Improve the Luminous Environment in a Classroom

Guodan Liu, Hanlin Li and Yunxing Kang
Environmental and Municipal Engineering, Qingdao Technological University, 16 Fushun road, Shibei District, Qingdao City, Shandong Province, China
Email: 739187214@qq.com

Abstract. This paper suggests a lighting design method by advanced software to design for optimizing the luminous environment in a classroom. The luminous environment affects the eyesight health and learning efficiency of students, while uncomfortable glare is an important indicator that affects the quality of classroom light environment. This paper describes the evaluation method of uncomfortable glare, and select a typical classroom light environment field survey and subjective questionnaire survey, which puts forward the optimization and improvement of the lighting layout scheme, and uses DIALux simulation analysis to simulate the illuminance and glare values of different schemes. The findings support the classroom installation of grille lampshades and LED lamps not only meet lighting requirements, can effectively reduce the impact of glare and benefit designers in the strategic design process with further potential for design options and lighting electricity reduction.

1. Introduction
There is evidence that classroom lighting may be important for students’ learning. A good light environment can improve learning efficiency and reduce visual fatigue, and protect students’ eyesight [1]. Glare is an important factor affecting the quality of classroom light environment [2]. The glare effect causes fatigue to the human eye and loss of concentration. Since 1925, many researchers have attempted to quantify discomfort glare [3-5]. Serious problems may occur however, when students study in the classroom, uncomfortable and glaring situations arise. If the problem of discomfort glare can be maximally reduced, not only will the lighting quality of the space be improved and physiological need might be satisfied, but also the savings in electric energy for artificial lighting can be increased due to the improved efficiency of daylight for the indoor illuminance.

Establishing causative links between aspects of classroom environment and the factors mentioned above is difficult, in part because of the practical and ethical difficulties in conducting controlled trials in the classrooms. Hence, this study takes a different approach, that is, to assess the extent to some of the aspects of in CN classrooms lighting, which to cause discomfort and impair task performance. This paper measured the illumination level and unified glare rating of the classroom, and propose three anti-glare luminaire designs. The current indoor lighting designs enhance lighting performance greatly compared to previous lighting designs.

2. The Design Theory Classroom Lighting Environment
Discomfort glare, as mentioned, is a sensation of distraction, annoyance and even pain from bright light. The cause of the sensation of discomfort glare seems to be composed of two effects a contrast effect and a saturation effect. A light source is used in an environment of much lower brightness, which the contrast effect results [6]. As reasons noted above, this Section begins with the brief
discussion of the requirements of classroom lighting environment, followed by the evaluation systems of discomfort glare from classroom.

2.1. The Requirements of Classroom Lighting Environment

The quality of lighting environment is good, which needs the appropriate level of illumination, modest brightness ratio, and avoid glare interference. For instance, CIE S008 provide recommended design illuminances for different types of classroom, which the value is 300 lx (Tab 1), adoption of such values helps to restrict glare to reasonable levels. It is worth noting that a new installation with new lamps and clean surfaces may give an illuminance 25% greater than the design illuminance, but only half this initial value when lamps are old and dirt has accumulated. The data reported these values in this paper, but do not take into account uniformity ratios across task area and classroom. However, rooms are not uniformly, with the immediate task area much brighter than the surrounding area, discomfort effects may be exaggerated.

| Place       | GB50034 — 2013 /lux | CIE S008 / E — 2004 /lux | IESNA — 2000 /lux | DIN 5035 — 1990 /lux |
|-------------|----------------------|--------------------------|-------------------|----------------------|
| classroom   | 300                  | 300                      | 500               | 300                  |

2.2. The CIE UGR Glare Rating System

Until now, CN classrooms have been installed fluorescent lamps. In this paper, we investigate the light conditions and glare in the classroom. The glare of the classroom mainly includes the following aspects: (1) classroom lighting is mostly fluorescent lamps, which can meet some basic classroom lighting. However, because of the naked lamp of the fluorescent lamp, there is a strong problem of "glare", which has a bad influence on the light environment of the classroom. (2) Different locations of the light source would produce different degrees of glare effect. When a light source has an incident angle at the top of the blackboard equal to a student's elevation at the top of the blackboard, it can cause glare to the student. (3) Due to the direct sunlight, the light in some areas of the blackboard or students' desk desktop close to the window is too strong to be seen clearly, which can affect students' learning and even affect their eyesight [7].

