Research on the Current Situation and Improvement Strategy of Light Environment in College Classroom

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Abstract. College classroom is an important place for teachers and student to teaching and learning. The quality of light environment directly affects the work and learning efficiency of teachers and students, as well as students’ physical and psychological health. This article mainly studies the light environment of college classrooms through in-depth investigations, analyzes whether the relevant parameters meet the norms and actual needs, discuss the main problems and influencing factors of the current classroom light environment, and proposes the optimization strategy of classroom light environment.

1. Introduction
College classroom is the main place for students to study, and its indoor light environment directly affects students' physical and mental health. Research shows that if the classroom light environment is bad or the uniformity of illuminance is not up to the requirements, it will make the students' visual organs have been regulating and their eye muscles overstrain, which is easy to cause visual fatigue. A good lighting environment can not only reduce students' visual fatigue, but also improve their learning efficiency.[1]

Ze Zhang, Li-Xin Wang and others conducted a survey on the illuminance of the light environment of college classrooms and compared it with relevant standards, but did not carry out a detailed analysis on the influencing factors.[2] Taking the classrooms of Zhejiang Sci-Tech college as research objects, Wan-Hong Mao and Xin-Yao Ma conducted visual experiments to investigate the light environment and visual satisfaction.[3] In addition, the research of Quan Chen and Chang-Geng Li mainly focused on the study of the classroom light environment under the condition of natural light and used the software to carry out the space simulation experiment.[4] Besides, Shuai Gao synthetically analyzed the relationship between students' preference for light environment and outdoor natural light source and other factors through experiments based on autonomous dimming.[5] Ying Zhang's master thesis studied the environmental behavior of architectural light environment.[6] Hai-Jing Huang and Gang Chen mainly studied the relationship between classroom illuminance and energy saving in the classroom light environment, and carried out experimental measurements on the changes of student's pupil with illuminance in the classroom artificial light environment.[7,8]

At present, there are few studies on the light environment in college classrooms and the research on the current situation of college building light shows that the average illuminance degree and uniformity of illuminance degree of most classrooms, library reading room and self-study room are far below the standard requirements. Therefore, it is necessary to carry out an extensive research on the
light environment of the classroom, and deeply discuss the main factors affecting the light environment, which can provide a basis for the college classroom light environment.

2. Basic requirements for classroom light environment

Whether from the aspect of reducing building energy consumption or considering students' mental health, the classroom light environment plays an important role in the environmental quality of college classroom. Due to the design defects and equipment deficiencies of the college classrooms, the light environment quality of the classrooms is poor, which is mainly manifested as poor indoor illuminance, low uniformity of illuminance and dazzling indoor light. Therefore, through the discovery and analysis of the main problems existing in the classroom light environment at the present stage, the design method of improving the quality of the classroom light environment can be discussed, which is of great significance to improve students' learning enthusiasm. [9]

The basic requirement of the classroom light environment is to provide sufficient lighting for teachers and students, meeting the visual comfort and avoiding the impact of dazzling light. In addition, it is necessary to ensure that students do not produce visual fatigue in the process of studying for a long time. Therefore, the classroom light environment should meet the requirements of:

(1) adequate illuminance and illuminance uniformity;
(2) avoid glare, including glare caused by direct sunlight and improper indoor lighting;
(3) ensure visual comfort and avoid visual fatigue. [10]

2.1. Standard index

Table 1. Main parameters of the classroom light environment

| General standard | Reference plane | Standard value of illuminance | Uniformity of illuminance |
|------------------|----------------|------------------------------|---------------------------|
| GB50034-2013     | The desk surface | 300lx                        | 0.6                       |
| GB50034-2013     | The board surface | 500lx                        | 0.7                       |

In the classroom light environment, this research focuses on the light environment conditions for students to read, which requires a certain level of illuminance on the desk surface to meet the requirements of reading and writing. According to the requirements of GB50034-2013 "Standard for lighting design of buildings", as shown in the table 1, the standard value of illuminance on the desk surface of the teaching building is specified as 300lx. [11] At the request of illuminance uniformity, in the old version 2004, public buildings around the surface of adjacent illuminance uniformity requirements is 0.5, while the new edition makes a more detailed division of the requirements for the uniformity of illuminance on different surfaces, among which the requirement for the uniformity of illuminance on the desk surface is 0.6, and the improvement of the standard also indirectly shows that, in the light of the classroom environment, intensity of illuminance uniformity is an important indicator should be focused on. [12]

2.2. Main parameter

Aiming at the lighting and illuminance design of teaching space, in order to create a good teaching environment, reduce visual fatigue and improve comfort, not only the quantity of light, but also the quality of light should be satisfied. There are many parameters related to lighting quality, such as illuminance, brightness, color temperature, color rendering index, etc. In this study, the two most important indexes were selected, namely the average illuminance and the uniformity of illuminance.

