

<sup>1</sup>Wenjing Dong<sup>2,\*</sup>Runzhao Qi<sup>3</sup>Wei Zhang<sup>4</sup>Xiaoran Liu<sup>5</sup>Ke Huang

# Research on Optimization of University Classroom Lighting Environment Based on Computer Simulation



**Abstract:** - In order to improve the comfort of classroom users and improve the lighting environment of university classrooms, this paper puts forward different optimization schemes based on computer simulation. Dialux, a lighting environment design software, is used to numerically simulate the lighting environment of university classrooms. The classroom lighting scheme is optimized and different solutions are proposed. Through computer simulation, the effect of lighting is compared and analyzed, in order to find the most beneficial scheme for students' mental health, which provides the basis for intelligent control of classroom lighting. The results show that the average illuminance decreases with the increase of suspension height, and the illuminance uniformity increases first and then decreases with the increase of suspension height. The solution of adjusting the projection direction and surface reflectivity of lamps is not suitable, and upgrading the type of lamps can solve the lighting environment problems and control glare. Increasing the number of lamps and adjusting the arrangement of lamps can improve the lighting environment, increase the average value but reduce the uniformity, but lead to a significant increase in energy consumption. Intelligent control based on computer simulation can solve the coordination problem of energy consumption and lighting effect. Through comparative analysis of the effects of different schemes on the classroom lighting environment in colleges and universities based on computer simulation, this paper provides data support for the selection of improved schemes, which is conducive to the selection of more suitable intelligent lighting control schemes, to ensure students' mental health and work efficiency, and has certain reference significance for creating a healthy and comfortable classroom lighting environment.

**Keywords:** Classroom Lighting Environment, Computer Simulation, Intelligent Lighting Control, Lighting Methods, Suspension Height, Type of Lighting Fixtures.

## I. INTRODUCTION

Good learning environment is crucial to the development of students. A quality artificially lit classroom environment is a key factor in student learning outcomes. Students will be more motivated and focused when they learn in a bright, comfortable environment. This article will discuss the importance of artificial lighting environment in classrooms for student learning efficiency, analyze the lighting environment effects under different factors based on computer simulation models, and propose relevant suggestions for using intelligent lighting control to improve the classroom lighting environment.

The physical environment of a classroom is crucial. The lighting environment, as a constituent of the classroom's physical surroundings, directly impacts the health and learning efficiency of college students.<sup>[1-7]</sup> A comfortable lighting setting helps alleviate fatigue experienced by teachers and students due to extended work and study periods, enhancing students' psychological comfort and learning efficiency. If the classroom lighting is subpar, such as when the uniformity of illuminance doesn't meet standards, students might find themselves adjusting their vision too frequently to adapt, leading to undue eye muscle tension and visual fatigue<sup>[8-9]</sup>. In traditional research, lighting control systems based on proportional integral differential feedback control or fuzzy controller control can adjust indoor illumination according to environmental changes and reduce energy consumption. But it is difficult to find an optimal set of lighting levels to control multiple lighting fixtures, so that the illuminance values of multiple measuring points are consistent, making it difficult to achieve uniform lighting. Some scholars have proposed a multi-objective predictive control method for public lighting spaces based on neural network models<sup>[10-12]</sup>, which combines real-time performance with robustness. There are numerous opportunities to reduce lighting energy consumption and improve indoor comfort. However, training such models requires a large amount of data and they do not yet have scalability. Therefore, computer simulation can provide data support to intelligently control the lighting environment and improve comfort. By collecting and analyzing environmental

<sup>1</sup> School of Architecture and Urban Planning, Chongqing Jiaotong University, Chongqing, China

<sup>2</sup> School of Architecture and Environmental Art, Sichuan Fine Arts Institute, Chongqing, China

<sup>3</sup> School of Architecture and Urban Planning, Chongqing Jiaotong University, Chongqing, China

<sup>4</sup> School of Architecture and Urban Planning, Chongqing Jiaotong University, Chongqing, China

<sup>5</sup> School of Architecture and Urban Planning, Chongqing Jiaotong University, Chongqing, China

\*Corresponding author: Runzhao Qi

Copyright © JES 2024 on-line : journal.esrgroups.org

data, artificial intelligence can automatically adjust the brightness, color temperature, and color of lighting according to different needs and scenes, providing the best visual experience and comfort.