Although at that time, the CIE formula was a significant milestone, had many difficulties in setting up a glare index method from this formula. Accordingly, in 1987, the CIE formed Committees TC-25 "Fundamentals of Discomfort Glare" and TC 3-13 "CIE Discomfort Glare Evaluation system" and adopted a new evaluation formula proposed by Sorensen (1987). This new CIE formula, a Unified Glare Rating (UGR) is as follows:

$$\phi_\alpha(F) = (2\pi)^{2/3} \exp\left\{ik \cdot \frac{1}{\omega} \right\}$$

Where:

- UGR = CIE UGR Glare Index
- $L_s$ = Luminance of the glare source (cdm$^2$)
- $L_b$ = Luminance of the background (cdm$^2$)
- $\omega$ = Solid angle of the source (sr)
- $P$ = Position index of the source

3. Method

To establish the extent to which students study in the inappropriate sources of glare, randomly selected from the schools, Qingdao Technological University. Within each school, sampling of classrooms was random. This approach ensure that the sample was representative of pupils’ experience throughout the school.
3.1. Illuminance at Desks

Illuminance was assessed using a lux meter positioned horizontally on the surface of students’ desks (as appropriate to the arrangement of students’ desks in the classroom), chosen to enable representative sampling across the classroom. At each point, illuminance levels were assessed under two lighting conditions: (a) lights off, curtains open, (b) lights on, curtains closed, the measured height is 0.75m. Prior to such measurements, a record of percentage cloud, and whether the sun was visible. According to the grid method, the number of measuring points were determined considering the room index. The room index is another character determines the choice of luminaries. If the lighting area length is L, the width is W and the height is h, the designer will calculate the room index through equation (2). According to the RI value, the designer should select a different light distribution curve of luminaries. It is very important to the green lighting design [8].

\[
RI = \frac{L \cdot W}{h(L + W)}
\]  

This paper selected seven classrooms to measure illuminance with illuminometer, and the measurement height is 0.75m.

3.2. Luminance and Glare from Lamps

The levels of luminance and glare from lamps using a luminance meter under conditions: lights off, curtains closed. At each point (Fig 1), the measurement of lamp brightness XYL-V by luminance meter, and use equation (2) to calculate UGR values, which the measured height is 1.2m (Fig 2). There were two pieces of equipment used for the photometric measurement. The first was a XYL-V luminance meter, mounted on a tripod. Measuring range for this device was from 1-500,000 cdm-2 and its measurement angle is 1°. The error is +2% or +1 digit of value display. The second was a CL-200 illuminance meter. Measuring range was 0.1-99,990 lux and the error is +2% or +1 digit of value display.

![Figure 1](image1.png)  
Figure 1. The measurement points in the classroom.

![Figure 2](image2.png)  
Figure 2. The measurement points in the classroom.

3.3. Luminance and Glare from Lamps

The questionnaire comprised two blocks. The first block gathered objective information on the individual: age, sex, education. The second block contained subjective information about subjective satisfaction and glare feelings of classroom light environment.
4. Results

4.1. Illuminance at Students’ Desks
Mean illuminance (Tab 2) ranged from inadequate (126.34 lux) to excessive (in excess of 733.51 lux). Mean illuminance was lower with curtains open and lights off (332.51-263.52 lux) and with curtains closed and lights on (733.51-126.34 lux), but still in excess of recommended design illuminances for school classrooms (which range from 300–500 lux depending on the type of classroom) (CIBSE, 2004). In the first condition (a), the classroom mean illumination did not meet the standard value (300 lux) requirements. There are only two classrooms meet the lighting standard, accounting for only 28% of the total. In another condition (b), the average level of illumination to achieve the standard only two classrooms.

