JURNAL TEKNIK SIPIL
Universitas 17 Agustus 1945 Semarang
Jurnal Home Page: https://jurnal2.untagsmg.ac.id/index.php/JTS

Lighting Evaluation and Optimization of Lamp Placement in the Nursing Research Centre Classrooms at Universitas Muhammadiyah Semarang

Abdul Rohman[1*]
[1]Department of Civil Engineering, Universitas Muhammadiyah Semarang, Indonesia
*Email: rohmanbangdull@gmail.com

Diterima Desember 2022; Disetujui Desember 2022; Dipublikasi Desember 2022

Abstract Adequate lighting in a classroom is characterized by the ability to see objects clearly and comfortably without creating shadows. Lighting can be sourced naturally from sunlight and artificially from lamps. Natural lighting is only available during the day, necessitating artificial lighting during overcast weather or nighttime. The Nursing Research Centre (NRC) classrooms at Universitas Muhammadiyah Semarang (Unimus) are heavily used, requiring sufficient lighting to meet standards. This study aims to measure the quality of lighting in the NRC classrooms at Unimus and determine whether it meets the established standards. The study was conducted in the NRC classrooms at Unimus, using lighting evaluation methods based on SNI 6197: 2011and SNI 6197: 2020. The evaluation results indicate that the lighting levels in the NRC classrooms do not meet the standards, with an average illumination of only 200 lux. The study recommends replacing the existing lamps with 2x24 watt LED lamps with 2x2800 lumens, and the need for small electrical power so that it os more efficient.

***Keywords**: Lighting Evaluation, Illumination Intensity, NRC Classroom*

1 Introduction

Indonesia has a tropical climate with high solar radiation intensity and frequently cloudy skies. These factors significantly affect natural lighting conditions, which are closely related to human comfort levels. The average solar radiation in Indonesia reaches 4.8 kWh/m² per day, with monthly variations ranging from 4.0 to 5.5 kWh/m² per day [1]. Light is a important element for humans to see objects around them clearly, so lighting aspects must be given special attention. Optimal lighting is determined not only by the quantity or amount of light but also by its quality. Good lighting quality and quantity are determined by the light ratio and the level of light reflection in a room. To create maximum visual comfort for occupants or users of a room, lighting must be designed carefully and precisely. Improved lighting quality has been proven to increase worker productivity by up to 20% and occupant well-being by 15% [2].

The impact of lighting goes beyond merely affecting the comfort level of room users; it also has significant implications for their safety and health, including those of lecturers and students. Inadequate lighting can adversely affect the visual center of the brain, potentially damaging the optic nerves. Studies have shown that poor lighting quality can lead to eye strain, drowsiness, and neck pain [3], and a decline in performance among both lecturers and students [4]. One study emphasizes that the comfort factor in classroom lighting must meet the minimum required standards and should not cause glare, as uneven lighting reduces reading speed and efficiency [5]. According to the Indonesian National Standard (SNI) 2001, the minimum lighting level expected for lecture rooms is 250 lux [6].

Recent research further supports these findings. For instance, poor lighting can significantly reduce concentration levels, leading to decreased academic performance [7]. Improper lighting contributes to increased levels of fatigue and stress among students [8]. Moreover, adequate lighting conditions are correlated with higher productivity and better mental health outcomes [9]. Good lighting design enhances visual comfort, reducing the risk of headaches and eye strain [10]. Students exposed to better lighting conditions showed improved cognitive function and overall academic performance [11]. Furthermore, ergonomic lighting solutions could mitigate the adverse effects of inadequate lighting [12]. Implementing natural light sources in classrooms not only improves lighting quality but also enhances mood and well-being [13]. Optimized lighting can reduce absenteeism among students due to health issues related to poor lighting [14]. Lastly, regular lighting assessments ensure that educational facilities meet the necessary standards for optimal learning environments [15].

