Re-designing vocational school technical drawing studio with 2 lightning system

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Abstract. The more detail drawing product in the shop drawing, the more drawing concentration is needed. One of supporting drawing concentration factors is lighting quality, because of that human pupil very responsive to emitting light. This research is intended to Re-Design technical drawing studio 2 SMK N 2 Tasikmalaya lightning system to be suitable from lightning standard. The result from lightning analysis in technical drawing studio 2 was showing poor lightning quality because lack of lighting intensity, differences lightning distribution, and high glare potential. The condition of drawing concentration class X DPIB 2 SMKN 2 Tasikmalaya was different each work table. The work table which has high glare potential and inconsistency lighting involve poor concentration. The result from Re-Design lightning system both natural and artificial in technical drawing studio 2 SMK N 2 Tasikmalaya was made by adding opening in the southside, installing a double-skin façade, changing wall interior color, and changing luminaire type will increase technical drawing studio 2 lightning quality from lightning standard so does drawing concentration. The result simulation of Re-Design was showing better lightning quality such as the increase of lightning intensity from 269 lux to 937 lux and minimize glare potential in 11 work tables.

1. Introduction
Lightning becomes one of the environmental factors that need to be considered in the learning process. Jago in Samani [1] has argued that It has a strong relationship with the student learning performance because everyone needs light to see, read, and other activities. One of the learning performance that need in “Desain Pemodelan dan Informasi Bangunan (DPIB)” is drafting manual competency. Technical drawing which is a special room for drawing practice often ignores the lightning factor, as happened in the vocational school SMKN 2 Tasikmalaya. DPIB SMKN 2 Tasikmalaya has 2 technical drawing studio known as “Bengkel Bangunan 2” (BB2/Technical drawing studio 1) and “Bengkel Bangunan 5” (BB5/Technical drawing studio 2). The BB5 room lightning quality looks bad because the opening for natural light just relies on one side on the north. Furthermore, the artificial light only uses 8 Tube Luminance Lamp with 18 watt which only produce 54.7 lux. The result from combine natural and artificial lightning intensity are less from the lightning standard of 750 lux.

Slameto has reveal that concentration was centralization of mind on a matter by putting aside all other unrelated things [2]. Drawing concentration means how student focused on drawing for quite a long time to produce a good quality drawing as required. Hakim mentions lightning was included in external factor that affect concentration [3]. Based on SNI 03- 03-6575-2001 [4], the light intensity
standard for technical drawing studio is 750 lux with group rendering color 1 which has a color appearance index value > 80. The standard said that the total 750 lux cannot rely just only on natural light, but it must use artificial lightning that produces quite high intensity. This research intended to give a solution design lightning system for technical drawing studio especially in BB 5 room based on the standard for technical drawing studio.

2. Research method

The sample used in this research was purposive sampling, from 30 students in class DPIB 2, 20 students were selected and divided into 2 group which made up by 10 students. The selected students are students who get used to drawing in one table. The first group is on the zone A which is closed to natural light source in north side, and the second group is on the zone B.

The research procedures undertaken to obtain and analyses both lightning quality or drawing concentration consist of following stages:

- Data accumulation which is consist of; measurement; 3D simulation of existing lightning verification and validation of lightning quality in BB 5 using Dialux Evo
- Analysis of data lightning system in BB 5 and division of two groups of zones to compare the condition of drawing concentration with different lightning quality in BB 5
- Distribution of drawing concentration questionnaires in BB 5 with existing lightning quality and analysis the impact of lightning quality on drawing concentration on the two group in BB 5
- Optimizing BB 5 lightning system using Dialux Evo Software and applying 3D simulation to get several recommendations

3. Result

3.1. Technical drawing of BB 5 lightning quality

The lightning system for technical drawing in BB5 is used a combination of natural and artificial lightning. The artificial lightning in BB 5 room use a direct sunlight with awning system from the north and the indirect sunlight which is utilizing the reflected light from building and vegetation around BB 5 room. The natural lightning in BB 5 room is only supported by two types of windows which have different size; 1.5 m x 0.65 m and; 1.5 m x 1.2 m on one side of the north. The artificial light or luminaries system which is used in the BB5 room are 8 Tube Luminance (TL) lamps.