In the classroom, the average illuminance and illuminance uniformity of lighting have an important impact on the overall environment. This paper will explore the influence of these factors on the classroom environment and students' learning outcomes. The average illuminance is the average level of light intensity at each location in the room. A suitable illuminance average provides enough light for students to clearly see objects and text in the classroom. Studies have shown that a suitable average illuminance helps improve students' attention and concentration. In a bright environment, students are more likely to concentrate and thus participate better in class activities. Therefore, ensuring that the average level of illumination in the classroom is within the appropriate range is crucial to creating a good learning atmosphere. Illuminance uniformity refers to the consistency of light intensity in different locations in a room. A uniform illuminance distribution reduces uneven reflection of light and glare, thus avoiding interference with students' vision. If there are too many illuminance differences in the classroom, such as some areas being too bright and others too dark, students may feel uncomfortable and have difficulty concentrating. Therefore, maintaining an appropriate illuminance uniformity is one of the important factors in providing a comfortable learning environment. The influence of the average illuminance and illuminance uniformity of classroom lighting on the overall environment can not be ignored. By ensuring the right average and evenness of illumination, you can create a comfortable and conducive environment for students to learn. Such an environment helps to improve students' attention and concentration, which ultimately promotes their learning outcomes. Therefore, in the design and layout of classroom lighting, attention should be paid to the average illuminance and illuminance uniformity to provide a quality learning environment. However, in practical scenarios, the indoor lighting environment constantly changes with the outdoor climate, and the lighting requirements should also be adjusted according to the changes in the natural lighting environment. Therefore, according to computer simulation results, intelligent control based on reasonable requirements is the best solution to optimize classroom lighting.

## II. CURRENT STATE OF RESEARCH

### A. Overview of Related Research

The light environment of the university classroom has a crucial impact on the mental health and work efficiency of students. According to the previous investigation and research on light environment of college classrooms, the main problem is that the average and evenness of illuminance of the working surface cannot meet specifications and practical needs. Improving the classroom lighting environment is an important measure to relieve students' anxiety and improve learning efficiency.

On the foundation of his research on the effects of lighting on human physiological rhythms, health, growth, and efficiency, Tanner <sup>[13]</sup> emphasized the viewpoint that the school lighting environment influences students' learning efficiency. Meng Chao and others <sup>[14]</sup>, considering the widespread issue of poor vision among Chinese students, undertook research on the classroom lighting environment, aiding the development of national standards and offering a reference for enhancing classroom lighting. Mao Wanhong and Ma Xinyao <sup>[15]</sup>, using classrooms from Zhejiang Sci-Tech University as their study focus, conducted visual experiments assessing lighting conditions and visual satisfaction levels. Sun BS explored the relationship between students' performance and environmental parameters, detailing the collection and analysis of data on learning environments, lighting conditions, and student performance, providing insights for researchers <sup>[16]</sup>. Govén T and LaikeT <sup>[17]</sup>, through experimental studies, discovered that elementary students under a 500lx illuminance performed better in reading, writing, and arithmetic than those under a standard 300lx illuminance. 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. <sup>[18-19]</sup> Castilla Nuria <sup>[20]</sup> study on classroom lighting conditions affect student academic performance due to the influence of light on learning. Illuminance is a lighting parameter recognised as an important factor in interior lighting. The objective of this study is to analyse the effect that a classroom's illuminance exerts on university students' memories; memory is one of the fundamental cognitive processes in learning. Forty subjects performed a psychological memory. Samiou, AI <sup>[21]</sup> and others evaluated climate-based daylight modeling methods as an assessment tool in daylighting design, determining the optimal daylighting design strategies for preschool classroom visual environments. The studies indicate that current classroom lighting standards cater only to basic functional needs. From health and comfort perspectives, merely meeting these standards isn't sufficient, suggesting a need for further enhancement.

### B. Research Foundation

The primary requirements for classroom lighting are to provide sufficient illumination for teachers and students while ensuring visual comfort, avoiding glare, and ensuring that students do not experience visual fatigue during prolonged periods of concentrated study. Therefore, classroom lighting should fulfill the following: 1) adequate illuminance and uniformity; 2) prevention of glare, which includes direct sunlight and glare resulting from improper indoor lighting; 3) ensuring visual comfort and avoiding visual fatigue.

The overall lighting environment of a classroom changes with the transition from day to night and the shift between natural and artificial lighting. In previous research by our team <sup>[22]</sup>, thorough surveys and data collection revealed that the average classroom lighting did not meet national standards in terms of illuminance uniformity and average illuminance. The reasons are multifaceted. In terms of natural lighting, variables such as floor level, outdoor illuminance, window-to-floor ratio, and vegetation influence the classroom lighting environment to varying extents. In terms of artificial lighting, factors like lighting methods, fixture arrangement, suspension height, and chalkboard area lighting all exert different impacts on the classroom's artificial lighting environment. The research proposes optimized fixture arrangement, glare control, improved chalkboard area lighting, and intelligent control methods, aiming to refine the classroom lighting environment and provide a better learning atmosphere for teachers and students.

Building upon this preliminary research, this paper will further delve into design strategies to enhance the classroom lighting environment. Given the constraints related to the building's original structure, layout, door and window openings, and floor levels, it's challenging to undertake extensive renovations. Therefore, this study primarily focuses on optimizing the lighting environment from the perspective of artificial lighting. Taking a typical university classroom as the subject, this paper establishes a model of its lighting environment. Various lighting optimization proposals are developed, analyzed, and compared to evaluate the quality of the university classroom's lighting environment. Among the various indicators affecting lighting quality, illuminance level and illuminance distribution uniformity are two crucial metrics. Hence, this research emphasizes the measurement, analysis, and evaluation of these two quantities.