3. Research and analysis of the college classroom light environment

3.1. Methodology and instruments
The experimental equipment is cylindrical illuminometer with a measuring range of 1 lx-500 klx, which is composed of a luminosity head receiving light energy and a reading display. The luminosity head includes photovoltaic conversion device, active optical device and cofactor corrector.

According to the width and depth of the classroom, the measuring place will be divided into grids of the same size. Generally, 1m×1m is used to mark the measuring points, so as to determine the measuring plane and the height of the measuring points. The height measurement is selected on the desk surface, that is, at the horizontal plane of about 0.8m from the ground, and the illuminance of each grid center point is measured and recorded in the prepared table. Meanwhile, the illuminance value of each point in the measured range is collected to calculate the average illuminance value of all measurement range, that is, the average illuminance value is calculated according to the following formula: The average illuminance = \( \frac{\sum E_i}{MN} \), where \( E_i \) is the illuminance of each grid center point and MN is the number of grids in the longitudinal and lateral direction.

3.2. Study subjects

This research selected the teaching building of Chongqing Jiaotong University as the research object, and before the actual measurement, the innovation industrial park, the second teaching building and the third teaching building of Chongqing Jiaotong University were investigated. According to the statistics, the classrooms in use can be divided into the following three modes according to their sizes: small classrooms with less than 100 seats, medium classrooms with 100~250 seats and large classrooms with more than 250 seats. In summary, twenty medium-sized classrooms in the second teaching building were selected as the main test objects in this experiment to represent the general situation of the classroom light environment. Meanwhile, considering the comprehensiveness and typicality of the samples, twenty classrooms were selected according to the different floors, orientations and plane positions of the second teaching building, as shown in Table 2.

| Floor         | Location         |
|---------------|------------------|
| First floor   | 101, 102, 103, 104 |
| Second floor  | 202, 203, 204, 205, 206, 210 |
| Third floor   | 301, 302, 304, 305, 306, 310 |
| Fourth floor  | 401, 402         |
| Fifth floor   | 501, 504, 505, 510, 506, 512, 515 |

According to the normal use state of the classroom, the measuring period can be divided into the day and night, in addition, when used during the daytime, because there are more rainy day in Chongqing and school teachers and students with visual perception of the natural day-lighting being insufficient, the lights are often on in the classroom during the day, so the measurement conditions of the daytime besides measuring natural lighting, also increased the coexistence of natural lighting and artificial lighting conditions, as shown in Table 3.

| Measurement conditions | Condition 1 | Condition 2 | Condition 3 |
|------------------------|-------------|-------------|-------------|
| Measurement time       | Daytime, light off, open the curtains | Daytime, light on, open the curtains | At night, light on |
| Corresponding state    | Natural lighting | Natural lighting and artificial lighting | Artificial lighting |

Table 2. The distribution of the studied classrooms

Table 3. Three different states of classroom light environment research
3.3. Results and discussion

![Statistical graph of illuminance uniformity of classroom in the second teaching building](image1)

Figure 1. Statistical graph of illuminance uniformity of classroom in the second teaching building

![Statistical chart of the average illuminance of classrooms in the second teaching building](image2)

Figure 2. Statistical chart of the average illuminance of classrooms in the second teaching building

The relevant measurement results of the classroom light environment are shown in FIG. 1 and FIG. 2. According to the data analysis, the uniformity of illuminance in the three states is mostly lower than the 300 lx required by the specification, and only the data 32%, 84% and 8% meet the requirements respectively, while the average illuminance is only 8%, 13% and 33% meet the requirements respectively compared with the specification. The results show that the classroom light environment cannot meet the basic requirements of reading and writing.

For the same classroom, the comparative analysis of the three lighting conditions is as follows:

1. According to the circumstance of whether to turn on the light during the day, it can be concluded that under the condition of the natural light during the day, illuminance and uniformity of the classroom are below the specification requirements, so the teachers and students turn on the lights when using the classroom, which make artificial light supplement can effectively improve the average illuminance and uniformity of the classroom, but in this case there are still 87% of the average illuminance is lower than the standard value, 16% of the uniformity of illuminance is lower than the standard requirements.

2. At night, the frequency of the classroom used for self-study and class is still high, while the external natural light can be almost ignored, and it can be regarded as all artificial lighting to provide light.