Table 2. Mean, highest (max) and lowest (min) classroom illuminance (lux) measured under different lighting conditions. Each row represents one classroom.

| Classroom | Cloud cover (%) | Illuminance with lights off–curtains open (lux) | Illuminance with lights on–curtains closed (lux) |
|-----------|-----------------|--------------------------------------------------|--------------------------------------------------|
|           | Mean, Max, Min  | Mean, Max, Min                                  | Mean, Max, Min                                  |
| 1         | 40              | 221.69, 653.21, 153.24                          | 305.23, 332.51, 283.21                          |
| 2         | 30              | 234.56, 536.56, 126.34                           | 287.31, 312.56, 263.52                          |
| 3         | 40              | 253.63, 671.32, 156.37                           | 283.57, 321.41, 273.51                          |
| 4         | 30              | 262.11, 555.31, 138.21                           | 287.61, 310.25, 271.53                          |
| 5         | 40              | 302.14, 673.21, 149.23                           | 296.51, 311.35, 284.31                          |
| 6         | 40              | 274.77, 583.16, 156.30                           | 288.32, 309.54, 271.23                          |
| 7         | 30              | 341.49, 733.51, 173.47                           | 301.53, 323.56, 285.35                          |

4.2. Luminance and Glare from Lamps
As can be seen from the results, we can be seen from the results, the UGR value of 5 classrooms exceeded the standard value, accounting for 71%. As research results show, the classroom glare is more serious. The UGR of classrooms ranges from 18 to 23 (Fig 3).

Figure 3. The UGR of the classroom.

4.3. Questionnaire
Surveyed classrooms were also distributed questionnaires, 200 questionnaires were distributed, the effective number of 198 copies. There are 123 boys and 75 girls. We know from the survey results that 41% of students in the classroom light environment is unsatisfied (Fig 4). At the same time, we investigated the students’ feeling of glare in the classroom. According to the survey results, 35% of students think the classroom glare is more obvious, other students think the classroom glare problem is acceptable (Fig 5). Therefore, the light quality of the classroom needs to be improved.
4.4. Simulation and Optimization

Today the current lighting software evaluate the efficient lighting scheme for the school with different types of lamps. DIALux is more convenient and swifter in computing in scenes than other lighting software and has its advantages with other lighting software in computing precision and speed [9]. The use of DIALux software can not only calculate the illumination, the designer of the layout of the effect of lighting programs have a clear and intuitive understanding, but also can help designers to optimize the lighting layout, a reasonable choice of the number of lamps. The DIALux software establish the three-dimensional simulation model (Fig 6), optimize the lighting arrangement based on the illumination calculation of DIALux software.

![Figure 4](image1.png)  ![Figure 5](image2.png)

**Figure 4.** The subjective feelings of classroom lighting environment.  
**Figure 5.** The subjective feelings of classroom glare.

Found by a field survey, the type of lamps is T8 straight tube in the classroom, which is fitted with a simple lampshade. T5 straight tube fluorescent lamp life expectancy is more than 30000 hours. LED lamp is very hot in the lighting field because of its potentially high efficacy, long life, pure color, solid state, and eco-friendly. Compared with other light sources, it has the advantages of simple structure, compact structure, due to the use of low-voltage driving chip power supply, making it easy to implement complex dimming control [10]. Aiming at the problem of glare, this paper simulate and optimize lighting about the type and layout of lamps. Option A is the original layout of the classroom lighting, which use T8 straight tubes.; Option B use T8 straight tube with grille lamp shade; Option C use T5 straight tube with grille lamp shade; Option D use LED with grille lamp shade. Option B-D were proposed to improve the indoor lighting environment (Tab 3).

By using DIALux lighting software simulation, we found that the light environmental quality of the option B-D is obviously better than the original arrangement of the classroom (Option A). It mainly includes the following aspects: (1) the average classroom illumination reached the standard value requirements, which is more than 300lux ; (2) the illumination uniformity at the student's desktop becomes better; (3) the classroom glare has been improved, UGR value decreased (Tab 4). According
to optimize the effect is good or bad sort, option D is the best, followed by option C, and then is the option B, the last one is A (Tab 5).

