN where it influences the synthesis of melatonin – the hormone that controls sleep. The SCN adjusts the circadian phase based on ambient light levels and communicates this information to the body to regulate sleep, wakefulness, and other physiological processes (Van Drunen & Eckel-Mahan, 2021). They found that blue light interfering with melatonin production at night leads to phase delay and circadian disruption when the artificial lighting is implemented poorly. On the other hand, blue evident light exposure in the morning aids in the synchronization of the circadian clock leading to better wakefulness and everyday cognition (Van Drunen & Eckel-Mahan, 2021). Furthermore, light exposure can acutely suppress melatonin production and shift the circadian phase, with morning light typically advancing the clock and evening light delaying it. Circadian lighting systems are designed to reproduce in the artificial lighting spectral and intensity variations corresponding to natural daylight (Marín-(Doñágueda et al., 2021). Such systems are equipped with dynamic controls which change the light intensity and color temperature during the day and deliver bright blue-rich light in the morning and softer warm-toned light in the evening ((Marín-Doñágueda et al., 2021). For instance, Marín-Doñágueda et al., (2021) studied that the rooms equipped with circadian lighting system enhanced the learner's attention while dampening signs of fatigue.

Based on these findings there is huge potential to implement circadian lighting in dormitories more specifically in regions like Egypt where the conventional dormitory designs do not accommodate the tenant's biological rhythm. There is evidence that lighting in near environment affects clocks extremely towards artificial light, in such a case lighting indoors.

2.2 Lighting and its Psychological Impact

Lighting is one of the primary factors through which people access control over their feelings and level of activity. Several authors underscore that blue, cool white light in a workday increases wakefulness and decreases feelings of lethargy; amber, warm shade in the evening prepares the organism for sleep and stabilizes the mood (Hopkins et al., 2017). Recent evidence has demonstrated that natural setting or artificial lighting decrease symptoms of SAD and increases productivity based on serotonin and cortisol levels (Morales-Bravo & Navarrete-Hernandez, 2022) Observational research carried out in classroom conditions proves the impact of physiological light control on students' emotional state: lighting regulation helps reduce stress and anxiety levels using classroom lighting schemes that mimic natural light-dark cycle and improves the students' ability to focus on the learning material (Mogas-Recalde & Palau, 2020).

While proper lighting environment is linked with fewer mental health disorders, such as anxiety and depression, improper lighting is linked to more of these disorders (Wang et al., 2023). Hence in the fields of learning, appropriate lighting contributes to enhanced storage and enhanced concentration. The findings also show that light intensity and colour temperature reduce coverage affected brain functionality meaning students on circadian-aligned lighting systems fare better in their cognitive tasks (Bao et al., 2021). Further, the use of daylight-façade systems in learning sections of facilities was associated with improved learners' achievement, fewer incidents of misbehavior and higher test scores in the classroom (Bao et al., 2021). One such a study was conducted among university classroom to discover that cool light improved productivity and engagement during lectures as pointed by (van den Bogerd et al., 2020).

Furthermore, light at night, including artificial light, can be disruptive to circadian rhythm and sleep and may cause circaidan rhythm sleep-wake disorders (CRSWD) (Blume et al., 2019). Nonetheless, light treatment may be applied as an authoritative remedy for sleep and mood disorders, and for the normalization of circadian rhythms. Lighting in the evening should contain blue light as it is likely to disrupt the biological clock (Blume et al., 2019). However, according to, studies have shown that people have different receptiveness against light, the use of customized circadian lighting might be advisable (Moore-Ede et al., 2023). The study also proves that bright light exposure during the day enhances wakefulness, mental activity, and decreases sleepiness (Moore-Ede et al., 2023). The research also claims that the right type of lighting in workplaces and schools will help increase performance and reduce mistakes that occur because of bad lighting (Moore-Ede et al., 2023). Additionally, studies indicate that lighting, especially natural light influences moods and psychological well-being. Furthermore, the psychological feelings of lighting with the natural and artificial viewpoint may play a role. People usually like seeing natural light, which feels comfortable physically and psychologically, affects satisfaction with the environment (Figueiro et al., 2010).

