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An Evaluation of Lighting Design Performance in Cafes as Informal Learning Spaces

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Abstract
The proliferation of urban cafes has driven a shift in spatial function, with these venues increasingly used by students as informal learning environments rather than solely for socializing. This phenomenon demands a spatial quality that supports user comfort, particularly regarding lighting design. This study aims to evaluate the performance of natural and artificial lighting in cafes functioning as informal study spaces. A quantitative approach was employed by directly measuring illuminance levels, Correlated Color Temperature (CCT), and glare perception across two cafe case studies. The results indicate that during the daytime, the average illuminance in both cafes complies with the baseline SNI 6197:2020 standard for cafe spaces; however, only one cafe meets the recommended standard for learning environments, and light distribution remains uneven, leaving certain areas below the required threshold. At night, illuminance in one cafe fell below the standard for studying, whereas the other remained compliant. Regarding CCT, daytime lighting in both cafes demonstrated a neutral warm-white ambiance, transitioning to a warm tone at night. Furthermore, daytime glare perception varied between the two cafes, whereas nighttime glare remained consistently low in both cafes. These findings provide an empirical basis for formulating recommendations to improve lighting design in cafes utilized as informal learning spaces.

Keywords: CCT, Café, Glare, Illuminance, Informal Learning Space

Evaluasi Kinerja Desain Pencahayaan pada Kafe sebagai Lingkungan Belajar Informal

Abstrak
Perkembangan kafe di kawasan perkotaan telah mendorong pergeseran fungsi ruang yang tidak hanya digunakan sebagai tempat bersosialisasi, tetapi juga dimanfaatkan sebagai area belajar informal bagi mahasiswa. Kondisi ini menuntut kualitas ruang yang mampu mendukung kenyamanan pengguna, khususnya dalam aspek pencahayaan. Penelitian ini bertujuan untuk mengevaluasi kinerja desain pencahayaan alami dan buatan pada kafe yang digunakan sebagai area belajar informal. Metode kuantitatif diterapkan melalui pengukuran langsung tingkat iluminasi, temperatur warna cahaya (CCT), dan persepsi silau pada dua studi kasus kafe. Hasil penelitian menunjukkan bahwa pada siang hari, rata-rata iluminasi kedua kafe memenuhi standar SNI 6197:2020, meskipun distribusinya tidak merata karena terdapat area dengan iluminasi di bawah standar. Pada malam hari, salah satu kafe menunjukkan tingkat iluminasi di bawah standar sebagai ruang belajar, sedangkan kafe lainnya masih memenuhi standar SNI tersebut. Dari aspek CCT, pencahayaan siang hari kedua kafe menunjukkan nuansa ruang putih netral (warm-white), sementara pada kondisi malam hari menunjukkan nuansa putih kekuningan (warm). Dari sisi persepsi silau, hasil menunjukkan bahwa pada siang hari terdapat perbedaan antara kedua kafe, sedangkan pada malam hari, persepsi silau di kedua kafe rendah. Hasil penelitian ini diharapkan dapat menjadi dasar dalam merumuskan rekomendasi perbaikan desain pencahayaan pada kafe sebagai ruang belajar informal.

***Kata-kunci** : CCT, Iluminasi, Kafe, Ruang Belajar Informal, Silau*

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Introduction

The proliferation of urban cafes demonstrates a significant shift in spatial functionality. These venues no longer serve exclusively as spaces for relaxation and socialization; they have evolved into alternative environments for work and study, particularly for students and creative professionals. This phenomenon is driven by the inherent characteristics of cafes, which offer flexible spaces, a relaxed atmosphere, and supporting amenities conducive to productive activities [1], [2]. As the number of cafes and coworking spaces continues to grow in major cities, including Surabaya, the necessity for adequate indoor environmental quality becomes increasingly paramount [3].

Lighting is a fundamental factor in determining the spatial quality of a cafe's environment. It plays a crucial role in shaping a space's visual quality and ensuring user comfort during activities. Optimal lighting quality enhances visual comfort, mitigates eye fatigue, and prevents visual impairments such as glare and headaches [4], [5]. Conversely, substandard lighting can cause visual discomfort, thereby disrupting users' activities over extended periods [6], [7]

In cafes, lighting design is typically orchestrated to foster a warm and intimate atmosphere that encourages social interaction. This approach is characterized by dim illumination and warm color temperatures. Several studies suggest that warm lighting elevates the perception of intimacy, emotional comfort, and overall user affinity toward a space [[8], [9], [10], [11]. However, excessively dim lighting may fail to meet users' visual requirements, particularly when cafes are used for focus-intensive activities over extended periods, such as studying and working. Evaluating lighting performance in cafe environments requires consideration of key parameters, namely illuminance levels and Correlated Color Temperature (CCT). Nonetheless, studies examining workspaces and informal learning environments frequently reveal that existing illuminance levels fall below recommended standards [12].