Compared with Option A, the school using Option B can save at least $5.83 \times 10^4$ kWh per year, which is equivalent to saving $0.23$ t of standard coal (Tab 6). It reducing $0.58$ t of carbon dioxide emissions. And the school using Option B can save at least $2.86 \times 10^4$ kWh per year, which is equivalent to saving $0.11$ t of standard coal, reducing $0.27$ t of carbon dioxide emissions; the school using Option B can save at least $5.10 \times 10^4$ kWh per year, which is equivalent to saving $0.20$ t of standard coal, reducing $0.50$ t of carbon dioxide emissions. Among them, Option B is the best in energy efficiency, followed by Option D and finally Option C.

Table 3. The different layout of classroom lighting.

| Option | The type of lamp | Lighting layout |
|--------|------------------|-----------------|
| A      | T8 MZL11136T-WH  |                 |
| B      | T8 MDP24314I-Y-D |                 |
| C      | T5 PPAR-PROSP-AE |                 |
| D      | LED MDP017036/L  |                 |

Table 4. The UGR of classrooms simple table.

| Measuring point | Option A | Option B | Option C | Option D |
|-----------------|----------|----------|----------|----------|
| 1               | 21       | 18       | 15       | 11       |
| 2               | 23       | 19       | 16       | 12       |
| 3               | 21       | 18       | 15       | 11       |
| 4               | 23       | 18       | 16       | 9        |
| 5               | 24       | 19       | 17       | 10       |
| 6               | 23       | 18       | 17       | 9        |
### Table 5. The simulation results of different illumination schemes.

| Option | Illuminance curve | Grayscale curve | Numerical distribution curve |
|--------|-------------------|----------------|-----------------------------|
| A      | ![Image]          | ![Image]        | ![Image]                     |
| B      | ![Image]          | ![Image]        | ![Image]                     |
| C      | ![Image]          | ![Image]        | ![Image]                     |
| D      | ![Image]          | ![Image]        | ![Image]                     |

### Table 6. The simulation results of different illumination schemes.

| Option | Total power (W) | Power density (W\cdot m^{-2}) | Illuminance with lights on /lux |
|--------|-----------------|-------------------------------|--------------------------------|
|        | Mean            | Max                           | Min                             |
| A      | 612             | 5.33                          | 326                             | 449                             | 217                             |
| B      | 396             | 3.42                          | 409                             | 920                             | 291                             |
| C      | 506             | 4.41                          | 423                             | 808                             | 299                             |
| D      | 423             | 3.68                          | 377                             | 695                             | 272                             |

### 5. Conclusion

This study has identified a number of problematic aspects of classroom lighting. Most of these problems are unnecessary and appear due to poor policy decisions. In most cases, action to correct the problems would be simple, due to increased efficiency, reduction of wastage, and benefits in terms of health of students.

(1) This article presents some of the research findings on classroom light conditions and glare issues. Through the actual measurement and simulation calculation, we found that the glare problem in the classroom of the school is rather serious, and the degree of glare in different areas of the classroom is different. Students in the back row feel more serious than the front glare. Relative to the field measurement, the use of lighting design software such as DIALux to calculate the classroom uniform glare value, simple and fast.
(2) In response to the glare problem in the classroom, we should take reasonable measures to reduce glare. First of all, adjust the shade angle lighting can effectively reduce the glare. Secondly, grille lamp can be used in the installation of the lamp to avoid the glare caused by the exposure of the lamp. and then, install the outer shade on the window or install sunshade blinds, by changing the angle of incidence to effectively limit the window side glare. Finally, T8 fluorescent lamp can be replaced by T5 or LED, but also can effectively reduce glare.

(3) The quality of classroom light environment is closely related to the students' light comfort and learning efficiency. To create a good classroom light environment, not only need to limit the glare, but also need adequate illumination, the appropriate illumination uniformity, pleasant color temperature and the color rendering index. Therefore, we need to consider other light environmental factors to continuously improve the model. Energy efficient lighting simulation proves beneficial for given building. Using DIALux software tool removal of unwanted shadow and glare takes place. The direct effect of efficient lighting on reducing of total cost. This paper aim is to focus on lighting simulation tools for advanced efficient lighting methods. The daylighting will provide cost reduction if properly controlled.

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