Optimization the Use of Artificial Lighting at Architectural Design Studios in Architecture Study Program of Universitas Syiah Kuala

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Abstract. Drawing, writing, cutting and composing materials, and displaying pin up are some activities carried out during architectural design course in an architectural design studio. These design activities require good lighting to see details. However, based on the results of the evaluation conducted by Jamil (2018), consisting of questionnaires and measurements of natural lighting in studio A, studio B, studio C, and studio D, four studios in Architecture Study Program of Universitas Syiah Kuala (Unsyiah), Banda Aceh, Indonesia, proved that artificial lighting is needed to support these design activities. This study aims to evaluate the use of existing artificial lighting by measuring it using lux meter. The data obtained were simulated through Dialux Evo 9.0, lighting evaluation software. Finally, the simulation data presented as three-dimensional modelling. This study provided design recommendation about artificial lighting for architecture students to carry out design studio activities such as tutorial, workshops, mentoring, reviews, and exhibitions effectively and efficiently.

Keywords: Architectural Design Studio, Artificial Lighting, Optimization

1. Introduction

Architecture Study Program, Department of Architecture and Planning, Faculty of Engineering, Universitas Syiah Kuala, Banda Aceh, Indonesia, has four architectural design studios, Studio A, Studio B, Studio C, and Studio D with different space dimension. Studio A, Studio C, and Studio D are 110 square meters, 220 square meters, and 110 square meters, respectively. Consecutively, the studios, except for studio B, are located on the second floor and used for each studio-based subject such as Basic Design, Architectural Communication, Architectural Design I-VI, Structure Construction and Material I, III, IV, Interior Design I-II, and Landscape Design. Tutoring, conducting workshops, mentoring, reviews, and exhibitions are some studio-based activities that happen in those studios. Workshop activities consist of drawing, cutting materials, and composing materials. All of these activities require excellent lighting need. Based on SNI, the lighting required for this activity is at least 600 lux.

However, the natural lighting received by the four architectural design studios was not optimal [1]. This evaluation was carried out through observation methods, questionnaires for architectural design studio users, measurements using a lux meter, and simulations using Autodesk Ecotect 2011. Based on the results of these evaluations, none of the natural lighting in the studio meets the lighting minimum.
standard, 600 lux, so the four studios need artificial lighting albeit during the day. Natural lighting that comes from sunlight does not enter the room optimally because the available openings are not located in the orientation where sunlight enters properly and have overshadowed shading [1].

However, the available artificial lighting does not support design activities too. The existing artificial light measured in studio A, studio C, and studio D at 10.00 am shows an average of 280 - 600 lux of illuminance each work plane. The minimum value is obtained at the point of indirect artificial light and near natural light sources while the maximum value is obtained at the point receiving direct light from two lighting sources.

Therefore, this study aims to optimize the use of artificial light in architectural design studio more effectively and efficiently. This optimization is also expected to produce maximum output of the design process in studio-based design course. In the long term, it is able to produce energy savings in 10 hours of design studio use every day. In addition, good lighting affects the level of eye health [2] and psychology [3] of architecture students as users.

This optimization is intended to produce 3D modeling recommendations for the three studios without changing the dimension of the space and the number or ratio of openings to walls.

2. Artificial Lighting at Architectural Studio

Architecture student activities in a design studio are more than just normal classroom activities. Lighting plays an important role to the student because high quality lighting can improve student mood, behavior, concentration, and their learning [4]. The lighting quality is a big consideration to improve the user's comfort and create an interesting room atmosphere [5] thus the studio assignment done throughout the day still produces maximum design results.

Artificial lighting provided and optimized in the design studio is not only shaping the atmosphere, but also provides the minimal lighting needed for tutoring, workshops, mentoring, reviews, exhibitions to be more effective and efficient. Therefore, the required artificial lighting must meet the standards. The lighting required for fairly hard work with small details such as a drawing studio is 600 lux [6] and meets the recommended minimum lighting level for educational institution building functions for the drawing room, which is 750 lux [7].

Artificial lighting is needed because natural lighting is insufficient, the illuminance cannot be adjusted, and not available evenly throughout the day [2]. The artificial lighting that will be used is even lighting combined with natural lighting thus meet illuminance standard in the work area. Evenly distributed artificial lighting is also expected to provide good illuminance for other activities such as tutoring and exhibitions. Artificial lighting helps architecture students to do task that requires high concentration such as drawing, cutting, and composing materials.