In addition to illuminance, Correlated Color Temperature (CCT) is a critical determinant of lighting quality. Color temperature significantly influences how a space is perceived and users' eye comfort. A CCT of approximately 4300 K has been shown to enhance visual clarity and focused attention [13], whereas other studies indicate that a CCT of 3300 K, combined with specific illuminance levels, yields superior visual comfort for prolonged activities [14]. The variance in these findings suggests that the evaluation of CCT conditions in cafe environments must be conducted in context, aligning with the specific spatial characteristics and the activities accommodated.

Another equally vital aspect of lighting evaluation is glare. Glare can result from excessive light intensity, uneven light distribution, or improper placement and direction of light sources. Glare conditions have been shown to degrade visual comfort and impair occupants' visual acuity in space [5]. In cafes, glare frequently occurs due to a combination of artificial lighting, uncontrolled natural daylighting through openings, or decorative luminaires used without proper regard for the direction of light emission.

Previous studies on the lighting quality of learning spaces have predominantly focused on formal environments, such as classrooms and libraries [15], [16]. By contrast, studies on cafe design generally place greater emphasis on social atmospheres and spatial experiences, rarely addressing the technical aspects of lighting [7], [17]. Consequently, a gap in the literature emerges as cafes transition into informal learning spaces. Quantitative studies specifically evaluating the adequacy of illuminance, CCT, and glare levels in cafes remain scarce, particularly those using field measurement methods in urban settings. This scarcity largely reflects the foundational assumption that cafes are purely recreational spaces, which leads to the frequent neglect of visual comfort evaluations for productive activities. This neglect results in a scarcity of empirical data, leaving designers without adequate references to create cafe lighting designs that are adaptive to this functional shift.

This research was conducted in cafes near university campuses, which students frequently use as informal learning environments. The selection of the research objects was based on the predominantly dim visual-spatial conditions, particularly in indoor areas, thus raising questions about the lighting's compliance with visual comfort standards for cafe spaces. Their proximity to the university results in high usage intensity, making lighting quality a critical factor to evaluate.

Based on that phenomenon, this study evaluates the lighting design performance of the two selected cafes by examining illuminance levels, Correlated Color Temperature (CCT), and potential glare. The objective of this research is to determine the existing lighting conditions in each cafe and assess their compliance with applicable lighting standards, thereby providing

an objective overview of the current lighting quality. The findings of this study are expected to serve as a reference for planners and facility managers in formulating lighting design strategies that adapt to the functional shift of cafe spaces toward informal learning environments.

Methods

This study aims to evaluate the lighting design performance in cafes utilized as informal learning environments, focusing on illuminance conditions, Correlated Color Temperature (CCT), and potential glare. The research approach employed is a field measurement study utilizing a quantitative descriptive method. This method was selected to obtain a factual, quantifiable representation of the existing lighting conditions and to assess their compliance with visual comfort standards.

Data Collection Methods

This research was conducted in two cafes that students use as informal learning environments, as shown in Figures 1 and 2. The two case studies were selected using a purposive sampling strategy to represent contrasting architectural and lighting conditions that may influence visual comfort performance. The selection was based on three principal environmental variables: material reflectance, daylight integration strategy, and artificial lighting configuration. Following a preliminary survey of cafes located near university campuses in Surabaya, two cafes were identified as representing substantially different environmental design conditions, making them suitable for comparative evaluation. The purpose of this selection was not to compare individual cafes, but to investigate how contrasting environmental design strategies influence illuminance distribution, correlated color temperature (CCT), and glare perception in informal learning environments. Therefore, the two cases provide an opportunity to examine the relationship between contrasting architectural design strategies and lighting performance within the same functional context of informal learning activities.

Figure 1. Visual conditions of Cafe A

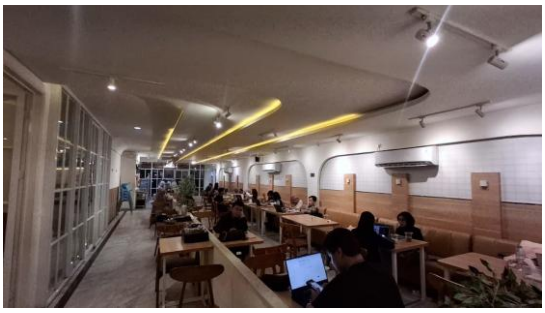

Figure 2. Visual conditions of Cafe B

Broadly, the fundamental differences between the two objects lie in their color palettes, spatial constituent materials, and the types of artificial lighting installed. Cafe A is designed with a visual-spatial character characterized by low light reflectance, primarily due to the dominant use of light greyish-brown wood-patterned surface materials (such as HPL and vinyl) on the wall, floor, and ceiling elements, coupled with a centralized distribution of artificial lighting. Conversely, Cafe B represents a spatial character with high reflectance, dominated by white paint finishes on the walls and ceilings, and light grey granite flooring that exhibits excellent light-reflecting properties. Furthermore, Cafe B features a more varied lighting scheme as it is integrated with