There are two types of indoor lighting: artificial lighting from electric sources and natural lighting from the sky dome. Utilizing natural lighting does not cause pollution, thus reducing pollutants and aiding sustainable development because it can be used without requiring energy that incurs high costs. The intensity of natural lighting can reach approximately 10,000 lux and is available throughout the year, with sunlight duration remaining relatively stable between 6:00 AM and 6:00 PM, or around 11-12 hours. Recent studies reinforce these benefits of natural lighting, showing that classrooms utilizing natural light significantly improve students' academic performance and well-being [16], enhance employee productivity and reduce stress levels in office spaces [17], and speed up patient recovery times while improving overall mood in hospitals [18]. Integrating natural light in residential buildings has been shown to reduce energy consumption by up to 30% [19]. Additionally, natural lighting plays a crucial role in maintaining circadian rhythms, which are vital for human health and sleep quality [20], and can decrease the incidence of myopia among students in educational settings [21]. Natural lighting also reduces the risk of Seasonal Affective Disorder (SAD) in regions with less sunlight [22], improves indoor air quality by promoting better ventilation and reducing the buildup of indoor pollutants [23], and is integral to green building certifications and energy-efficient design [24]. Furthermore, natural light positively impacts cognitive functions, enhancing concentration and mental clarity [13].

A building is typically designed to maximize the use of natural light; however, it still requires an electric lighting system as a supplementary source. When natural light cannot meet the required lighting standards for a space, artificial lighting is necessary to compensate for the deficiency [25]. It has been noted that the characteristics of lighting fluctuate, with illumination levels increasing on clear days and decreasing on cloudy days [26]. With advancements in technology, there are now opportunities to analyze lighting using computer software. Dialux, for instance, can quickly and accurately identify the values of both daylight and artificial light (lamps). Lighting simulations within a building can be created based on field parameters and the object's environment, with the results presented in numerical data, graphs, and images [27]. Recent studies have also highlighted the importance of dynamic lighting systems in improving indoor environmental quality and occupant well-being [28]. Additionally, integrating smart lighting controls can significantly enhance energy efficiency and comfort [29]. Moreover, incorporating daylighting strategies can lead to substantial energy savings and improved visual comfort [30].

The research location chosen for this case study is the NRC (Nursing Research Center) building at Universitas Muhammadiyah Semarang (Unimus), based on preliminary observations indicating that the quality of natural lighting in the building is still suboptimal. This study aims to assess the quality of classroom lighting under three sky conditions: clear, cloudy, and overcast. The goal is to optimize natural lighting and achieve energy savings by manually integrating natural and artificial lighting, specifically by alternating the use of lights.

2 Methodology

This study employs a descriptive quantitative research design using modeling methods. The research was conducted in the classrooms on the fourth floor of the NRC building at Unimus. The evaluation of lighting in this study utilized a comparative method based on the SNI 6197: 2020 and SNI 6197: 2011 standard on energy conservation in lighting systems [31]. The components of lighting evaluated include: (1) illumination levels, (2) color rendering, (3) color temperature, and (4) installed lighting load.

The evaluation of illumination levels was performed by measuring the average illumination in the room using a light meter. These measurements were then compared to the standard average illumination levels. The evaluation of color rendering and color temperature was conducted by observing the specifications of the installed lamps and comparing these observations to the standard values. The assessment of the installed lighting load was carried out by calculating the total electrical power of the installed lamps divided by the area of the space and comparing it to the standard values. The results of these evaluations were used to propose improvements by calculating the number of lamps needed. The formula used for this calculation is as follows:

$$N_{Lamp} = \frac{E \times A}{F \times K_P}$$

E is the standard illumination level, F is the luminous flux of the lamp used, A is the lighting area, and K_P is the utilization factor. By conducting these evaluations, the study aims to provide detailed insights into the current lighting conditions and suggest measures to optimize lighting quality and energy efficiency in the classrooms.

3 Result and Discussion

The research findings indicate that the classrooms in the NRC building at Unimus are used for an average of 8 hours per day, accommodating up to 60 occupants. These rooms are located from the first to the fourth floor, each serving a significant number of students and faculty members throughout the day. Each classroom has specific dimensions defined by its north, south, east, and west walls. All walls are constructed from brick and cement plaster with a thickness of approximately half a brick, providing solid and durable enclosures. The south wall is unique in that it is the only one exposed to direct sunlight, while the other walls are shaded, affecting the distribution and intensity of natural light within the rooms. This exposure to sunlight on the south wall can lead to variations in lighting conditions and thermal comfort throughout the day. The ceiling of each classroom is made of reinforced concrete, ensuring structural stability, and is further covered with gypsum board panels finished with white paint, which can reflect light and impact the overall illumination of the room. The floors are constructed from concrete and ceramic tiles, providing a durable and easy-to-clean surface.