### C. Standards and Requirements for Lighting Quality

High-quality classroom lighting requires consideration of various factors such as illuminance uniformity, luminance contrast, correlated color temperature, glare, and color rendering index. These factors collectively contribute to creating an optimal learning environment for students. In classroom lighting, the surface of the desk should have a certain level of illuminance to meet the requirements of reading and writing. Key lighting quality indicators include illuminance uniformity, luminance contrast, correlated color temperature, glare, and color rendering index. 1) Illuminance uniformity and average illuminance. China's national standard GB7793-2010 "Lighting and Illumination Sanitation Standard for Primary and Middle School Classrooms" stipulates that the illuminance uniformity on the classroom desk surface should not be less than 0.7. The CIE standard recommends a value of 0.8. Meeting these standards ensures that students receive consistent lighting across their workspace, reducing eye strain and promoting better reading and writing experiences. GB50034-2013 "Architectural Lighting Design Standard" requires an illuminance standard value of not less than 300lx for educational buildings, with a uniformity of not less than 0.6. This standard ensures that students have sufficient brightness for their tasks while maintaining uniform lighting distribution throughout the classroom. 2) Glare. Glare is one of the critical indicators for evaluating classroom lighting quality. In 1995, CIE introduced the Unified Glare Rating as the evaluation metric for discomfort glare, and GB50034-2004 "Architectural Lighting Design Standard" stipulates that the UGR for classrooms should not exceed 19. By adhering to this standard, classroom lighting designers can prevent glare-related issues, such as visual fatigue and difficulty in focusing, which can hinder students' attentiveness and overall academic performance.

To meet the aforementioned lighting quality indicators while ensuring an optimal learning environment, it is essential to consider various aspects of lighting design. First, using appropriate light fixtures and ensuring proper placement and distribution of light sources can help achieve uniform illuminance levels. By strategically positioning light fixtures, designers can minimize shadows and increase the overall efficiency of lighting. In conclusion, maintaining high quality classroom lighting requires adherence to specific standards and consideration of various factors. By ensuring illuminance uniformity and illuminance averages, controlling glare, educators can create an optimal learning environment that promotes student engagement, comfort, and overall academic success.

### III. ESTABLISHMENT OF THE CLASSROOM ARTIFICIAL LIGHTING MODEL

Dialux is an auxiliary design software used for lighting analysis and computation. Some scholars have already utilized this software in their research for designing optimization schemes. To propose a more comprehensive optimization scheme for illuminance uniformity in university classrooms, this study employs the lighting design and simulation software Dialux. Building on prior research and analysis of classroom lighting environments, we further investigate and analyze the lighting conditions in current university classrooms and put forth a more refined optimization scheme.

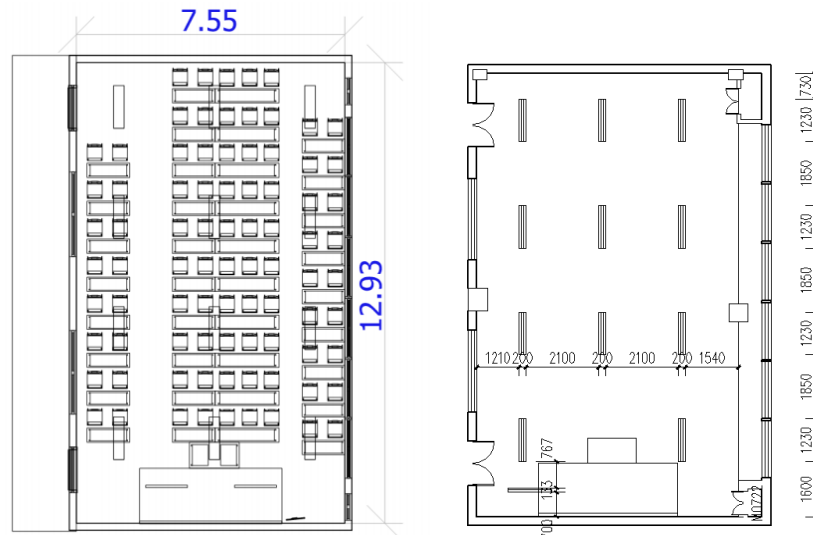


Figure 1: Floor Plan of a Typical Classroom and the Current Lighting Fixture Layout

Left: Floor Plan of a Typical Classroom

Right: The Current Lighting Fixture Layout

As depicted in Figure 1, the foundational model of the classroom measures 12.93m in length, 7.55m in width, and 4m in height. The room features two doors, six regular exterior windows, and two high side windows. The reflection coefficients are set at 70.0 percent for the ceiling, 50.0 percent for the walls, and 20.0 percent for the floor, with a maintenance factor of 0.80. After examining the main issues in the current classroom lighting environment, a lighting optimization plan for the classroom is designed, and its effectiveness is evaluated through simulation comparison.