According to Strasse [5] the quality of lightning in a space can be influenced by various factors, such as; glare, maintenance, wall and ceiling, material reflection, light color, light intensity, light distribution, and energy efficiency [6]. The factors of lightning quality can be measured using a lux meter and analysis using Dialux Evo. As the result of the measurement of intensity using a lux meter and analysis of the lightning quality factor using Dialux Evo in BB 5 room DPIB SMKN 2 Tasikmalaya which has room spacious 10.45 x 11.70 = 122.26 m2 are:

| Room Element       | Material                | Reflection Factor |
|--------------------|-------------------------|-------------------|
| Wall               | Dark yellow paint       | 52%               |
| Floor              | White ceramic 30 x 30 cm| 76%               |
| Drawing Table      | White melamine          | 77%               |
| Ceiling            | White gypsum            | 70%               |
| Intensity of the natural light |                | 164 lux          |

Table 1. List material BB 5 in use.
Table 2. Result from measurement of light intensity and unified glare rating in BB 5.

| No | Zone List | Light Intensity Measurement Result (Lux) | SNI 750 LUX | UGR Calculation Result |
|----|-----------|------------------------------------------|-------------|------------------------|
|    | Zone      | Average                                   | Suitable O | Not Suitable O         | UGR         | Suitable <16 O | Not >16 O |
| 1  | A1        | 412                                      | O           | 18                     | O           |
| 2  | A2        | 510                                      | O           | 18                     | O           |
| 3  | A3        | 656                                      | O           | 19                     | O           |
| 4  | A4        | 814                                      | O           | 19                     | O           |
| 5  | A5        | 834                                      | O           | 19                     | O           |
| 6  | A6        | 686                                      | O           | 20                     | O           |
| 7  | A7        | 341                                      | O           | 16                     | O           |
| 8  | A8        | 400                                      | O           | 16                     | O           |
| 9  | A9        | 464                                      | O           | 17                     | O           |
| 10 | A10       | 502                                      | O           | 17                     | O           |
| 11 | A11       | 440                                      | O           | 17                     | O           |
| 12 | A12       | 348                                      | O           | 18                     | O           |
| 13 | A13       | 230                                      | O           | 14                     | O           |
| 14 | A14       | 253                                      | O           | 14                     | O           |
| 15 | A15       | 240                                      | O           | 15                     | O           |
| 16 | A16       | 247                                      | O           | 15                     | O           |
| 17 | A17       | 191                                      | O           | 15                     | O           |
| 18 | A18       | 148                                      | O           | 16                     | O           |
| 19 | B1        | 180                                      | O           | 11                     | O           |
| 20 | B2        | 191                                      | O           | 11                     | O           |
| 21 | B3        | 181                                      | O           | 12                     | O           |
| 22 | B4        | 193                                      | O           | 12                     | O           |
| 23 | B5        | 151                                      | O           | 13                     | O           |
| 24 | B6        | 94                                       | O           | 14                     | O           |
| 25 | B7        | 155                                      | O           | 12                     | O           |
| 26 | B8        | 164                                      | O           | 12                     | O           |
| 27 | B9        | 149                                      | O           | 13                     | O           |
| 28 | B10       | 158                                      | O           | 13                     | O           |
| 29 | B11       | 120                                      | O           | 13                     | O           |
| 30 | B12       | 81                                       | O           | 14                     | O           |
| 31 | B13       | 118                                      | O           | 14                     | O           |
| 32 | B14       | 120                                      | O           | 14                     | O           |
| 33 | B15       | 109                                      | O           | 14                     | O           |
| 34 | B16       | 120                                      | O           | 14                     | O           |
| 35 | B17       | 91                                       | O           | 14                     | O           |
| 36 | B18       | 52                                       | O           | 15                     | O           |
Figure 1. Result of light distribution in the morning, noon, and afternoon. The colour bar level shows that the higher colour level the greater light intensity in the studio. The light intensity on the zone A has better than zone B but the light distribution in the zone A not constant [6].

To simplify the lightning analysis process, the BB 5 room is divided into 2 lightning zones based on lightning distribution, luminaire placement, and daily student workplace. Zone A is closer to the natural light source on the north side while zone B is on the south side. From the result of measurements and analysis using Lux meter and Dialux Evo, it can be concluded that comparison lightning quality factors between zone A and B in BB 5 room is as follows:

| No | Lightning Factor | Quality Explanation | A Zone | B Zone |
|----|------------------|---------------------|--------|--------|
| 1  | Glare            | High potential for disability glare and discomfort glare | Low potential for disability glare and discomfort |
| 2  | Light Intensity  | The combined light from natural and artificial produces is 383 less than the standard 750 lux | The combined light from natural and artificial produces is 128 less than the standard 750 lux |
| 3  | Light color      | The color is accordance with color rendering group 1 which has the color of white light with a color index more than 80 | |
| 4  | Wall and ceiling surface | The average light reflected by the surface of the walls and ceiling is less than standard 165 lux which is just 132 lux in existing. | |
| 5  | Material reflection | The average reflection of material result is accordance with the standard of 70% | |
| 6  | Lightning distribution | The lightning distribution is not harmony | The lightning distribution is harmony |