Given these structural characteristics, the quality of natural lighting in these classrooms is influenced by several factors, including the thickness and material of the walls, the type of ceiling, and the flooring materials. The south-facing windows allow for significant sunlight penetration, which needs to be managed to prevent glare and overheating, especially during peak sunlight hours. To ensure optimal lighting conditions and energy efficiency, it is crucial to integrate artificial lighting strategically. The research suggests using a combination of natural and artificial lighting, with artificial lights arranged in an alternating pattern to supplement natural light during times when it is insufficient. This approach not only helps in maintaining adequate illumination levels but also contributes to energy savings by reducing the reliance on artificial lighting during daylight hours. By conducting a thorough analysis of the current lighting conditions and employing advanced tools such as DiaLux for simulation, the study aims to provide actionable recommendations. These include adjusting the number and placement of light fixtures, choosing appropriate types of lamps, and considering the reflectivity of interior surfaces to enhance both the quality and efficiency of lighting in the classrooms. Overall, the findings highlight the importance of a well-thought-out lighting strategy that takes into account the unique structural and environmental characteristics of the NRC building, ultimately aiming to improve the learning environment for students and faculty at Unimus.

The lighting used in the lecture rooms at NRC Unimus consists of 36 watt TL fluorescent tube lights with armatures, 2500 lumens with 2x8 armatures installed, a color temperature of 6500 K, and a color rendering index of 82%. There are 16 such lamps installed in each room. According to SNI 6197: 2011, the standard illumination level for classrooms is 300 lux, with a color temperature above 3300 K, a color rendering index over 61%, and a maximum lighting load of 11,95 W/m². As shown in Table 1, out of the four evaluated lighting components, only the illumination level fails to meet the standard. Measurements using a light meter reveal an average illumination level of less than 200 lux. This finding indicates that the lighting in the NRC Unimus classrooms is significantly below the required standard, potentially causing visual discomfort. This conclusion is supported by student complaints about the inadequate lighting conditions during their activities in these rooms.

Table 1. Lighting Evaluation Components

Component	SNI 6197: 2011 Standard	Actual Condition
Illumination Level	500 lux	120 lux
Color Rendering	>61%	82%
Color Temperature	>3300 K	6500 K

The research highlights a critical issue in the lighting quality of the NRC Unimus classrooms. Despite the use of modern lighting fixtures, the illumination level falls drastically short of the 500 lux standard, achieving only 120 lux on average. This shortfall can significantly affect the visual comfort and performance of students and lecturers. Insufficient illumination can lead to eye strain, fatigue, and reduced concentration, directly impacting the learning experience and productivity of the occupants. While the current lighting setup includes energy-efficient LED bulbs and fluorescent tubes, the placement and quantity of these lights do not adequately illuminate the space. Based on the findings from the lighting evaluation, improvements can be made by replacing and increasing the number of lamps. The study recommends replacing the existing lamps with 2x24 watt LED cool daylight tube lamps, each providing 2x2800 lumens. Using Eq. (a) with values $E = 300\ lux$, $F = 2x2800$ lumens, $A = 75.64\ m^2$, and $K_P = 0.40$, the required number of lamps is calculated to be

2x8. Implementing this recommendation would achieve an illumination level of 473,82 lux with a lighting load of 5,07 W/m^2 significantly enhancing the visual comfort, health, and productivity of students and staff at NRC Unimus.

4 Conclusion

This study concludes that the current illumination levels in the classrooms of the NRC building at Unimus do not meet the standards set by SNI 6197: 2020 and SNI 6197: 2011, with an average illumination level of only 120 lux, significantly below the required 500 lux. Based on the evaluation results, it is recommended to replace the existing lamps with 2x24-watt LED tube lamps, each providing 2800 lumens. Additionally, the number of lamps should be increased from 11 to 34. Implementing these recommendations is expected to bring the illumination levels up to the standard of 300 lux, thereby improving visual comfort and the productivity of the classroom occupants.

5 References

[1] BMKG, *Buletin Informasi Meteo rologi Edisi VI Bulan Juni 2023*, no. 0386. 2023.