In summary, the uniformity of illuminance is the lowest under the condition 1, and the uniformity of illuminance is improved because of the artificial light supplement under the condition 2. the highest in the condition 3. Due to the full usage of artificial lighting under condition 3, the uniformity of illuminance of the classroom is higher than the previous two conditions.

4. Influence factor analysis

The field survey and the measurement of the lighting status show that the lighting of the classroom mainly changes with the changes of day and night, natural lighting and artificial lighting. In addition to the factors mentioned above, the following factors should be analyzed.
4.1. Natural lighting

4.1.1. The effect of glazing floor area ratio.

According to the requirements of GB50033-2013 "Standard for daylighting design of buildings", the minimum value of the daylight factor of the school classroom is 2%, and 76% of the studied classrooms meet the requirements. As shown in FIG.3, the data analysis shows that the glazing floor area ratio is closely related to the daylight factors. Under the condition of natural lighting, natural light mainly enters the classroom through the side window, and the size of the side window area determines the amount of light entering the classroom, which affects the illuminance and the uniformity of illuminance of the classroom. Therefore, the higher glazing floor area ratio, the higher daylight factor.

4.1.2. Exterior illuminance. Survey data show that the average indoor illumination increases with the increase of outdoor illumination on sunny days. But when the direct sunlight shines into the room, it is easy to create a strong glare, resulting in a decrease in uniformity of illumination. In contrast, the exterior illuminance on cloudy days is relatively low and it is the similar changes in average indoor illuminance, while the illuminance distribution is relatively uniform.

4.1.3. Floor and greening. By measuring data distribution in different floors can be seen that the average illuminance is not as obvious changes in the distribution of floor, but the uniformity of illuminance has obvious changes. Among them, the uniformity of the first floor, second floor and third floor is relatively low and the variation range is large, while the degree is relatively stable above the fourth floor and fifth floor, which is closely related to the greenery height around the building. For example, the surrounding greenery is dominated by 6~10m small arbors, which has a certain impact on the natural lighting below the third floor. Therefore, it is necessary to reasonably adjust the surrounding greening environment, control the distance between the building and the greenery, and optimize the plant configuration, achieving that the thick foliage can shade in summer and sparse leaves reduce shading in winter.

4.1.4. The effects of orientation and shading Way. The layout of the second teaching building is shaped like an lateral H-block, with a single-sided corridor in the north and a double-sided corridor in the south. Therefore, the rooms that can receive direct sunlight are the rooms on the south side of the corridor, namely the 310, 512 and 515 classrooms in the study and sampling classrooms. It can be seen from the average illumination of the classroom that, as shown in FIG. 2, the values of these three classrooms are significantly higher than other classrooms in the case of condition 1 and condition 2. Through the analysis, it is found that the orientation of the classroom is north-south, which belongs to the mode of unilateral lighting. That is, when the classroom facing south encounters a sunny day with strong light, the sunlight will come in directly, thereby increasing the illumination value of the area near the window, resulting in the increase of the average illumination and the decrease of the...
uniformity of illumination. In addition, the shading and rain shielding measures will also affect the natural lighting of the room to a certain extent. However, there are no fixed shading measures in all the Windows of the classroom in this teaching building, which only have movable curtains, and all the curtains are open during the measurement of natural lighting, leading that the influence of shading measures is not reflected in measured value.

4.2. Artificial lighting

4.2.1. Lamps arrangement. It is widely use fluorescent lamp for lighting in the classroom, which are mostly arranged in a direction perpendicular to the classroom. In the process of using the classroom, lights will be put on at night and during the day when the lighting is insufficient. When students look up at the blackboard and the screen, there will be a particularly bright light in the field of vision, whose brightness is much higher than that of the screen and the blackboard, leading an obvious uneven distribution of brightness, that is the problem of dazzling light. Students looking up for a long time will cause their visual fatigue, which will lead to the decline of learning efficiency. Thus, the lighting choice and lighting arrangement of lamps need to be improved.

4.2.2. Suspension height of lamps. The suspension height of lamps will also affect the indoor light environment. The suspension height of lamps in some classrooms is too low, leading to the low illumination of the surrounding corner of the classroom and the poor illumination distribution. Generally speaking, the height of 40w naked light should not be lower than 1.7 m above the desk surface.

4.2.3. The blackboard lighting. The main visual objects of the lectern in the teaching building are the projection screen and the blackboard. In the light environment of the classroom, the lighting system was specially added to this part. However, due to the large brightness difference between the screen and the blackboard, the screen did not work well when the lighting system was on, but the blackboard did not work well when it was closed. Therefore, whether or not it is turned on cannot do both, which is a matter for improvement.

