Lighting Quality In The Architectural Design Studio (Case Study: Architecture Design Studio at Universitas Katolik Parahyangan, Bandung, Indonesia)

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Abstract. Lighting designs, both daylight and artificial light, have a major effect on creating visual comfort and room atmosphere. The Parahyangan Catholic University's architectural design studio room has its limitations in providing daylight into the room, where a lot of the literatures express the importance of daylight's role to room quality. This study aims to evaluate the lighting quality in the studio and provide lighting design recommendations to improve the user’s productivity and creativity. Data were collected through observation to obtain physical room data and existing lighting design. DiaLux software is used to simulate the lighting performance. User’s perception about the room quality obtained through questionnaires distributed to students. The results show that despite the below-standard illumination level, respondents are still well-rated the studio lighting quality. Visual comfort perception is higher than the room atmosphere perception. The lighting techniques, illumination levels, light colors, room reflection factors, and daylighting contribution are the factors that most affect the room quality.

1. Introduction
In architecture, light plays not only as a functional fulfillment, but also can create psychological effects to the user and gives a deeper impression of a place. Daylighting and artificial lighting design need to be optimized to get good lighting quality. In architectural study, the design studio is highly important, with a longer duration of use than other classrooms. Therefore, the lighting quality is a big consideration to improve the user’s comfort and creating an interesting room atmosphere. In the design studio, the activity is not only to produce images, but also used as a place to explore the design. Therefore the room needs to be able to stimulate user creativity in building design. The case study was the architectural design studio at Parahyangan Catholic University, Bandung, Indonesia. The room has limited access openings so that only part of the area gets daylight. This study aims to explore and evaluate the studio’s lighting design and providing recommendations to improve the lighting quality that can impact the student’s productivity and creativity.

2. Literature Review
The room layout, order, form, elements, and its furniture have an influence on the lighting performance. The factors that affect daylighting, including sky conditions and building /room data. Room data include it’s geometry (orientation, shape, and dimension), openings (geometry and material
used), reflection factors (internal and external), artificial lighting contributions, barriers or shadings (internal and external), maintenance factors, pollution factors, and its furniture (1).

Light color and illumination level affects the visual comfort and room atmosphere perception. The minimum daylight factor values for a classroom is 2%. He also suggests the requirement for uniform illumination of 150 Lux generally in the room, and 1500 Lux in the workplane to perform visual tasks for drawing (1). Meanwhile, according to Indonesian National Standard, the illumination level requirement for drawing studio is 750 Lux (2). The European Standard (EN 12464-1) details the minimum recommended level of illumination for office space based on the activity performed. For technical drawing activities, 750 Lux illumination is required, while for other activities it ranges from 200-500 Lux.

Light simulation can produce a different impression of space. Stimulation of light with a high intensity level can increase the spirit and pleasure feeling (enjoyment), otherwise low intensity level produces a comfort feeling, more relaxed and improve focus. Complex, asymmetrical, sophisticated, unfamiliar lighting techniques that contain surprises, and random are categorized as high load. While simple, symmetrical, conventional, familiar, un-surprising and regular categorized as low load. Both have a role in creating a certain atmosphere in the room. Low and high light contrast can also create different psychological effects. In a study of lighting perception and various lighting techniques in a workspace by Wright, he concluded that comfort and pleasant feeling to work can be improved by adding luminations to the wall space (3). A commonly, indirect lighting techniques can improve the impression of spaciousness than direct lighting techniques (4).

Since 1970, Flynn has been researching the role of light for people’s impression. User’s feeling can be corroborated by the lighting that confirms the spaciousness/confinement, visual clarity/haziness, relaxation/activation, private/public impression (5). This is related to the illumination level, light color selection, and also the light source placement technique in the room. Lee (2014) examines the role of light color and visual perceptions for office space. It states that lower light temperatures (3000$^\circ$K) have greater potential to cause visual glare and discomfort (both paper and monitor-based activities), so it is not recommended for use in office space. However, the atmosphere/mood created by the warm light color gives a better effect than other color temperature (4000$^\circ$K and 6500$^\circ$K) (6).

Lighting design for a workspace needs to be conditioned to improve worker productivity and creativity. The lighting variances in a workspace contribute significantly to perceived comfort (7). The workspace that requires creative thinking needs to be designed with attention to that can stimulate creativity. A low light illumination and dark impression can improve work performance that requires creativity (8). Artificial light control to accommodate variations in light illumination levels can be distinguished by switching and dimming or made light scenarios according to space requirements. Lighting considerations for drafting, drawing or painting by using general diffused lighting and task lighting from both sides to minimize glare from light sources (1).