Table 1. Architectural and material properties of Cafe A

Element	Properties
Wall	
Material	Brick+ Wallboard/ Glass
Color	Light Brown / Transparent
Ceiling	Slat ceiling
Material	HPL
Color	Light Brown
Floor	
Material	Vinyl
Color	Light Brown
Furniture	
Material	Wood
Color	Light Brown

Table 2. Architectural and material properties of Cafe B

Element	Properties
Wall	
Material	Brick / Glass
Color	White Paint / Transparent
Ceiling	Drop Ceiling
Material	Gypsum
Color	White
Floor	
Material	Granite
Color	Light Grey Marble
Furniture	
Material	Wood
Color	Light Brown

natural daylighting openings (skylights). A detailed comparison of the architectural and lighting specifications of both cafes is presented in Tables 1 and Table 2. The interior visual conditions of Cafe A are shown in Figure 1, while those of Cafe B are depicted in Figure 2.

Field data collection was conducted through observation, lighting measurements, and the distribution of questionnaires to patrons. Observations were conducted to identify the existing lighting design conditions, including the types and positions of luminaires, the direction of light emission, the layout of tables and chairs, and potential sources of glare from both artificial and natural light. The observation results for Café A regarding seating layout, zoning, and measurement points are illustrated in Figure 3, while the luminaire position and condition are illustrated in Figure 4. Similarly, for Café B, the seating layout, zoning, and measurement points are illustrated in Figure 5, whereas the luminaire position and condition are illustrated in Figure 6.

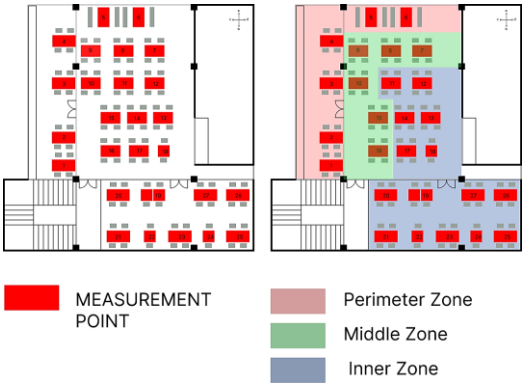

Figure 3. Seating layout (left) and spatial zoning distribution (right) of Cafe A

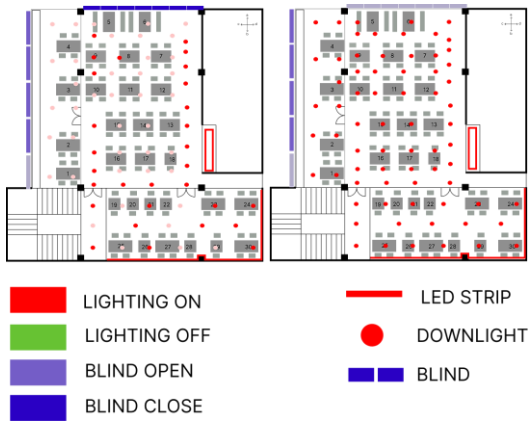

Figure 4. Luminaire condition daytime (left) and nighttime (right) in Cafe A

Technical lighting measurements were conducted directly on the visual work plane, specifically the surfaces of the users' tables, to obtain data on horizontal illuminance levels (lux) and Correlated Color Temperature (CCT). These measurements focused on individual tables rather than using a uniform grid of measurement points across the entire floor area. This approach was selected to record the factual lighting conditions directly received and perceived by users while engaging in activities at their seating areas. The height of the measurement plane was set to approximately 70–80 cm above floor level, corresponding to the standard height of a work desk.

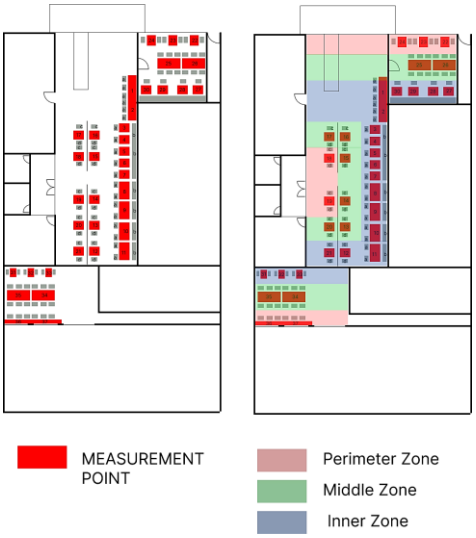

Figure 5. Seating layout (left) and spatial zoning distribution (right) of Cafe B