### IV. CLASSROOM ARTIFICIAL LIGHTING OPTIMIZATION PROPOSALS

#### A. Simulation Analysis of Adjusting the Lighting Fixture Suspension Height

The suspension height of lighting fixtures directly influences the indoor lighting environment. Conventional fixture heights typically range between 2.5-2.9m, positioning them 1.7-2.1m above the desks. Using data from the current classroom lighting fixtures and environmental parameters for simulation, the model condition is set to nighttime, with conventional 36w fixtures arranged in a  $3 \times 4$  grid. Adjustments to the fixture suspension height were made at intervals between 2m and 4m, and the resulting desk illuminance values are shown in Table 1.

Table 1: Relationship between Desk Illuminance and Suspension Height

|                              |      |      |      |      |      |      |      |      |      |      |      |
|------------------------------|------|------|------|------|------|------|------|------|------|------|------|
| Suspension Height/m          | 2.0  | 2.1  | 2.2  | 2.3  | 2.4  | 2.5  | 2.6  | 2.7  | 2.8  | 2.9  | 3.0  |
| Average Desk Illuminance/lx  | 221  | 207  | 204  | 201  | 198  | 196  | 193  | 190  | 188  | 186  | 183  |
| Desk Illuminance Uniformity  | 0.58 | 0.62 | 0.66 | 0.69 | 0.7  | 0.7  | 0.69 | 0.69 | 0.69 | 0.68 | 0.68 |
| Suspension Height /m         | 3.1  | 3.2  | 3.3  | 3.4  | 3.5  | 3.6  | 3.7  | 3.8  | 3.9  | 4.0  | -    |
| Average Desk Illuminance /lx | 181  | 179  | 177  | 175  | 174  | 173  | 171  | 170  | 168  | 166  | -    |
| Desk Illuminance Uniformity  | 0.67 | 0.66 | 0.66 | 0.66 | 0.65 | 0.64 | 0.64 | 0.63 | 0.63 | 0.68 | -    |

From Figure 2 left, it is evident that by adjusting the suspension height of the luminaires, the relationship of the lighting environment on the classroom desk changes as follows: the average illuminance decreases as the suspension height increases. From Figure 2 right, the uniformity of illuminance first rises and then falls as the height increases, reaching a higher value in the range of 2.4m-2.9m, with the uniformity of illuminance being the greatest between 2.5-2.7m. The current suspension height in the classroom is within the appropriate range, but not at the optimal height. It can be adjusted slightly to improve lighting effects but should not be reduced too much to

avoid affecting the viewing effect on the blackboard. Based on the current conditions of the classroom lights, adjusting the height cannot achieve the required average illuminance as per the standards.

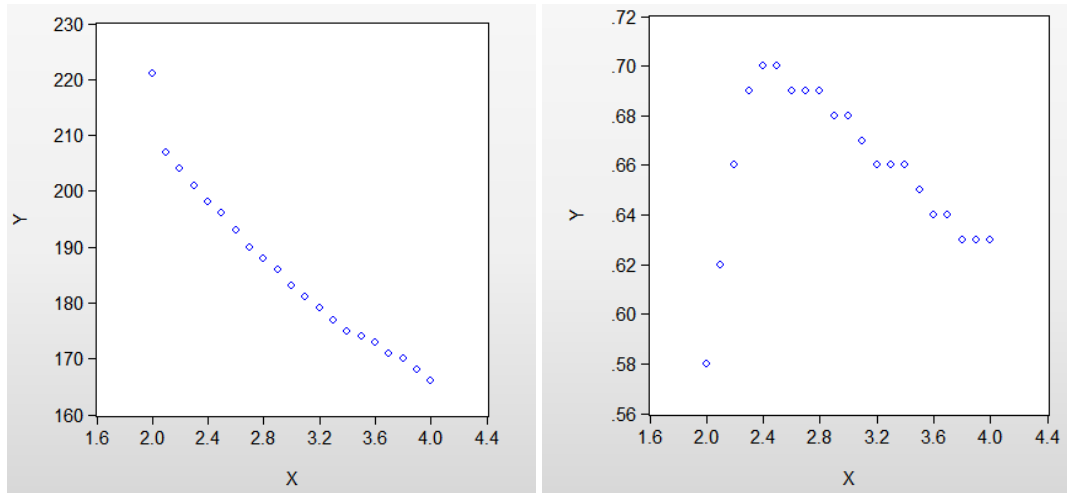


Figure 2: Changes in Average Illuminance and Uniformity of Illuminance under the Influence of Suspension Height

Left: Changes in Average Illuminance under the Influence of Suspension Height

Right: Uniformity of Illuminance under the Influence of Suspension Height

From the data in Table 2, the maximum blackboard illuminance occurs at 3.5-3.7m, but the average values have not reached the standard. The uniformity reaches the standard requirement of above 0.7 when the suspension height rises above 3.5m.