The importance of daylight has been realized by architects early long ago. Farley (2001) collected previous studies from Wells (1965), Mark (1967), Manning (1965), Collins (1975) who conducted surveys to see a participants’ preference for daylight needs. All of them have the same conclusion, that daylight is desirable and preferable (9). Farley also states that “windows with views of nature were found to enhance work and well-being in a number of ways including increasing job satisfaction, interest value of the job, perceptions of self-productivity, perceptions of physical working conditions, life satisfaction, and decreasing intention to quit and the recovery time of surgical patients.”

3. Case Study: General View

This paper evaluated the lighting design for architectural design studio with the first year students as a user. As a basic design studio, students are enhanced to use paper media with the hand-method drawing production (sketches). The room is designed with an open plan system, rectangular shape with L/W/H : 40 x 28 x 3.7 m. There are two separated areas of the main entrance and the circulation path. On the front side, the enclosure are walls and window without direct access to the outside (no daylight penetration). While in the back, it surrounded with windows that has daylight access (on the
south and east side) and nature view (hills and mountain). Hereafter, it will categorize as windowed and windowless area (Figure 1). The opening is a side window type that most of the glass is coated with a sandblast sticker. This reduces the glass transparency value by 89% to 11%. The room walls and ceiling are painted with bright colors with no texture. The floor uses a light colored ceramic. The table used as a workspace is colored white, coated with clear glass and has a hinge so the angle can be adjusted.

The artificial lighting used a general lighting system and the lamps arranged with grid patterns on the ceiling. Lamps used are fluorescent lamp downlight 2 x T5 28 Watts. White light color used (4000 °K) with good rendering index (CRI = 85). The lamp housing has an aluminium diffuser for glare reduction. Another lamp type is LED downlights 13 Watt with cool daylight temperature color which positioned along the main circulation that divides the space.

![Figure 1. Room plan, calculation points, and room view](image)

4. Research Methods

Data collected by observation to get the room data, including form, furniture layout, and room elements. Lighting data include daylighting (window orientation, dimensions, glass material, and environmental conditions) and artificial lighting data (lighting system, light source and armature type and its specification). Simulations using the DiaLux software were carried out to obtain lighting illumination data, daylight factor values, light distribution, and possible direct glare disturbances from sunlight.

Questionnaires are distributed to know the lighting effects on user perceptions. There are 86 participating response which almost 50% of the student population in class. Purposive sampling method was used, to ensure that respondents spread evenly in all seating positions. A questionnaire was modified based on previous research conducted by Lee J. H (2004) and Wright (1999). The question is divided into 2 groups, the first is to analyze the visual comfort and potential disruption to visual activity, the second is to analyze the visual stimulation related to the atmosphere / mood of the space.

Use of sections to divide the text of the paper is optional and left as a decision for the author. Where the author wishes to divide the paper into sections the formatting shown in table 2 should be used.
Table 1. Questionnaire questions for visual comfort perception

| No | questionnaire content          | 1 | 2 | 3 | 4 | 5 | questionnaire content          |
|----|--------------------------------|---|---|---|---|---|--------------------------------|
| C1 | room feel dim                  |   |   |   |   |   | room feel bright               |
| C2 | task area feel dim             |   |   |   |   |   | task area feel bright          |
| C3 | not satisfied with light color |   |   |   |   |   | satisfied with light color     |
| C4 | feel visual distraction        |   |   |   |   |   | feel no visual distraction     |
| C5 | feel eye fatigue               |   |   |   |   |   | feel no eye fatigue            |
| C6 | see object visually unclearly  |   |   |   |   |   | see object visually clearly    |
| C7 | see detailed object visually   |   |   |   |   |   | see detailed object clearly    |
| C8 | recognize color unclearly on   |   |   |   |   |   | recognize color clearly on     |
| C9 | feel glare for task            |   |   |   |   |   | feel no glare for task         |

Table 2. Questionnaire questions for room atmosphere perception

| No | questionnaire content          | 1 | 2 | 3 | 4 | 5 | questionnaire content          |
|----|--------------------------------|---|---|---|---|---|--------------------------------|
| M1 | feel visually cold             |   |   |   |   |   | feel visually warm             |
| M2 | feel room is cramped           |   |   |   |   |   | feel room is spacious          |
| M3 | feel tense                     |   |   |   |   |   | feel relaxed                   |
| M4 | feel unpleasant                |   |   |   |   |   | feel pleasant                  |
| M5 | feel no attraction to space    |   |   |   |   |   | feel attraction to space       |
| M6 | feel fidgety                   |   |   |   |   |   | feel no fidgety                |
| M7 | feel room is not cozy          |   |   |   |   |   | feel room is cozy              |
| M8 | light make you feel dislike    |   |   |   |   |   | light make you feel like space |