Studio A, Studio C, and Studio D are used almost 10 hours every day in architectural design course. These three studios are located between two buildings with relatively deep canopy (overshadowed), minimum ratio of the opening to sun orientation wall, and the quality of the opening material so that natural lighting received not optimal.

![Figure 1](image1.png) (a) Studio A interior, (b) Studio C interior, (c) Studio D interior

Design studio uses direct and indirect artificial lighting, namely LED downlight and tube light. Studio A uses 24 units of downlight, 14 units indirect tube light, and 15 units direct tube light with a capacity of 28 drawing table units. Studio C uses 44 downlight units, 55 indirect tube light units with a
capacity of 48 drawing table units. Studio D uses 18 direct tube lights with a capacity of 30 drawing table units.

Artificial lighting simulation is conducted using a freeware, Dialux evo 9.0. Dialux is a software that is able to calculate the illuminance generated by the type of lamp in a certain environment.

3. Method
This study is conducted in three design studios, studio A, studio C, and studio D of Architecture study program, Unsyiah. Studio B was not subjected to observations and simulations because no longer used for design activities in architectural design course.

![Figure 2. (a) Laser Distance Meter, (b) Lux Meter](image)

This optimization study was carried out through the existing 3D modelling, measurement of illuminance, model exploration, and simulation using Dialux evo 9.0. Existing modelling is done after measuring the dimensions of space using a laser distance meter, Krisbow series 10106734. The results of space dimension measurements are modelled on Google SketchUp and Autodesk Revit. Next, doing illuminance calculation produced by existing artificial lighting and natural lighting at six points (studio A) and nine points (studio C and studio D) using a lux meter, Yokogawa series 3281A. These points represent user position exposed to direct artificial light, indirect artificial light, and combination of indirect artificial light and natural light. Measurements with a lux meter were carried out at 10:00 a.m.

Illustrations below are the existing models of studio A, studio C, and studio D which show the position of the illuminance measurement point with a lux meter. This measurement is done by activating all available artificial light sources. Lux meter was put on 270-280 cm below the artificial lighting.

![Figure 3. (a) Laser Distance Meter, (b) Lux Meter](image)

Furthermore, space exploration is carried out by rearranging the drawing table position. This reset is adjusted to maximize the effectiveness and efficiency of student work groups and student capacity by increasing the number of drawing desks, namely 4 drawing desks (studio A), 16 drawing desks (studio C) and 2 drawing desks (studio D).
Figure 4. Rearrangement of drawing table position in (a) Studio A, (b) Studio C, (c) Studio D

The results of this exploration are used to explore a simulated model using Dialux evo 9.0. Exploration is carried out to obtain an effective and efficient artificial lighting design by optimizing the illuminance exposed on the drawing table surface according to standards. Artificial lighting is explored the types and locations of the lighting points and the height of the light points against the work table.

Simulations on Dialux evo 9.0 are generally carried out through six stages. The preparation stage is to export the Revit 3D file to the IFC file format so that it can be simulated in Dialux evo 9.0 (figure 5).

Figure 5. 3D Revit modelling is exported to IFC format

The first step is to import the IFC object file that you want to simulate in Dialux evo 9.0 (figure 6).

Figure 6. Import IFC File in Dialux evo 9.0

The second stage is to set the location of the model object (Figure 7a) and the model object material (Figure 7b).
The artificial lighting simulation started by changing the view mode into plan view. Then choose the light menu to choose the type of lamp that will be used (figure 8).

The lamp used in this simulation is the Philips Maxos Fusion LL512X 1 xLED31S / 940 DA25W. This type of lamp has a luminate luminous flux close to the type of lamp used in the three existing studios.

The fourth stage is to place the light points according to exploration by selecting the Draw rectangular arrangement menu, then drawing the lamp placement above the drawing table area (Figure 10.a).
The placement of light points in accordance with the amount explored can be arranged based on the x and y axes. Then enter the target data of 600 lux capacity as the minimum standard for the drawing space. The calculation is automatically performed and generates a provisional calculation (Figure 10.b).

The distance of the lamp from the floor and the number of lamps can be adjusted so that the target lux capacity in the room is fulfilled. Other types of lamps can be added in a way described earlier at this stage (Figure 11.a). Press Start Calculation (Figure 11.b) so that the software can calculate the amount of lux capacity of each room accurately. As well as displaying the results of artificial lighting illuminance in the room. To get a more precise amount of lux on the drawing table surface per object, select the "calculation object" menu and then select the "Result on Surface" menu (figure 12.a). Finally, click on the object surface to simulate (Figure 12.b).