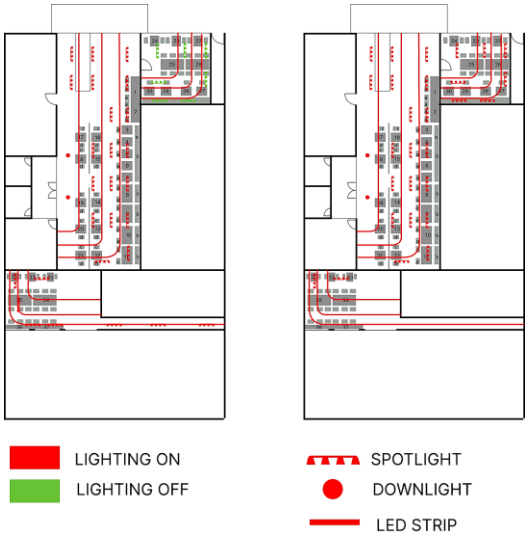

Figure 6. Luminaire condition daytime (left) and nighttime (right) in Cafe B

To capture two extreme lighting conditions (the integration of natural and artificial daylighting and the dominance of artificial lighting), measurements were taken at 12:00 PM (daytime) and 6:00 PM (nighttime). This time selection follows a methodological approach

commonly used in lighting studies to capture boundary conditions, representing the maximum contribution of daylight (daytime) and the fully artificial lighting condition (nighttime), thereby enabling a clear comparison of lighting performance under extreme operational scenarios. Data collection was conducted under clear-sky conditions to minimize anomalies due to natural light fluctuations. Field measurements at Cafe A were conducted on October 30, 2025, while those at Cafe B took place on November 2, 2025 shown in table 3. Details of the measuring instruments used in the data collection process are provided in Table 4.

Table 3. Measurement schedule and environmental conditions

Location	Date	Time	Weather Condition
Café A	30 Okt 2025	12.00	Clear
		18.00	Clear
Café B	2 Nov 2025	12.00	Clear
		18.00	Clear

Table 4. Data collection instruments

Variable	Instrument	Unit
Iluminance	Light Meter, EXTECH, SDL400	Lux
CCT	Spectrometer, LINSHANG, LS330	Kelvin

Data on glare perception were collected by distributing questionnaires to patrons actively engaged at their tables. The questionnaire measured perceived glare on a 5-point Likert scale (1 = no glare, 5 = severe glare). It also included open-ended questions to identify primary sources of glare, such as reflections from table surfaces, laptop screens, direct artificial lighting, or light entering through openings. While objective glare indices such as Unified Glare Rating (UGR) or Daylight Glare Probability (DGP) are widely used, subjective evaluation remains essential in post-occupancy studies, as visual discomfort is inherently perceptual and influenced by user experience [18], [19]. Therefore, a perception-based approach was adopted to capture the actual visual comfort users' experience. User behavior variables, such as duration of stay and activity patterns, were deliberately excluded to isolate the effect of lighting parameters (illuminance, CCT, and glare) on visual comfort. This approach ensures that the analysis remains focused on the environmental performance of lighting rather than behavioral variability.

Data Analysis Methods

The measurement data for horizontal illuminance and CCT were analyzed using a quantitative descriptive approach. The illuminance values in the tables were analyzed by calculating the mean, minimum, and maximum to assess the adequacy and uniformity of lighting in each cafe. These illuminance values were then compared with the Indonesian National Standard (SNI) 6197:2020 to assess compliance with the existing lighting. According to this standard, the recommended illuminance for cafe and restaurant functions is 100 lux, whereas for classrooms or visual work areas it is 350 lux [20], [21]. CCT data were analyzed descriptively in accordance with SNI 6197:2011 to identify the measured range of light color appearance groups and spatial color temperature characteristics. [21], [22]. According to this standard, lighting for cafe functions is recommended to have a warm color temperature with a CCT value below 3300 K, while classrooms or work areas are recommended to utilize a warm-white color temperature ranging between 3300 K and 5300 K [20], [23]. A summary of the standard illuminance criteria and CCT ranges utilized as the analytical reference in this study is presented in Table 5.

Table 5. SNI standards for recommended illuminance levels and CCT

Spatial Function	Illumination Level Standard (Lux)	Correlated Color Temperature / CCT (Kelvin)
Cafe	100 lux (SNI-6197 2020)	<3300K (Warm) (SNI-6197 2011)
Study	350 lux (SNI-6197 2020)	3300K – 5300K (Warm White) (SNI-6197 2011)

Meanwhile, the glare questionnaire data were analyzed descriptively by calculating the percentage distribution and the mean perceived glare score for patrons in each cafe. The tabulated results of this glare perception study were then synthesized with observational findings on glare sources, luminaire positions, and table illuminance conditions to identify the primary factors that may induce visual discomfort. Overall, the integration of these analytical results was utilized to descriptively evaluate the actual performance of the cafes' lighting design by benchmarking it against applicable spatial comfort standards.