5. Discussion

The result shows that average illumination level (E.av) in the room is 108 lux (daylight only) and 568 Lux (both daylight and artificial light). This value is still below the standard based on Lechner (1500 Lux) also on SNI and EN (750 Lux). The room only uses a general lighting system and has no local lighting that leads directly to the drawing table so that it does not meet the requirement for image activity. The lower illumination is in the center of space, that is, along the circulation. This is caused because the type of lamp used is different and has lower power than other work areas. As a result, the workbench adjacent to the path also has a smaller illumination level. Nevertheless, the use of bright colors on the room perimeter helps to reflect light and contribute to increase the illumination.
Windowed area has higher illumination levels than windowless area. Daylight contributes to this addition, but not significant because there is shaded corridor outside the building and large tree in the east.

Lighting distribution is sufficiently uniform, with $u_0 = 0.56$ and CoU max / min = 0.35. Sandblast stickers as glass coatings help to reduce glare and distribute light more evenly. However, the daylight contribution is also reduced. The use of bright-colored room material also increasing the uniformity. Simulation results show the daylighting factors in calculating points are ranging from 0.13–4.34% (DF av= 0.88 %). This result are still bellow the DF requirement (2 %). The use of white and glass-covered table can cause visual disturbance because of reflective glare from the lamp. Although lamp housing have been using aluminium baffles, but because of using direct lighting techniques (downlight) then at a certain position, the reflected glare is still occurring.

![Figure 3. Graphic result for illumination level and daylight factor](image)

Figure 3. Graphic result for illumination level and daylight factor

![Figure 4. Picture shows the daylight contribution in the room](image)

Figure 4. Picture shows the daylight contribution in the room

The results show a variety responses to the lighting quality for visual comfort. In windowless areas, respondents are more likely to feel eyestrain than windowed areas. While the visual disturbances from glare are more often felt in the windowed area. Despite having an outside corridor, the shading is wide enough, and the glass window is sandblast coated, in the morning the sun can still enter the room and potentially cause glare. Armature lamps used are equipped with aluminum baffles that commonly help to reduce glare disturbance. Overall, respondents’ ratings of lighting quality for visual comfort had a positive score of 4.03 (out of 5).
Figure 5. Lighting perception result visual comfort (left) and the impression of the atmosphere of space (right)

The level of respondents’ visual satisfaction for the room atmosphere is slightly higher in the windowed area. Respondent visually feels warmer, relaxed, pleasant and feel the room more attractive compared to windowless area. Daylight is dynamic which can bring a mood changing throughout the day, while artificial lighting is constant, making the atmosphere less attractive. White light color, uniform illumination, symmetrical arrangement of lamps, and no lighting control variation also gives the formal effect, cold feeling, and less impressive. The windowless area is constrained by walls that reinforce the confined impression, on the other hand the windowed area feel more spacious. However, the use of high reflective color of the room elements help provide wider, more comfortable, and more pleasurable effects in windowless areas. Overall, the respondents’ assessment score for the room atmosphere is lower than its function for visual activity, which is 3.4 (out of 5) but still above average.

Respondents also provide suggestions to add illumination level with task lighting in the working space, especially in the middle area of the room whose illumination level is lower than other areas. The need for daylight is also one of the aspects assessed necessary by respondents to improve work productivity. Warm atmosphere is also much desired, so that the atmosphere of space is not stressful and inhibits creativity. The morning sun glare is also complained of for some respondents who are near the window, so it needs a special design to anticipate.

6. Conclusion
The room has a lower illumination level than the specified minimum requirement, but the respondents’ assessment is still adequate. Difference of illumination value is generally influenced by the type of lamp used and the contribution of daylighting through the openings. In general, the lighting distribution is evenly distributed because it uses general lighting techniques, the use of sandblast stickers on window panes, and the bright color room elements. Glare is found in some workspaces that close to the window and from the reflection of lights on the glass-coated desk.

Respondents perception about the room atmosphere is lower than the assessment of its function for the fulfillment of visual activity. This is due to the lack of areas that have access to daylighting and monotonous artificial lighting designs. Surveys also show that the room atmosphere is better at the windowed area. This corroborates the results of previous studies that emphasize the need for daylight access to the work area.

The main advice that can be done to improve the lighting quality in the room is by adding task lighting to the workspaces. Task lighting works to improve contrast, illumination levels, and provide focus for activity. Task lighting should be equipped with individual control so that it can be adapted to the type of activity and preferences of each student. In addition, to improve the user productivity, in determining the working spaces, the windowed area needs to be met first before spreading the students to other areas. Another suggestion is adding luminations on the wall to improve the atmosphere to be more comfortable and fun to work.
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