Table 2: Relationship between Blackboard Illuminance and Suspension Height

|                                      |      |      |      |      |      |      |      |      |      |      |      |
|--------------------------------------|------|------|------|------|------|------|------|------|------|------|------|
| Suspension Height/m                  | 2.0  | 2.1  | 2.2  | 2.3  | 2.4  | 2.5  | 2.6  | 2.7  | 2.8  | 2.9  | 3.0  |
| Average Blackboard Illuminance       | 70.2 | 78.3 | 87.9 | 99.2 | 112  | 128  | 146  | 167  | 189  | 213  | 234  |
| Uniformity of Blackboard Illuminance | 0.62 | 0.57 | 0.52 | 0.47 | 0.44 | 0.43 | 0.43 | 0.43 | 0.45 | 0.48 | 0.51 |
| Suspension Height /m                 | 3.1  | 3.2  | 3.3  | 3.4  | 3.5  | 3.6  | 3.7  | 3.8  | 3.9  | 4.0  | -    |
| Average Blackboard Illuminance       | 253  | 270  | 284  | 295  | 303  | 307  | 306  | 301  | 294  | 286  | -    |
| Uniformity of Blackboard Illuminance | 0.55 | 0.58 | 0.61 | 0.67 | 0.75 | 0.83 | 0.8  | 0.79 | 0.78 | 0.77 | -    |

In addition, the glare index on the desktop is above 19, exceeding the specification requirements. Thus, considering only the suspension height with the current number and arrangement of lights, it's impossible to meet the standards. Therefore, we need to continue analyzing the impact of other factors.

To achieve the required average illuminance as per the standards, it is necessary to make some changes in the classroom lighting system. The current suspension height, although within the appropriate range, does not provide optimal lighting effects. One possible solution is to install adjustable suspension systems for the luminaires. This would allow teachers to easily adjust the height of the lights according to their specific needs. By doing so, they can ensure that the average illuminance on the classroom desk meets the recommended levels. In addition to adjusting the suspension height and improving the lighting fixtures, it is essential to regularly maintain and clean the luminaires. Over time, dust and dirt can accumulate on the lights, reducing their overall brightness. By regularly cleaning and replacing any faulty bulbs, the lighting quality can be maintained at its best. Moreover, it is crucial to involve the input and feedback from the teachers and students in the decision-making process. Conducting surveys or interviews to gather their opinions on the lighting conditions in the classroom can provide valuable insights. Their feedback can help determine the specific requirements and preferences regarding lighting, ultimately leading to a better learning environment.

In conclusion, while the current suspension height of the luminaires in the classroom is within the appropriate range, it is not at the optimal height to achieve the required average illuminance. Adjusting the height slightly can improve the lighting effects without compromising the viewing effect on the blackboard. However, other measures such as installing adjustable suspension systems, upgrading lighting fixtures, maximizing the use of natural light, and regular maintenance are also necessary to ensure the desired lighting conditions in the classroom. By taking these steps, students can benefit from a well-lit and comfortable learning environment, which can enhance their concentration and overall academic performance.

*B. Simulation Analysis of Adjusting Luminaire Projection Direction and Surface Reflectivity*

In lighting design, the projection direction of the luminaire and the reflectivity of each projection surface can also affect the indoor illuminance distribution. Data from Table 3 shows that, under the condition of traditional 36W lights with downward projection, the average illuminance is 188lx, which does not meet the usage requirements. However, when the luminaire is changed to a school-specific LED, it can meet the standard. By keeping other conditions constant and changing the projection direction upwards, the average illuminance is halved, and uniformity also decreases. Therefore, an attempt to increase the reflectivity of the surface to achieve higher average and uniform values is needed. After testing, when the reflectivity of various surfaces reaches 90 percent for the ceiling, 80 percent for walls, and 70 percent for floors, the average illuminance of the desk is close to the standard. However, this reflectivity differs significantly from the current situation and exceeds China’s GB50034-2004"Building Lighting Design Standard" recommended values for classroom surface reflectivity. It’s not easy to implement from a construction perspective due to its large scale, consumption of resources, non-energy-saving nature, potential discrepancy between theoretical values and actual construction results, and incompatibility with the classroom environment. Therefore, overall, this plan is not practically feasible.

Table 3: Comparison of Different Strategies Including Luminaire Upgrade and Adjustment of Projection Direction

| Luminaire Height 2.8m, 3x4 arrangement | Projection Direction | Reflectivity Coefficient |           |           | Desk Perpendicular Illuminance |                 | Glare Index |
|--|----------------------|--------------------------|-----------|-----------|--------------------------------|-----------------|-------------|
|  |                      | Ceiling                  | Wall      | Floor     | Average                        | Minimum/Average |             |
| Traditional Lamp 36W                   | Downwards            | 70percent                | 50percent | 20percent | 188                            | 0.69            | > 19        |
| LED Lamp 36W                           | Downwards            | 70percent                | 50percent | 20percent | 304                            | 0.72            | 18          |
| LED Lamp 36W                           | Upwards              | 70percent                | 50percent | 20percent | 145                            | 0.63            | < 10        |
| LED Lamp 36W /Increased Reflectivity   | Upwards              | 90percent                | 80percent | 70percent | 287                            | 0.76            | < 10        |

*C. Analysis of Luminaire Upgrade Plan*

From the survey of classroom lighting environment, it is evident that the luminaire is outdated and lacks maintenance, which is a common issue. In the classroom lighting design, the selection of luminaires is crucial. Currently, the artificial lighting environment with traditional classroom luminaires is not ideal. It fails to provide high-quality illumination, which would offer teachers and students a comfortable and pleasant environment that minimizes visual fatigue. Therefore, this study investigated options for luminaire upgrades. Without changing the existing quantity and arrangement, the simulation analysis was conducted by upgrading the traditional luminaires to specialized classroom LED luminaires [23].