This study prioritizes performance-based evaluation over design intention analysis. Therefore, direct interviews with designers were not conducted, as the primary objective is to assess the actual lighting conditions experienced by users rather than the conceptual design rationale.

Results and Discussion

Lighting Performance of Cafe A

1. Illuminance Levels

The illuminance measurement in Café A shows fluctuating conditions, particularly during the daytime shown in Figure 7. Table 6 summarizes the illuminance measurements in Café A. During the daytime, the minimum illuminance was 102 lux, and the maximum was 690 lux, yielding an overall average of 263.37 lux. According to SNI 6197:2011, which recommends a minimum illuminance of 100 lux for cafe spaces and 350 lux for classrooms or visual work areas, the measured minimum (102 lux) complies with the baseline standard for a cafe. However, when the space is used as an informal learning environment, the average illuminance (263.37 lux) falls below the recommended 350 lux threshold. Furthermore, the substantial variance between the minimum and maximum values indicates uneven light distribution across the users' seating areas.

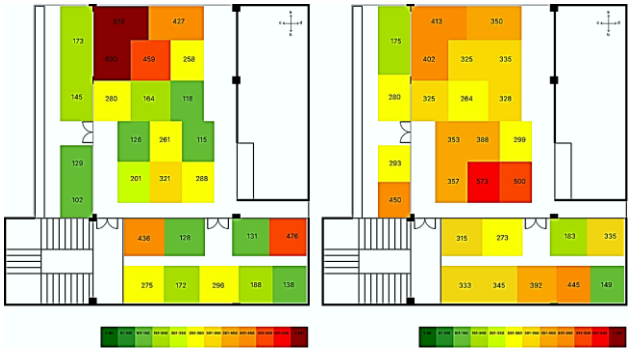

Figure 7. Illuminance level measurements during daytime (left) and nighttime (right) in Cafe A

Table 6. Illuminance level measurements in Cafe A

	Illuminance level (Lux)	
	Daytime	**Nightime**
Min	102	149
Maks	690	573
Mean	263	338
Café Standard	100	100
Study Standard	350	350

2. Correlated Color Temperature (CCT)

The CCT measurement exhibits varying light color characteristics between daytime and nighttime conditions shown in Figure 8. Table 7 summarizes the CCT measurements. During the daytime, the CCT values ranged from 3600 K to 4250 K. According to SNI 6197:2011, this entire daytime lighting range falls within the warm white category (3300–5300 K). This condition indicates that the daytime lighting characteristics in Cafe A technically meet the light color standards for light visual work areas due to the presence of natural daylight. Meanwhile, at night, the measured CCT values in the seating areas experienced a decrease, ranging from 2550 K to 3750 K. Referring to the SNI classification, this range indicates a dominance of warm light characteristics (< 3300 K), which is synonymous with the relaxed atmosphere of a cafe, alongside several table points reaching the lower threshold of warm white. The reduction in the maximum CCT range at night underscores that, in the absence of sunlight, the installed artificial lighting helps restore and maintain the intimate, warm visual atmosphere typical of cafes.

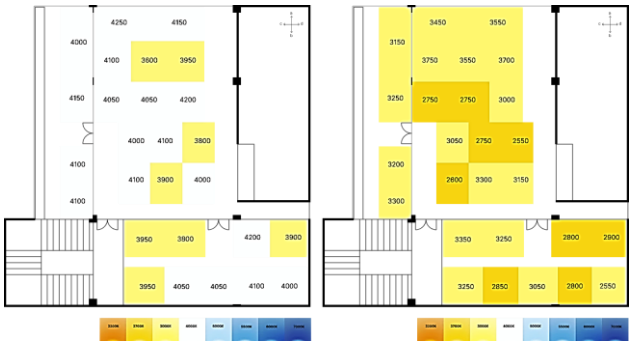

Figure 8. CCT measurements during daytime (left) and nighttime (right) in Cafe A

Table 7. CCT measurements in Cafe A

	CCT (K)	
	Daytime	**Nightime**
Min	3600	2550
Maks	4250	3750
Range	3600 - 4250	2550-3750
Café Standard	<3300	<3300
Study Standard	3300 – 5300K	3300 – 5300K

3. Glare

The glare analysis at Cafe A was evaluated using a patron perception questionnaire with a 1–5 Likert scale. The distribution of patrons' perception regarding glare levels is presented in Figure 9. Under daytime conditions (37 respondents), most patrons experienced low to moderate glare. The dominant responses fell on scale 2 (49%) and scale 3 (35%), while 11% of respondents reported very low glare (scale 1), and only 5% reported high glare (scale 4). No respondents rated the glare at a very high level (on a scale of 5). Regarding the identified sources, daytime glare complaints were primarily triggered by material surface reflections (68%), followed by luminaire emissions (11%) and sunlight (5%), whereas the

remaining 16% reported experiencing no glare. Under nighttime conditions (a total of 39 respondents), the results indicate that most patrons experienced very low to low glare levels, with dominant responses on scale 1 (39%) and scale 2 (36%), followed by scale 3 (19%). Only 3% of respondents reported high glare. Nighttime glare sources were dominated by the no-glare condition (41%), followed by material surface reflections (33%) and luminaire exposure (26%), with naturally excluded sunlight. These findings confirm that the potential glare level at Cafe A is relatively low and well controlled. Interestingly, the visual discomfort was predominantly due to light reflections from interior materials (such as solid-wood table surfaces or flooring) rather than to the luminaire's emission intensity.