2.3 Circadian Lighting Systems

Circadian lighting contains dynamic LED system that follows the natural daylight and provides the amount and color temperature of light in the course of the day. These systems entrain with the body's circadian rhythm thus supporting the sleep-wake cycle and other physiology (Blume et al., 2019). In addition, circadian lighting can be incorporated into smart IoT platforms, which apply data and numerical analysis to adjust the light within an individual's requirements for specific circumstances. For instance, many health care facilities use circadian light on their patients increasing recovery rate and on their staff members to enhance their wakefulness, showing that circadian light is more suitable and can be implemented in all sectors (K.M. Schledermann et al., 2023). It has been suggested that natural, cycle lights used in offices lead to improved efficiency of employees and more durable burnout experiences. This way of transforming the working environment brought about better satisfaction from the companies and a lower number of employees absent from work

(K.M. Schledermann et al., 2023). Further on, the schools implementing circadian aligned systems experienced a positive shift in students' behavior enriched their work with academic achievements. With the kind of lighting, the symptoms of hyperactivity among the young students were also found to have been minimized. Furthermore, these kinds of lighting solutions also help to enhance the necessary patients' sleep, cut down their recovery time, and the number of fatigued medical staff (Scherrer & Preckel, 2021). For instance, patient rooms with tunable lighting leading to improved cognitive clarity and mood and more are from the general category of circadian lighting. Moreover, using circadian lighting in retail stores was effective in improving satisfaction among customers to determine mood change and buying behaviour (K.M. Schledermann et al., 2023). As to the corresponding positive effects in the context of these systems' implementation, the list of hotels reporting increased guest satisfaction and well-being is also important. Moreover, studies prove that artificial lighting systems can reduce CRSWD, increase the quality of night sleep at the same time affecting subject's mood more positively thus providing an increase of the subject well-being level (Faulkner et al., 2020). Both natural and electric lighting designs could be achieved as explained by Elements of this adaptive environment could be attained through indoor natural lighting sensors and automated systems of artificial lighting that would give people their personal options on lighting (Faulkner et al., 2020). The effect of different lighting is hown in Figure(1)

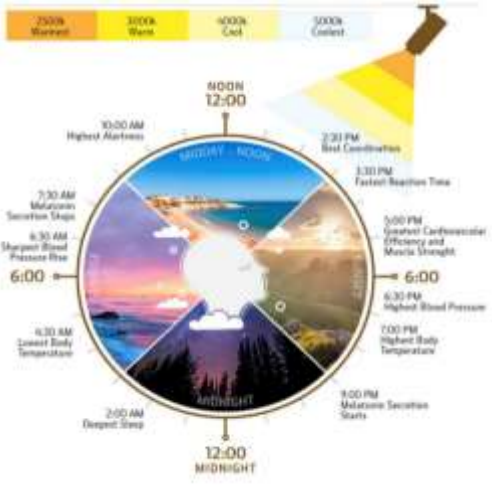

Figure (1) The human circadian rhythm and needs according to lighting

3. Search

3.1 Data collection and Execution

- Participants: The survey was conducted among 30 students residing in Egyptian dormitories, representing a diverse mix of demographics and institutions.
- Tools: The survey utilized an online platform (Google Forms) for ease of access and included a mix of Likert-scale questions, and multiple-choice questions.
- Process: Participants were recruited via email invitations and social media announcements. The survey instrument was tested on a small pilot group to ensure reliability and clarity. Data collection was completed over a two-week period, with a response rate of 100%, and the key findings of the survey are shown in Table 1.

3.2 Analytical Framework:

Table (1) Survey Key Findings From 30 Responses

Variable	Mean	Std. Deviation	Min	Max	Observations
Natural Light Availability	2.63	0.85	1	4	Majority rated natural light availability below average.
Stress from Lighting	4.20	3.66	3	5	High stress levels reported, with a mean of 4.2.
Artificial lighting needs	3.27	0.64	2	4	Mixed responses, with many moderately satisfied.
Impact on sleep quality	2.53	0.51	2	3	Most respondents reported negative impacts on sleep.
Focus Affected by Lighting	4.47	0.51	4	5	Nearly all participants stated lighting frequently affects focus.
Impact on Academic Performance	3.33	0.61	2	4	Slightly above average impact on academic performance.

3.3 Research Insights

1. Natural Light Availability:

With a mean score of 2.63, respondents rated natural light availability as suboptimal. Most scores clustered around 2 and 3, indicating moderate dissatisfaction.