From the result of the lightning quality data in BB 5 room (Technical Drawing Studio 2), it can be concluded that the lightning quality in BB 5 room both zone A or B is not good because some factors are not supporting to give good lightning quality as the standard for technical drawing studio and the best workplace which has lightning quality in BB 5 room are in zone B.

3.2. Class X DPiB 2 drawing concentration

Drawing activity is requiring high concentration in quite a long time more than learning in a normal way needs. Previous studies prove that through quasi-experiments the lightning quality affect student’s concentration positively [7]. So, in this studies the concentration data will be taken from the questionnaire to find out the state of concentration in two different zones. 2 students in the zone A which is take a seat in A4 and A5 workplace did not have good concentration. Furthermore, if the zone A and B are compared, it has a different condition of drawing concentration. The A zone has lower drawing
concentration than B zone. The lightning system in a workplace zone A and B are different which zone B is better than zone A. This condition proves that zona A student have lower drawing concentration than zone B because the lightning quality factor in zone A is lower than in zone B. the lightning system in zone A is more distract drawing concentration student than in zone B.

3.3. Re-design lightning system in BB 5 room
Improvement of lightning quality in BB 5 room is prioritized on factors that are less supportive from analysis before, there are; intensity, glare, and light distribution. Re-design of BB 5 lightning system was made by 3D simulation Dialux Evo lightning design program. The parameter input for lightning system using observational data that had been previously measured. Based on the data from observation and analyses that had been done, there are several possibilities for optimizing natural and artificial light in BB 5 room. The natural light system in BB 5 can be done by following methods: (a). Double Skin Façade Application, (b). Material color modification, (c). Luminaire modification (d). Add and modification an opening in the north side.

Figure 2. Double skin façade place installation. It placed in the highest disability glare potential resource close to A4-A6 worktable.

Figure 3. Double skin façade module illustration. This module is made with aluminium sliding system which is tied to the aluminium main frame, so the module can be moved between the main frame adjust to sun position.
Figure 4. Adding and modifications an opening in the north side. The opening will be utilizing the indirect light resource from the south side. So the sun light will enter the room without disability glare.

(source: personal data)

3.4. Comparison lightning quality before and after re-design

Re-design lightning system with some optional in both natural and artificial light will make lightning quality in BB 5 better as the standard for technical drawing studio. Comparison lightning quality between before and after re-design can be seen in the following table:

Table 4. Comparison lightning quality before and after re-design lightning system.

| No | Zone | Table | Mean of Lighting Morning - Evening (Lux) | Unified Glare Rating (UGR) |
|----|------|-------|-----------------------------------------|---------------------------|
|    |      |       | Eks                  | Optimal | Eks | Optimal |
| 1  |      | A1    | 412                   | 866     | 18  | <10     |
| 2  |      | A2    | 510                   | 849     | 18  | <10     |
| 3  |      | A3    | 656                   | 857     | 19  | <10     |
| 4  |      | A4    | 814                   | 898     | 19  | <10     |
| 5  |      | A5    | 834                   | 937     | 19  | <10     |
| 6  |      | A6    | 686                   | 905     | 20  | <10     |
| 7  |      | A7    | 341                   | 882     | 16  | <10     |
| 8  |      | A8    | 400                   | 960     | 16  | <10     |
| 9  |      | A9    | 464                   | 832     | 17  | <10     |
| 10 |      | A10   | 502                   | 976     | 17  | <10     |
| 11 |      | A11   | 440                   | 1035    | 17  | <10     |
| 12 |      | A12   | 348                   | 1005    | 18  | <10     |
| 13 |      | A13   | 230                   | 945     | 14  | <10     |
| 14 |      | A14   | 253                   | 1006    | 14  | <10     |
| 15 |      | A15   | 240                   | 976     | 15  | <10     |
| 16 |      | A16   | 247                   | 1017    | 15  | <10     |
| 17 |      | A17   | 191                   | 1074    | 15  | <10     |
| 18 |      | A18   | 148                   | 1040    | 16  | <10     |
| 19 |      | B1    | 180                   | 914     | 11  | <10     |
| 20 |      | B2    | 191                   | 946     | 11  | <10     |
| 21 |      | B3    | 181                   | 970     | 12  | <10     |
| 22 |      | B4    | 193                   | 971     | 12  | <10     |
| 23 |      | B5    | 151                   | 982     | 13  | <10     |
| 24 |      | B6    | 94                    | 1021    | 14  | <10     |
| 25 |      | B7    | 155                   | 908     | 12  | <10     |
| 26 |      | B8    | 164                   | 926     | 12  | <10     |
| 27 |      | B9    | 149                   | 948     | 13  | <10     |
| 28 |      | B10   | 158                   | 969     | 13  | <10     |
| 29 |      | B11   | 120                   | 1020    | 13  | <10     |
| 30 |      | B12   | 81                    | 927     | 14  | <10     |
| 31 |      | B13   | 118                   | 798     | 14  | <10     |
| 32 |      | B14   | 120                   | 837     | 14  | <10     |
| 33 |      | B15   | 109                   | 844     | 14  | <10     |
| 34 |      | B16   | 120                   | 874     | 14  | <10     |
| 35 |      | B17   | 91                    | 896     | 14  | <10     |
| 36 |      | B18   | 52                    | 923     | 15  | <10     |