As seen in the aforementioned comparison tables, another option is to replace the existing luminaires with more efficient ones. LED lights, for example, are known for their energy-saving capabilities and higher luminous efficiency. By upgrading the lighting fixtures, the overall illumination in the classroom can be improved, even if the suspension height remains the same. By upgrading the luminaire type to specialized school LED luminaires, as depicted in Figure 3, the simulation can achieve an average value of 304lx and uniformity of 0.72 under the same energy consumption conditions, meeting the specification requirements. It is a relatively simple and feasible implementation solution. Notably, the glare problem, which is common in traditional luminaires, has been somewhat improved, reducing the glare index from greater than 19 to 18. Though not as satisfactory as the adjusted projection direction scheme, it meets the requirements and is highly feasible.

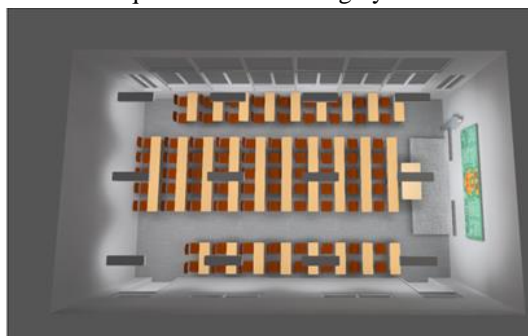


Figure 3: Schematic Illustration of Lighting Effects after Luminaire Type Upgrade

*D. Simulation Analysis of Adjusting Luminaire Arrangement and Luminaire Quantity Scheme*

Currently, the sample classroom seating area has 12 traditional luminaires, conventionally arranged in a 3x4 pattern with a suspension height of 2.8m. Both the average illuminance and uniformity under the current setup

during evening solely artificial lighting phases cannot meet the standard requirements. The simulation plan first considers increasing the luminaire count and rearranging their layout without changing the type, studying the changes in the lighting environment. The values of the adjusted number of lamps, average illuminance and illuminance uniformity are shown in Table 4. The number of luminaires is increased to 20, arranged in a 4x5 pattern. As shown in Figure 4, Figure 4 left is desk illuminance distribution before adjusting luminaire arrangement and figure 4 right shows the result after. After adjusting the arrangement, the average illuminance can reach 315lx. Although the uniformity slightly decreases, it still meets the requirements. Thus, this adjustment plan moderately improves the student’s work area lighting environment. In summary, by increasing the luminaire count and adjusting their arrangement, while the average value improves, the uniformity decreases. From a construction perspective, this method is not complicated and is easy to implement. However, the downside is that without changing the traditional luminaires and only increasing their quantity, there will be a significant increase in energy consumption.

Table 4: Comparison of Illumination Before and After Adjusting Luminaire Arrangement

|                                       | Quantity | Luminaire  | Average Value | Minimum/Average |
|---------------------------------------|----------|--|---------------|-----------------|
| Traditional 36W lamp, 3x4 arrangement | 12       | T8 standard bracket, luminaire luminous flux: 2064lm | 188           | 0.69            |
| Traditional 36W lamp, 4x5 arrangement | 20       | T8 standard bracket, luminaire luminous flux: 2064lm | 315           | 0.62            |