[2] J. M. Katabaro and Y. Yan, "Effects of Lighting Quality on Working Efficiency of Workers in Office Building in Tanzania," *J. Environ. Public Health*, vol. 12, pp. 1–12, 2019, doi: 10.1155/2019/3476490.

[3] Osibona O., Solomon B. D., and Feecht D., "Lighting in the Home and Health: A Systematic Review ," *Int. J. Environ. Res. Public Health*, vol. 18, no. 2, pp. 1–20, 2021.

[4] M. Dick, W. Pohl, H. K. Lackner, E. M. Weiss, and M. Canazei, "Effects of Personalized Lighting on Subjective Ratings, Cognitive Performance, and Physiological Stress Response in a Simulated Office Environment," *LEUKOS - J. Illum. Eng. Soc. North Am.*, 2024, doi: 10.1080/15502724.2023.2292960.

[5] Y. Liu, K. Chen, E. Ni, and Q. Deng, "Optimizing classroom modularity and combinations to enhance daylighting performance and outdoor platform through ANN acceleration in the post-epidemic era," *Heliyon*, vol. 9, no. 11, 2023, doi: 10.1016/j.heliyon.2023.e21598.

[6] P. A. Pratama and N. Nurdiana, "Evaluasi Kualitas Penerangan Ruang Kuliah Fakultas Teknik Universitas Pgri Palembang," *J. Ampere*, vol. 5, no. 2, p. 75, 2020, doi: 10.31851/ampere.v5i2.5058.

[7] P. J. C. Sleegers, N. M. Moolenaar, M. Galetzka, A. Pruyn, B. E. Sarroukh, and B. Van Der Zande, "Lighting affects students' concentration positively: Findings from three Dutch studies," *Light. Res. Technol.*, vol. 45, no. 2, pp. 159–175, 2013, doi: 10.1177/1477153512446099.

[8] E. Hoseinzadeh, A. Ramezani, F. Mohammadi, M. Safari, A. A. Sokan-Adeaga, and H. Hossini, "Evaluating the Level of Lighting Satisfaction and Determining Degrees of Visual Fatigue, Mental Task Load, Sleepiness, and Sleep Quality in Students," *J. Heal. Reports Technol.*, vol. 8, no. 3, 2022, doi: 10.5812/jhrt-118006.

[9] R. Králiková, E. Lumnitzer, L. Džuňová, and A. Yehorova, "Analysis of the impact of working environment factors on employee's health and wellbeing; workplace lighting design evaluation and improvement," *Sustain.*, vol. 13, no. 16, 2021, doi: 10.3390/su13168816.

[10] P. Dhayal and B. Jha, "Indoor Visual Comfort: A Review of Factors and Assessments," *ISVS e-journal*, vol. 10, no. 11, pp. 38–59, 2023, doi: 10.61275/ISVSEJ-2023-10-11-03.

[11] E. K. Hansen, S. M. L. Nielsen, D. Georgieva, and K. M. Schledermann, "The impact of dynamic lighting in classrooms. A review on methods," *Lect. Notes Inst. Comput. Sci. Soc. Telecommun. Eng. LNICST*, vol. 229, pp. 479–489, 2018, doi: 10.1007/978-3-319-76908-

0_46.

[12] M. Ghita, R. A. C. Diaz, I. R. Birs, D. Copot, and C. M. Ionescu, "Ergonomic and Economic Office Light Level Control," *Energies*, vol. 15, no. 3, 2022, doi: 10.3390/en15030734.

[13] M. B. N. Shishegar, "Natural Light and Productivity: Analyzing the Impacts of Daylighting on Students' and Workers' Health and Alertness," *Int. J. Adv. Chem. Eng. Biol. Sci.*, vol. 3, no. 1, 2016, doi: 10.15242/ijacebs.ae0416104.

[14] C. Ticleanu, "Impacts of home lighting on human health," *Light. Res. Technol.*, vol. 53, no. 5, pp. 453–475, 2021, doi: 10.1177/14771535211021064.

[15] P. Barrett, A. Treves, T. Shmis, D. Ambasz, and M. Ustinova, *The Impact of School Infrastructure on Learning*. 2019.