(source: personal data)
Based on all result from re-design of natural and artificial lightning in BB 5 room, shows an enhancement in lightning quality factors such as; light intensity, light distribution, and potential of glare. The effect of improving the lightning quality in BB 5 is highly dependent on natural and artificial light. To produce an intensity of 750 lux on each work table, it cannot rely on natural light, because if natural light too large it will increase the potential of disability glare. So, it need a double skin facade for dispel the direct sunlight. Meanwhile, the reduction of natural light source in BB 5 after apply double skin façade can be overcome with adding an opening in south side and changing material colour with 70% factor reflection. The luminaire modification with indirect light distribution and 5200 lumen for each lamp will make the intensity in the room reach 750 lux without raise the disability glare.

4. Conclusion
The result of lightning quality in zone A and B shows that differences in several lightning factors quality especially light intensity, glare potential, and light distribution. The best light quality in BB 5 are on the zone B which has lower intensity (0 of 18 worktable has 750 lux) than in zone A (2 of 18 worktable has 750 lux) but the light distribution more harmony and there is no glare potential in zone B. But, from the factor lightning quality in zone A and B produce poor light quality for technical drawing.

The condition of drawing concentration in class X DPJB 2 SMKN 2 Tasikmalaya has good score from the results of questionnaire calculation. However, the condition of drawing concentration between zone A and B has a significant difference. Students who are sit in the zone B has better score (3.4 with very good concentration) than students in zone A (3.0 with good concentration). This result was verifying that high light intensity in zone A not too take effect in drawing concentration, but the glare potential especially disability glare from direct sunlight are more react to drawing concentration. Re-design of lightning system in BB 5 to reach lightning standard quality in technical drawing can be done by several methods for natural and artificial lightning. Optimizing natural light will be applying by; installation of double skin façade on the north side, adding natural light openings for indirectly sunlight from the south side by changing the function of plumbing storage with a drawing storage, and replacing the colour of the interior walls with white colour which has 70% light reflection factor. While, optimizing artificial lightning will be applying by changing the type of luminaire into luminaires that produce indirect light distribution, replacing and adding the number of lamps with 5200 lumen or 52 Watt as many as 36 lamps.

References
[1] Samani S A 2012 The Impact of Indoor Lighting on Students’ Learning Performance in Learning International Journal of Business and Social Science 3(24) 127-136
[2] Slameto 2015 Belajar Dan Faktor-Faktor Yang Mempengaruhinya Jakarta: PT RINEKA CIPTA
[3] Hakim T 2012 Mengatasi Gangguan Konsentrasi Jakarta: Puspa Swara
[4] Standar Nasional Indonesia 03-6575-2001 2001 Tata cara perancangan sistem pencahayaan buatan pada bangunan gedung [Online] retrieved from http://sni.litbang.pu.go.id/index.php?r=/sni/new/sni/detail/id/688
[5] Strasse S 2018 The Lightning Handbook Dornbin: Zumtobel pp 13
[6] DiaLux Evo www.dial.de
[7] Sleegers P J C, Moolenaar N, Galetzka M, Pruyn A T H, Sarroukh B E and van der Zande B 2013 Lighting affects students’ concentration positively: findings from three Dutch studies Lighting research & technology 45(2) 159-175