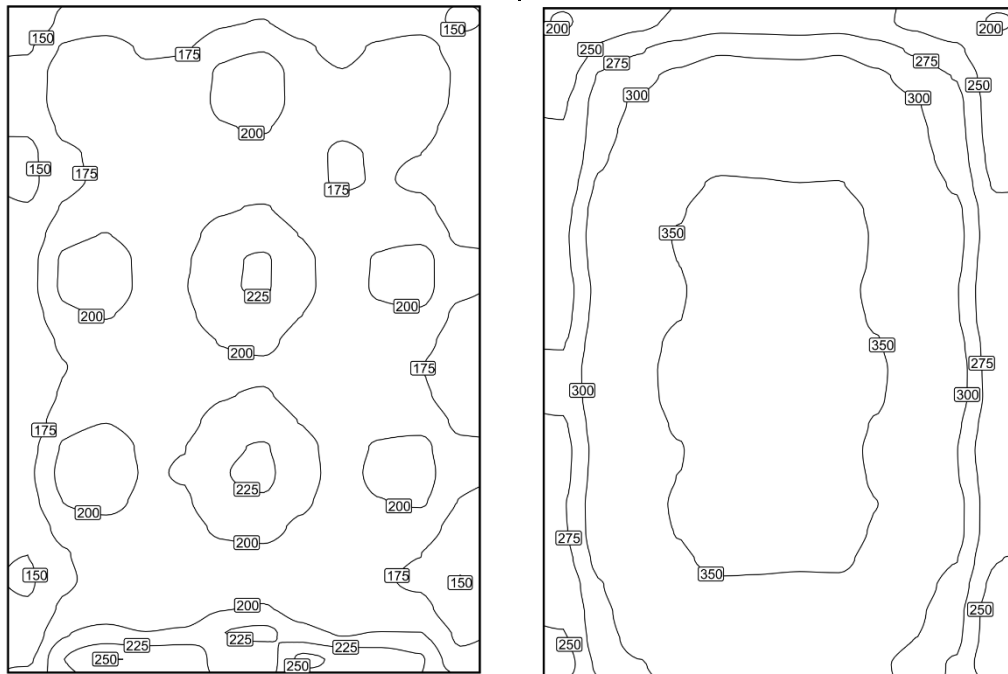


Figure 4: Comparison of Desk Illuminance Distribution Before and After Adjusting Luminaire Arrangement

Left: Desk Illuminance Distribution Before Adjusting Luminaire Arrangement

Right: Desk Illuminance Distribution After Adjusting Luminaire Arrangement

To address the issue of increased energy consumption due to the increase in luminaire count, alternative solutions need to be explored. One possible solution is to replace the traditional luminaires with energy-efficient LED luminaires. By replacing the 20 traditional luminaires with LED luminaires, it is possible to achieve the desired illuminance levels while reducing energy consumption. The simulation plan is adjusted to incorporate LED luminaires into the classroom lighting setup. The selected LED luminaires provide the same illuminance levels as the traditional ones but consume significantly less energy. The new layout considers factors such as the positioning of the LED luminaires to ensure optimum illumination and uniformity throughout the classroom.

After implementing the changes, a post-installation simulation is conducted to evaluate the effectiveness of the LED luminaires. The results show that the average illuminance remains at 315lx, meeting the standard requirements. However, the uniformity improves compared to the previous adjustment plan, ensuring a more consistent lighting environment for students. Besides the improved lighting conditions, the replacement of traditional luminaires with LED luminaires brings additional benefits. LED luminaires have a longer lifespan, reducing maintenance costs and minimizing disruption to the learning environment. Moreover, LED luminaires are known for their better color rendering properties, providing a more visually comfortable and true-to-life lighting experience. In terms of energy

consumption, the switch to LED luminaires significantly reduces the classroom's overall energy usage. Compared to traditional luminaires, LED luminaires can provide the same amount of light while consuming approximately 50% less energy. This reduction in energy consumption not only lowers electricity bills but also contributes to environmental sustainability.

To further optimize energy efficiency, additional measures can be taken, such as incorporating daylight harvesting and occupancy sensors. Daylight harvesting systems utilize natural daylight to supplement artificial lighting, automatically adjusting the intensity of the luminaires based on the available natural light. Occupancy sensors detect the presence or absence of occupants in the classroom, allowing for automatic lighting control and energy savings when the space is unoccupied. In conclusion, by replacing traditional luminaires with energy-efficient LED luminaires and implementing advanced lighting control systems, it is possible to achieve both optimal lighting conditions and reduced energy consumption in the classroom. This solution not only enhances the learning experience for students but also contributes to a more sustainable future. Embracing innovative lighting technologies and design strategies is crucial for creating well-lit, energy-efficient educational environments

## V. CONCLUSION

To improve the quality of artificial lighting environment in university classrooms and solve the current problems in the lighting environment of university classrooms. This study investigated different design schemes through computer simulation models, such as adjusting the height of lighting fixtures, upgrading the type of lighting fixtures, adjusting the projection angle and reflectivity, and rearranging the layout of lighting fixtures. Using Dialux software for computer numerical simulation, the following conclusions were drawn.

1) The average illuminance decreases with the increase in suspension height. The trend of illuminance uniformity increases first and then decreases as height increases. A suspension height of 2.5-2.7m can maximize illuminance uniformity.

2) After adjusting the projection direction of the luminaire and the reflectivity of the surface layer, the uniformity of illuminance significantly improves, and the problem of glare gets greatly alleviated. However, the average value drops considerably. To achieve a satisfactory average value, a higher energy consumption is needed, and feasibility from a practical construction standpoint is relatively low.

3) Upgrading the type of luminaire, converting traditional luminaires to specialized school LED luminaires, can solve lighting environment issues in a relatively simple and straightforward manner. Furthermore, it can control glare within permissible limits.

4) Increasing the quantity of luminaires and adjusting their arrangement improves the average illumination but decreases its uniformity. This approach is relatively easy to implement from a construction standpoint. However, if the traditional luminaires are not changed and only their quantity is increased, there will be a significant increase in energy consumption.

The fact shows that intelligent control is an effective way to regulate indoor lighting environment. By perceiving and analyzing environmental data, intelligent control of classroom lighting equipment can provide better lighting effects and comfort, while achieving energy-saving and personalized settings. This study simulated the lighting effects of different schemes using Dialux computer simulation. Comparing the results of different schemes provides data support for intelligent control of classroom lighting in universities, which will help improve the quality of learning and teaching environment in classrooms, and create a healthy and comfortable classroom lighting environment for teachers and students.