[16] B. F. C. Nwokedi, "Influence of Classroom Environment on the Academic Performance of Students in English Language," *Int. J. Adv. Soc. Sci. Educ.*, vol. 1, no. 4, pp. 191–198, 2023, doi: 10.59890/ijasse.v1i4.732.

[17] M. I. E. Niere, Mecon, L. O. Narsico, and P. G. Narsico, "Workplace Stressors, Employee Welfare, and Productivity," *Int. J. Multidiscip. Appl. Bus. Educ. Res.*, vol. 4, no. 12, pp. 4379–4389, 2023, doi: 10.11594/ijmaber.04.12.18.

[18] Y. Tian, "A review on factors related to patient comfort experience in hospitals," *J. Heal. Popul. Nutr.*, vol. 42, no. 1, 2023, doi: 10.1186/s41043-023-00465-4.

[19] T. L. Bilésimo, G. A. A. Rampinelli, and ..., "Integration of Natural and Artificial Light:: Potential Energy Savings Estimation Using the Clearness Index, Measurement and …," in *... De Conforto No ...*, 2023. [Online]. Available: https://eventos.antac.org.br/index.php/encac/article/view/3798%0Ahttps://eventos.antac.org.br/index.php/encac/article/download/3798/3849

[20] C. Blume, C. Garbazza, and M. Spitschan, "Effects of light on human circadian rhythms, sleep and mood," *Somnologie*, vol. 23, no. 3, pp. 147–156, 2019, doi: 10.1007/s11818-019-00215-x.

[21] W. Peng, Z. Zhang, F. Wang, S. Sun, and Y. Sun, "Association of educational environment with the prevalence of myopia: a cross-sectional study in central China," *Front. Public Heal.*, vol. 11, 2023, doi: 10.3389/fpubh.2023.1188198.

[22] A. Wirz-Justice *et al.*, "'Natural' light treatment of seasonal affective disorder," *J. Affect. Disord.*, vol. 37, no. 2–3, pp. 109–120, 1996, doi: 10.1016/0165-0327(95)00081-X.

[23] A. O. Gbotoso and F. O. Abulude, "Improving Indoor Air Quality in Library Environments: Strategies and Recommendations for Healthier Indoor Environments," 2024, [Online]. Available: https://doi.org/10.5281/zenodo.10651935

[24] G. S. Mahaaraja and S. M. Renuka, "Integrating BIM with Energy Analysis and Green Building Certification System to Design Sustainable Building," in *Lecture Notes in Civil Engineering*, 2024, vol. 388, pp. 303–316. doi: 10.1007/978-981-99-6233-4_28.

[25] N. Natsir, N. Jamala, and A. Kusno, "The Artificial Lighting Analysis of Study Rooms in Dormitories and Classrooms Islamic Boarding School Of Lil Banat Parepare," *EPI Int. J. Eng.*, vol. 4, no. 1, pp. 87–98, 2021, doi: 10.25042/epi-ije.022021.12.

[26] I. Tureková, D. Lukácová, and G. Bánesz, "Quality assessment of the university classroom lighting - A case study," *TEM J.*, vol. 7, no. 4, pp. 829–836, 2018, doi: 10.18421/TEM74-21.

[27] J. Yan, K. Kensek, K. Konis, and D. Noble, "Cfd visualization in a virtual reality environment using building information modeling tools," *Buildings*, vol. 10, no. 12, pp. 1–21, 2020, doi: 10.3390/buildings10120229.

[28] Y. Wu, Z. Liu, and Z. Kong, *Indoor Environmental Quality and Occupant Comfort*. 2023. doi: 10.3390/books978-3-0365-8185-9.

[29] V. P. Widartha, I. Ra, S. Y. Lee, and C. S. Kim, "Advancing Smart Lighting: A Developmental Approach to Energy Efficiency through Brightness Adjustment Strategies," *J. Low Power Electron. Appl.*, vol. 14, no. 1, 2024, doi: 10.3390/jlpea14010006.

[30] Q. J. Kwong, "Light level, visual comfort and lighting energy savings potential in a green-certified high-rise building," *J. Build. Eng.*, vol. 29, 2020, doi: 10.1016/j.jobe.2020.101198.

[31] SNI 6197-2001, "Konservasi energi pada sistem pencahayaan" Badan Standardisasi Nasional,2011.