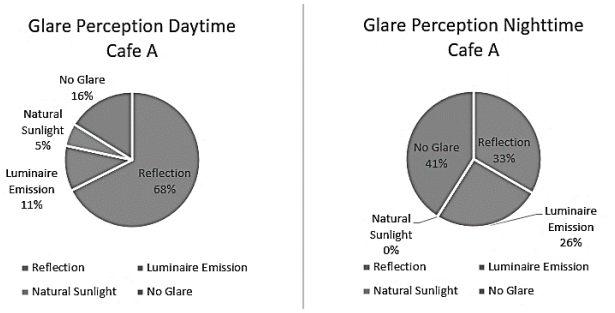

Figure 9. Glare perception during daytime (left) and nighttime (right) in Cafe A

Lighting Performance of Cafe B

1. Illuminance Levels

The illuminance measurements in Cafe B show a highly significant disparity between daytime and nighttime conditions shown in Figure 10. Table 8 summarizes the illuminance measurements. The minimum illuminance was 84 lux, while the maximum reached 3040 lux, yielding an overall average of 512 lux. According to SNI 6197:2011, which recommends 100 lux for cafe spaces and 350 lux for visual work areas, the average daytime illuminance in Cafe B exceeds both standards. Nevertheless, the excessively wide range between the minimum (84 lux) and maximum (3040 lux) values indicates an extremely uneven light distribution across users' seating areas, primarily due to substantial penetration of natural daylight. Conversely, under nighttime conditions, the illuminance levels in Cafe B decreased drastically, with a minimum of 22 lux, a maximum of 88 lux, and an average of 54.5 lux. This value falls significantly below the SNI standard, both for the baseline function of a cafe space (100 lux) and, more notably, for learning environments (350 lux). This condition proves that the nighttime artificial lighting installation in Cafe B is inadequate in facilitating the visual needs of users engaging in studying or working activities.

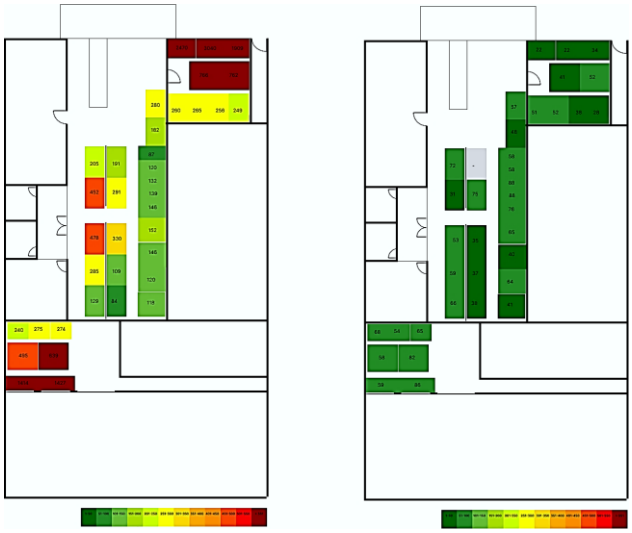

Figure 10. Illuminance level measurements during daytime (left) and nighttime (right) in Cafe B

Table 8. Illuminance level measurements in Cafe B

	Illuminance level (Lux)	
	Daytime	**Nighttime**
Min	84	22
Maks	3040	88
Mean	512	54,5
Café Standard	100	100
Study Standard	350	350

2. Correlated Color Temperature/CCT

The Correlated Color Temperature (CCT) measurements in Cafe B reveal contrasting light color characteristics between daytime and nighttime conditions shown in Figure 11. Table 9 summarizes CCT measurements. During the daytime, the CCT values in the seating areas ranged from 2950 K to 4500 K. Referring to the SNI 6197:2011 classification, this range indicates a blend of the warm color category (< 3300 K) in areas shielded from exterior daylight, reaching up to the warm white category (3300–5300 K) in areas exposed to daylight penetration. The presence of this warm white characteristic technically supports the visual clarity of patrons engaged in studying. Under nighttime conditions, the CCT values in Cafe B narrowed and decreased drastically to a range of 2300 K to 2900 K. Based on the SNI standard, this entire nighttime lighting range consistently falls into the warm light color category (<3300 K). This value range is well-suited to establishing the visual atmosphere and spatial character of a commercial cafe. However, when used as an informal learning area, this CCT

range falls below the recommendation for light visual activities (warm white), which may accelerate users' eye fatigue during prolonged use.