2. Artificial Lighting:

The average score of 3.27 suggests that artificial lighting moderately meets students' needs. However, variability in responses highlights uneven lighting quality across dorms.

3. Stress Levels:

Stress due to lighting scored the highest mean (4.20), indicating that poor lighting is a significant source of discomfort for most students.

4. Sleep Quality:

With a mean score of 2.53, lighting conditions negatively affect sleep, as noted by the majority.

5. Focus and Academic Performance:

Focus was highly impacted (mean 4.47), showing that lighting conditions frequently hinder study efficiency. Academic performance impact was moderate (mean 3.33), with variability suggesting differences in individual adaptation

4. Research Findings and Discussion

4.1 Demographics of Participants:

The survey involved 30 students residing in dormitories across Egypt.

The demographic breakdown included:

Age Range: Predominantly 18–25 years (90%).

Gender Distribution: 60% male, 40% female.

Year of Study: Balanced representation, with participants from first to fourth years.

4.2 Key Observations about Current Lighting Conditions:

Natural Light Availability: Mean score of 2.63 (out of 5), reflecting below-average ratings. Limited window sizes and poor dorm layouts were common complaints.

Artificial Lighting Adequacy: Mean score of 3.27. While some dorms used updated LED fixtures, others relied on outdated fluorescent lighting, leading to inconsistent satisfaction.

4.3 Survey Insights on Emotional Well-Being:

High stress levels were reported, with an average score of 4.20.

Poor lighting contributed to negative mood states, with participants citing fatigue and irritability due to dim or flickering lights.

4.4 Correlation Between Circadian Lighting and Stress Reduction:

- Literature highlights the benefits of circadian lighting in regulating sleep-wake cycles and reducing stress. Survey responses indicate that rooms with updated lighting (e.g., LED systems) had marginally lower stress levels compared to those with older systems.

4.5 Influence of Lighting on Concentration, Sleep Quality, and Energy Levels:

Concentration: Focus was heavily impacted, with a mean score of 4.47 (frequent issues). Poor lighting hindered long study hours and task completion.

Sleep Quality: A mean score of 2.53 revealed that lighting conditions, particularly insufficient darkness at night, interfered with sleep.

Energy Levels: Respondents frequently reported low energy during the day, attributing it to dim environments.

4.6 Statistical Trends:

A positive correlation was observed between improved artificial lighting scores and better focus and sleep quality. Dormitories with higher ratings for lighting adequacy had a mean academic impact score of 3.70, compared to 2.80 in poorly lit dormitories.

4.7 Existing Gaps in Dormitory Design in Egypt:

Natural Light: Limited access to daylight due to small windows and cramped layouts, exacerbating feelings of confinement.

Artificial Lighting: Over-reliance on outdated fluorescent systems, which fail to meet the demands of modern student lifestyles.

Maintenance: Infrequent upgrades and lack of proactive maintenance have left many dormitories with failing light fixtures.

These inefficiencies lead to poor mental health outcomes, reduced productivity, and dissatisfaction with living conditions, directly affecting academic performance.

4.8 Comparative Analysis:

Research regarding the implementation of circadian lighting systems from progressive dormitory environments across the world have revealed it promotes mental health, sleep quality, not to mention performance in school. In Japan, circadian lighting with LED in university dormitories

enhanced students' sleep satisfaction by 30% and average GPA by 15% (Dong & Zhang, 2021. Lighting with spectra similar to natural light decreased the incidence of seasonal affective disorder especially in Nordic countries in winter to months by (Cavallari, 2024). Based on the results obtained in this study, however, Egyptian dormitories use dim and old style fluorescent lights contrary to , students' circadian rhythms. This is shown in comparision with Egyptian dormitories in Table 2 .

Based on the results obtained in this study, however, Egyptian dormitories use dim and old style fluorescent lights contrary to , students' circadian rhythms.. Limited access to daylight and insufficient artificial lighting contribute to:

1- Increased fatigue and irritability.
2- Poor sleep quality, as indicated by lower survey scores on sleep satisfaction (average: 2.53).