The results and discussion

4. Results and Discussion
Before describing the simulation, results using Dialux evo 9.0, table shown below are the results of measurements of artificial lighting illuminance in the three studios using a lux meter at the points described (Figure 3).

| Table 1. Illuminance Measurement at Studio A |
|---------------------------------------------|
| Point | Illuminance (lux) |
|-------|-----------------|
| A1    | 380             |
| A2    | 600             |
| A3    | 240             |
| A4    | 370             |
| A5    | 600             |
| A6    | 300             |

Table 2. Illuminance Measurement at Studio C

| Point | Illuminance (lux) |
|-------|-----------------|
| C1    | 360             |
| C2    | 520             |
| C3    | 500             |
| C4    | 400             |
| C5    | 510             |
| C6    | 490             |
| C7    | 400             |
| C8    | 490             |
| C9    | 500             |

Table 3. Illuminance Measurement at Studio D

| Point | Illuminance (lux) |
|-------|-----------------|
| D1    | 400             |
| D2    | 460             |
| D3    | 280             |
| D4    | 380             |
| D5    | 500             |
| D6    | 280             |
| D7    | 420             |
| D8    | 500             |
| D9    | 280             |

The results of existing illuminance measurements at these studios show that not all drawing table surfaces are illuminated according to the standard. This happened because the location of the lighting position does not directly locate above the drawing table. Natural lighting does not provide significant illuminance to the drawing table which can be seen at points adjacent to the opening.

After the calculation in the Dialux evo 9.0 simulation completed, lux capacity will appear in each simulated space, namely Studio A, Studio C, and Studio D. The simulation is done repeatedly in order to obtain the desired result capacity on the work plane (600 - 750 lux) parallel to the drawing table in
the existing space height of 3.6 m. The following are the measurement results for the three design studios.

Based on the simulation results, the average artificial lighting illuminance at Studio A is 703 lux using 24 units of Philips Maxos Fusion LL512X 1 xLED31S / 940 DA25W lamps. The light points are placed at the center point of each cluster group. Therefore, without changing the ceiling height and low, studio A reduced 29 units of light points.

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**Figure 13.** (a) Illuminance simulation result at studio A, (b) Illuminance on drawing table surface

**Figure 14.** (a) lighting plan at studio A (b) exploration of lighting at studio A

Based on the simulation results, the average illuminance of artificial lighting in Studio C is 754 lux using 42 unit of the Philips Maxos Fusion LL512X 1 xLED31S / 940 DA25W lamps. Therefore, without changing the ceiling height and low, studio C reduced 57 units of light points.

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**Figure 15.** (a) Illuminance simulation result at studio C, (b) Illuminance on drawing table surface
Finally, the average artificial lighting illuminance at Studio D is 667 lux using 24 units of Philips Maxos Fusion LL512X 1 xLED31S / 940 DA25W lamps. Therefore, without changing the ceiling height and low, studio D should be added 6 units of light points.

5. Conclusion
The illuminance results obtained of existing artificial lighting in the three studios on the drawing table surface were minimum 280 lux and maximum of 600 lux. Based on data, simulation was running on the exploration of artificial lighting so each drawing table surface obtained an illuminance value close to an average of 600 - 750 lux. Therefore, through 3D modelling simulated by Dialux evo 9.0, it could be concluded that to get the desired illuminance according to the standard without changing space height, the type of lamp used was the Philips Maxos Fusion LL512X 1 xLED31S / 940 DA25W. Lighting was
placed in the middle of the cluster consist of 4 drawing table so that it need 24 units in Studio A, 42 units in studio C, and 24 units in studio D.

This simulation was conducted to obtain 3D modelling of artificial lighting recommendations for effectiveness and efficiency at architectural design studio. Effectiveness and efficiency of the use of artificial lighting, not only having an impact on energy use, but also was able to improve student performance at architectural design studio. This research could be continued with the measurement of the energy use and the psychological effects on users in exploration artificial lighting.

Acknowledgments
This article was supported by the Ministry of Research and Technology/National Research and Innovation Agency of Republic Indonesia. Grant numbers 458/UN40.D/PT/2020 under LPPM Universitas Pendidikan Indonesia.

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