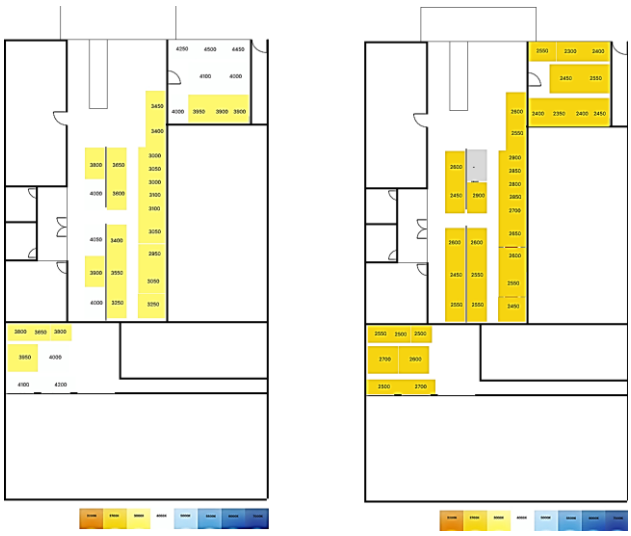

Figure 11. CCT measurements during daytime (left) and nighttime (right) in Cafe B

Table 9. CCT measurements in Cafe B

	CCT level (K)	
	Daytime	**Nighttime**
Min	2950	2300
Maks	4500	2900
Range	2950 - 4500	2300-2900
Café Standard	<3300	<3300
Study Standard	3300 – 5300K	3300 – 5300K

3. Glare

The glare analysis at Cafe B was evaluated using a patron perception questionnaire with a 1–5 Likert scale. The distribution of patrons' perception during daytime and nighttime conditions is presented in Figure 12. Under daytime conditions (16 respondents), the results indicate that most patrons experienced moderate to high glare levels. Dominant responses fell on scale 3 (50%) and scale 4 (44%), while only a small fraction of respondents reported very low glare on scale 1 (6%). Regarding the identified sources, visual discomfort during the daytime was reported to originate from luminaire emissions (50%) and interior surface reflections (44%), with natural daylight penetration surprisingly not being explicitly identified as a primary glare source by the respondents. Under nighttime conditions (26 respondents), the level of glare complaints decreased drastically. The majority of patrons experienced no glare, with reports dominated by very low (scale 1) to moderate (scales 2 and 3) levels; only 4% of respondents reported high glare. Nighttime glare sources were dominated by a no-glare condition (50%), followed by material surface reflections (27%) and luminaire emissions (23%). These findings indicate that the potential for glare in Cafe B at night is relatively lower and controlled, wherein the minor visual disturbances that emerged were more influenced by the directional placement of spotlights and reflections from the white wall materials or tables, rather than resulting from high illuminance levels.

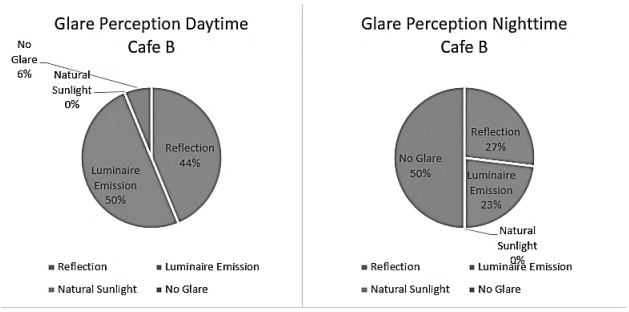

Figure 12. Glare perception during daytime (left) and nighttime (right) in Cafe B

Comparative Lighting Performance Café A and B

The field measurement results reveal starkly contrasting lighting performance between Cafe A and Cafe B, directly influenced by their spatial enclosure design strategies and the reflectance levels of their interior materials.

1. Illuminance Distribution

Cafe B, dominated by high-reflectance materials (white wall paint and light granite flooring) alongside natural daylighting openings (skylights), experienced extreme illuminance fluctuations. During the daytime, light reflections in Cafe B surged to 3040 lux, exceeding visual comfort thresholds. Ironically, at night, when relying entirely on artificial lighting, its average illuminance plummeted to 54.5 lux, well below the minimum standard for a cafe space (100 lux). Conversely, Cafe A, which uses low-reflectance materials (light greyish-brown wood-patterned wall and floor coverings), exhibited more controlled fluctuations in light. The darker characteristic of the materials in Cafe A effectively absorbed excess light, resulting in a more stable illuminance range, even though its overall average illuminance (263.37 lux during the day) did not fully meet the ideal standard for learning environments (350 lux).