5. Improvement strategy

5.1. Control lighting glare

According to the CIE standard and the distribution ratio of luminous flux in the upper and lower space, there are five lighting modes: direct mode, semi-direct mode, diffuse mode, indirect mode and semi-indirect mode. At present, the lighting used in the classroom belongs to direct mode, in which 90%~100% of the luminous flux is directly projected below, so the utilization rate of the luminous flux is the highest, which is the most easy to produce dazzling light and not applicable in the classroom lighting.

Through the contrast analysis shows that the diffuse mode lamps is almost the same luminous flux of upward and downward and the light can be evenly in all directions to produce a better lighting effect, while the chimney mouth of indirect mode lamps is opposite up, which can shoot the light to the ceiling hind reflex comes back again, making its light relatively downy, and avoiding dazzle completely light and shadow. However, the light loss in this mode is very large, so it is suitable for use with other lamps. Therefore, on the choice of classroom lamps, diffuse lamps and indirect lamps should be used together, which can not only fully meet the functional needs of classroom teaching and learning, but also avoid glare and improve the quality of classroom lighting environment.

5.2. Improve blackboard lighting

With the development of modern teaching methods, multimedia is more and more widely used in teaching, and teaching aids have changed as well. At present, the school classroom has installed the
multimedia teaching system generally, including many display equipment, the projector screen and the traditional writing frosted blackboard and so on. In the process of research on the classroom, it is found that the brightness of the projection screen is high, while the illumination of the traditional blackboard is relatively low. When the projection screen is turned on, the handwriting on the blackboard has a very poor visual effect. The solution to this contradiction is to add a light source to the screen of the platform and the blackboard, which increases the illumination of the blackboard and reduces the contrast of the brightness of the screen, making the visual effect of the screen worse, which is also an important problem in the classroom light environment.[13]

The key to solve the problem of the light environment of the platform is to reduce the brightness contrast between the blackboard and the screen. Three solutions are proposed as following. The first solution is that the brightness of the blackboard can be appropriately improved, such as adding a projection light source to the blackboard alone, or adding a light source at the back of the blackboard to produce light transmission effect as well as the use of more intense color contrast chalk to improve the recognition of writing content. The second solution is to replace the traditional blackboard with white writing board, and replace the chalk with markers, so as to improve the visual effect and improve the classroom air environment, which is beneficial to the physical and mental health of teachers and students. The third solution is to use more intelligent multimedia teaching equipment to replace the traditional chalk writing blackboard, such as the interactive smart classroom blackboard of Nanjing University, which is including the broadcast of teaching courseware, video pictures and notes and other rich multimedia teaching functions, for the school to create a highly intelligent information campus.

5.3. Optimize the arrangement of lamps
Classroom desks are generally facing the blackboard into a regular arrangement, so it is appropriate to use the lighting method of the ceiling uniform distribution of lights, and the best height is 2.5~2.9m, meanwhile the best distance from the desk is 1.7~2.1m. It is more scientific for lamp lighting to make its light direction consistent with the window, by changing the arrangement of lamps. Before the actual installation of lamps, the installation and debugging should be carried out after design simulation and analysis to ensure the installation effect.

5.4. Intelligent control mode
With intelligent lighting control system, the classroom lights are automatically adjusted according to the brightness of the ambient light to reduce energy consumption. When the classroom is in normal use, the illumination of the desk should be kept above 300 lx as required by the national standard, and when people leave the classroom and do not need lighting, it can be closed automatically to save resources. Intelligent control can provide different scenarios the best intelligent lighting to improve teaching efficiency, and be based on the requirement of the classroom use to set a variety of intelligent model, such as a class model, activity mode, test mode, self-study mode, projection mode, rest mode and so on, meanwhile it is selected linkage control model to control lighting, projection and curtain, thus achieves the optimal effect.

6. Conclusion
Through sufficient research and data collection, the general classroom lighting environment has not reached the national standard level in illumination uniformity and the average illumination. Analyzing natural daylighting factors, including floors, exterior illumination, glazing floor area ratio and greening, and artificial lighting factors, including the arrangement of lamps, suspension height, the blackboard lighting, etc., this article carries out specific analysis to each influence factor, sort out the specific reasons for the poor light environment in the classroom and put forward various suggestions for improvement, including optimizing the arrangement of lamps, controlling the dazzle, optimizing the blackboard lighting and intelligent control. It is expected to optimize the classroom light
environment through specific measures to provide a better teaching environment for teachers and students.

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