## REFERENCES

- [1] Fang, Yuhang, Luo, Xiaoyu, Lu, Jiang. A review of research on the impact of the classroom physical environment on schoolchildren's health. *Journal of Building Engineering*, 2023, 4(65): 105430.
- [2] J. Laurent, A. Williams, Y. Oulhote, A. Zanobetti, J.G. Allen, J.D. Spengler, Reduced cognitive function during a heatwave among residents of non-air conditioned buildings: an observational study of young adults in the summer of 2016, *PLoS Med.* 15 (2018).
- [3] J.C. Sherwin, M.H. Reacher, R.H. Keogh, A.P. Khawaja, D.A. Mackey, P.J. Foster, The association between time spent outdoors and myopia in children and adolescents, *Ophthalmology* 119 (2012) 2141–2151.
- [4] M. Sliwinska-Kowalska, K. Zaborowski, WHO Environmental Noise Guidelines for the European Region: A Systematic Review on Environmental Noise and Permanent Hearing Loss and Tinnitus, *Int. J. Env. Res. Pub. He* 14 (2017).
- [5] P. Wargocki, J.A. Porras-Salazar, S. Contreras-Espinoza, W. Bahnfleth, The relationships between classroom air quality and children's performance in school, *Build. Environ.* 173 (2020) 106749.
- [6] K. Savelieva, T. Marttila, J. Lampi, S. Ung-Lanki, M. Elovainio, J. Pekkanen, Associations between indoor environmental quality in schools and symptom reporting in pupil-administered questionnaires, *Environ. Health-Glob.* 18 (2019).



- [7] H. Xiao, H.L. Cai, X.F. Li, Non-visual Effects of Indoor Light Environment on Humans: A Review, vol. 228, *PHYSIOL BEHAV*, 2021.
- [8] Kong Yiping, Zhao Yunsheng, Liu Lei. Model construction and solution for optimizing classroom lighting uniformity . *Safety and Environmental Engineering*, 2012, 19(2):61-65.
- [9] van Someren, K; Beaman, P and Shao, L. Calculating the lighting performance gap in higher education classrooms. *International journal of Low-Carbon Technologies*,2018,13(1):15-22.
- [10] Fang, PX, Wang, M, Li, JZ, Zhao, QC, Zheng, XH, Gao, H, A Distributed Intelligent Lighting Control System Based on Deep Reinforcement Learning , *Applied Sciences-Basel* , 2023 .13(16):2076-3417.
- [11] Seyedolhosseini, A.; Masoumi, N.; Modarressi, M.; Karimian, N. Daylight adaptive smart indoor lighting control method using artificial neural networks. *J. Build. Eng.* 2020, 29, 101141.
- [12] Garces-Jimenez, A.; Castillo-Sequera, J.L.; Del Corte-Valiente, A.; Gómez-Pulido, J.M.; González-Seco, E.P.D. Analysis of artificial neural network architectures for modeling smart lighting systems for energy savings. *IEEE Access* 2019, 7, 119881–119891.
- [13] Tanner KC.Explaining relationships among student outcomes and the school’s physical environment. *Journal of Advanced Academics*,2008,19:444–471.
- [14] MENG Chao. Analysis of Daylighting and Lighting of Some Classroom in Beijing. *China Illuminating Engineering Journal*,2006,01:34-37+41.
- [15] Wanhong M, Xinyao M and Hongyan Z. Light Environment Measurement and Visual Experiment of Multimedia Classroom in College. 2012 *Huazhong Architecture*. 02 4951.
- [16] Sun, BS; Zhang, QL and Cao, S. Development and Implementation of a Self-Optimizable Smart Lighting System Based on Learning Context in Classroom. *International Journal Of Environmental Research And Public Health*,2020,17(4):1217.
- [17] Govén T, Laike T, Raynham P, et al.The influence of ambient lighting on pupils in classrooms considering visual,biological and emotional aspects as well as use of energy. *Proceedings of the International Commission on Illumination Conference*,Vienna,Austria,2010.
- [18] Haijing H and Gang C Illumination and energy saving in classroom light environment , 2012 *Journal of Central South University(Natural science)*. 43 12 .
- [19] Haijing H and Gang C Discussion on Lighting Situation of University Classroom and Subjective Evaluation of the Visual Environment . 2010 *Light and Lighting*. 4 2226.
- [20] Castilla, Nuria, Higuera-Trujillo, Juan Luis; Llinares, Carmen. The effects of illuminance on students’ memory. A neuroarchitecture study. *Building and Environment*, 2023,15[228]:109833.
- [21] Samiou, AI; Doulos, LT and Zerefos, S. Daylighting and artificial lighting criteria that promote performance and optical comfort in preschool classrooms .*Energy And Building*,2022,258:111819.
- [22] DONG WJ, LIU QP, Research on the Current Situation and Improvement Strategy of Light Environment in College Classroom .*IOP Conference Series: Earth and Environmental Science*,2023(7):531.
- [23] Samiou, AI; Doulos, LT and Zerefos, S. A field study of fluorescent and LED classroom lighting. *Lighting Research & Technology*,2018,50(4):631-651.