2. Correlated Color Temperature (CCT)

Regarding Correlated Color Temperature, both cafes used different approaches at night. Cafe B consistently used very warm lighting (2300 K to 2900

K), strongly emphasizing a relaxing, social atmosphere. Meanwhile, Cafe A maintained a balance with a nighttime CCT range between 2550 K and 3750 K. The presence of luminaires that meet the lower threshold of the warm white category (above 3300 K) in Cafe A makes it slightly more adaptable to patrons engaged in light visual activities, such as reading or looking at computer screens. This contrasts with Cafe B's lighting, which may accelerate drowsiness and eye fatigue due to its excessively yellow or warm color. This finding is consistent with previous studies suggesting that moderate CCT ranges support visual comfort and cognitive performance, whereas excessively warm lighting primarily enhances relaxation at the expense of alertness [24], [25].

3. Glare

Differences in spatial constituent materials have the most significant impact on visual comfort with respect to glare. Daytime glare complaints in Cafe B were classified as high (scales 3 and 4), caused by significant light bouncing off the bright white interior elements exposed to daylight through the overhead openings. Conversely, daytime glare complaints in Cafe A were predominantly low to moderate (scales 2 and 3). The characteristics of Cafe A's interior elements, which absorb more light, successfully minimized reflection glare, ensuring that users' vision was not severely disrupted despite the high intensity of sunlight.

4. Synthesis of Informal Learning Space Suitability

Overall, the comparison between these two objects underscores the gap between aesthetic cafe design intentions and the requirements of productive visual ergonomics. The use of centralized spotlights or downlights, combined with a dominance of warm light color (< 3300 K), is highly effective in establishing a cafe's commercial identity. However, when space transitions to an informal learning area with prolonged use, these specifications can cause visual discomfort (either due to under-illumination at night or glare from reflections during the day). This indicates that the future design of multifunctional cafes requires task-lighting strategies specifically zoned over solid-wood table areas. This approach would meet visual work comfort standards (350 lux and warm white) without compromising the warm atmosphere in the cafe's primary circulation areas.

Conclusion

This study demonstrates that the lighting performance of cafes used as informal learning environments cannot be adequately evaluated using standard criteria for commercial spaces alone. Although both case studies generally meet the minimum illuminance requirements for cafe functions (100 lux), the findings reveal a consistent failure to meet the visual demands of task-oriented activities, particularly in illuminance sufficiency, distribution uniformity, and appropriate Correlated Color Temperature (CCT).

The results indicate that lighting performance is not determined solely by installed lighting systems but is significantly influenced by the interplay among daylight integration, material reflectance, and spatial configuration. In Cafe B, high-reflectance materials combined with uncontrolled daylight penetration produced excessive illuminance variability and increased glare risk. In contrast, Cafe A exhibited more stable lighting conditions due to absorptive materials, though this led to insufficient illuminance for learning activities. These contrasting conditions highlight a critical trade-off between lighting uniformity and illuminance adequacy in real-world environments.

From a perceptual perspective, the dominance of warm lighting (<3300 K) in both cafes reinforces their atmospheric identity as social spaces but limits their effectiveness as environments for sustained cognitive activities. This finding confirms that lighting strategies designed for hospitality contexts may conflict with the visual requirements of informal learning, particularly regarding alertness and visual clarity.

Furthermore, glare conditions in both cafes were found to be more strongly influenced by material reflectance and spatial light interaction than by light intensity alone. This suggests that glare control should be approached as an integrated design issue involving surface properties, luminaire positioning, and daylight management.

Overall, this study identifies a fundamental mismatch between commercial lighting design strategies and the emerging functional role of cafes as hybrid social–productive environments. The findings emphasize the need for a shift toward adaptive and layered lighting systems, where ambient lighting is complemented by task-specific illumination to accommodate diverse user needs.

This research contributes to the development of a performance-based understanding of lighting design in multifunctional spaces, highlighting that compliance with general lighting standards alone is insufficient to ensure visual comfort in evolving spatial typologies. Future studies are recommended to explore adaptive

lighting interventions, user behavior dynamics, and interactions between architectural lighting and digital device use to further refine design strategies for contemporary informal learning environments.

AI Use Declaration

The authors acknowledge the use of Gemini to refine specific academic phrasing and verify crucial building science terminology. The prompts used are "Refine this text for academic clarity" and "Verify the architectural terminology used in this section." The output from these prompts was used to ensure precise use of crucial technical terms (e.g., Correlated Color Temperature, illuminance levels) and to subtly improve sentence structure in complex sections. While the authors acknowledge the usage of AI, they maintain that MUHAMMAD DAFFA SAMUDERA, ASRI DINAPRADIPTA, and IMA DEFIANA are the sole authors of this article and take full responsibility for the content therein, as outlined in COPE recommendations and journal policies.

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