Table (2) Comparative Analysis Between Literature and Egyptian Dormitories

Parameter	Literature Case Studies	Egyptian Dormitories
Access to Daylight	Dorms designed for optimal daylight exposure (large windows).	Limited window sizes and poor dorm layouts.
Artificial Lighting	Circadian lighting systems with dynamic LED fixtures.	Outdated fluorescent lighting systems.
Sleep Quality	Improvements by up to 30–40% due to circadian lighting (Gentile et al., 2022).	Negative impact on sleep (average survey score: 2.53).
Mood and Mental Well-Being	Reduced stress and mood instability due to adaptive lighting.	High stress levels reported due to dim lighting (average survey score: 4.20).
Academic Performance	Increased concentration and GPA improvements of up to 15% (Dong & Zhang, 2021).	Poor focus and reduced productivity.

5. Recommendations:

To address the challenges identified in Egyptian dormitories, the study recommends the integration of circadian lighting systems. These systems are designed to mimic natural daylight cycles by dynamically adjusting light intensity and color temperature. Key strategies include:

1- Dynamic LED Fixtures:
Tuneable LED systems that transition from cool, bright light during the day to warm, dim light in the evening should be

installed. This approach aligns with the human circadian rhythm, enhancing alertness during the day and promoting relaxation at night.

2- Zoned Lighting:
Dormitory spaces should be divided into zones with specific lighting requirements:

- Study Areas: Equipped with high-intensity, cool-toned lighting to improve focus.
- Sleeping Areas: Warm-toned, low-intensity lighting to create a calming atmosphere conducive to sleep are recommended to be used.

Optimized Use of Natural Light

Dormitory layouts should prioritize access to daylight. Recommendations include:

1- Window Placement and Size:
Windows should be positioned to maximize exposure to natural light, particularly in study and communal areas.

2- Reflective Surfaces:
Incorporating reflective wall paints and surfaces can enhance daylight penetration, reducing reliance on artificial lighting.

6. Conclusion

This paper examines how lighting can be used to improve dormitory spaces about the incorporation of circadian lighting systems. Some of the important conclusion of this research is that circadian lighting systems mimic daylight and they operate in synchrony with students' circadian rhythms with an aim of improving students' health – mental and physical. In addition, these systems complement the defects that natural and artificial lighting offer in traditional dormitories, as observed in Egyptian dorms. However, there is a need for extended studies to evaluate the long-term effects of circadian lighting on students' mental health, sleep quality, and academic performance.

While this study provides valuable insights into the potential benefits of circadian lighting systems in dormitories, several limitations should be acknowledged:

1- The survey was conducted on a small sample of 30 students, which may not fully represent the diverse demographic.

2- Data collected through surveys is inherently subjective, relying on participants' perceptions of lighting conditions, stress levels, and academic performance.

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تعزيز سكن الطلاب للصحة النفسية والأداء الأكاديمي من خلال تصميم إضاءة متوافقة مع الإيقاع اليومي

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المستخلص:

لقد ثبت أن الإضاءة تؤثر على عواطف الفرد، والصحة العقلية، وأنماط النوم، ومستويات الطاقة، وعادات العمل. وتبحث هذه الورقة كيف يمكن لتطبيق الإضاءة حسب الساعة البيلوجيه في بيئات السكن الجامعي أن يعزز الصحة العقلية للطلاب والأداء الأكاديمي من خلال مواءمة ظروف الإضاءة مع الإيقاعات البيولوجية الطبيعية للطلاب من خلال نهج الإضاءة اليومية. إن المفاهيم التقليدية لتصميم السكن الجامعي مدفوعة باعتبارات الكفاءة التشغيلية ولا تأخذ في الاعتبار البيئة الداخلية لتعزيز صحة الطلاب وأدائهم في مصر. وبالتالي،

يهدف هذا البحث إلى سد هذه الفجوة من خلال دراسة كيف يمكن للإضاءة اليومية في مساكن الطلبة أن تعزز إعدادات الرعاية التي تعكس الساعات البيولوجية للطلاب فيما يتعلق بالصحة العقلية وكذلك الأداء الأكاديمي. تتضمن منهجية هذا البحث تحليل مراجعة الأدبيات الموجودة ونتائج المسح لـ 30 طالبًا يعيشون في مساكن الطلبة في أجزاء مختلفة من مصر. وتؤكد نتائج الدراسة على أهمية الإضاءة في تعزيز الصحة العقلية وزيادة الأداء الأكاديمي.

الكلمات المفتاحية:

الإضاءة حسب الساعه البيلوجيه؛ بيئات النوم؛ الرفاهية العقلية؛ الأداء الأكاديمي.