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# Light Environment Evaluation and Optimization of College Classrooms from a Dual-Carbon Perspective

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***Abstract:*** *Under the background of the country's vigorous advocacy of "carbon peaking and carbon neutrality", in order to understand the current situation of the light environment of university classrooms and provide reference for the direction and measures of the improvement of university classrooms, this paper selected a typical classroom in a university in Henan province to carry out subjective and objective assessment of the light environment. Objectively, from two aspects of daylighting coefficient and artificial lighting measurement, the results show that the average illumination and evenness of the classroom are lower than the national standard value under the condition of natural lighting and night lighting. Subjectively, a questionnaire survey was conducted on the classroom light environment of the students who have used the classroom, and it was concluded that under both natural lighting and night lighting conditions, most of the students believed that the subjective feeling of the classroom light environment was poor, and the classroom light environment needed to be improved.In addition, the paper uses DIALux software to optimize the light environment according to the current situation, and simulates the current situation and optimization measures of the light environment of the classroom, so that the classroom can realize the requirements of energy saving while meeting the comfort of the indoor light environment.*

***Keywords:*** *University classroom, Natural lighting, Artificial lighting, Light environment, Dual-Carbon goals*

## 1. Introduction

With the vigorous implementation of the "carbon peak, carbon neutrality" strategy in recent years, people have gradually realized that creating a good environment requires not only comfort but also energy conservation. Therefore, how to create a classroom light environment that meets both learning needs and energy conservation needs has become an urgent problem for many colleges and universities.

At present, a research method that combines data measurement and subjective evaluation for light environment evaluation has been developed [1-5], and this method has been used to evaluate the light environment from the perspective of the impact on adolescent visual acuity [6]. Yanjun Chen [7], Xiaoming Su [8] use the software Desktop Radiance to evaluate the quality of indoor light environment. Tongyue Wang [9], Wenxuan Wang [10], Yang Yuan [11], Quan Chen [12] and others use DIALux evo software simulation technology to simulate classroom light. Environmental characteristic parameters, and various optimization strategies are put forward. Jiawei Han [13] simulates the lighting and sunshade in winter and summer in typical classrooms of a university in Xi'an, and puts forward suggestions to improve the quality of the light environment. In addition, Daqiang He's research [14] shows that in the design of indoor natural light environment, effective light environment treatment techniques can be explored by ensuring the balance of brightness distribution, avoiding glare, and cleverly using sunshade facilities.

In the previous research, not many studies have been conducted to comprehensively evaluate the quality of light environment and energy consumption in university classrooms from a "dual carbon" perspective. Therefore, the purpose of the article is to evaluate and optimize the design of the light environment of a university in Henan from the perspective of energy conservation, using the combination of subjective and objective methods, and adopt software simulation analysis, and provide reference for solving such problems.

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## 2. Subject of Study

The current state of the light environment experiment selected Classroom 2501 of Henan Polytechnic University in Jiaozuo City as the research object, and measured by an illuminometer (model JTG01). Lighting experimental measurements are carried out in all cloudy days, and lighting experimental measurements measure the full light on at night. The surveyor's clothes are dark and do not block the light receiver.

When collecting lighting and lighting experimental data, natural lighting measurement points (see Figure 1) and artificial lighting measurement points (see Figure 2) are arranged in the classroom, and the illuminance values are measured during the day and night respectively, and the following lamp layout is drawn (see Figure 3). It is determined that the measuring plane is 0.75 m away from the ground. Record each illuminance value in the table and find the average illuminance value of the whole measurement range.

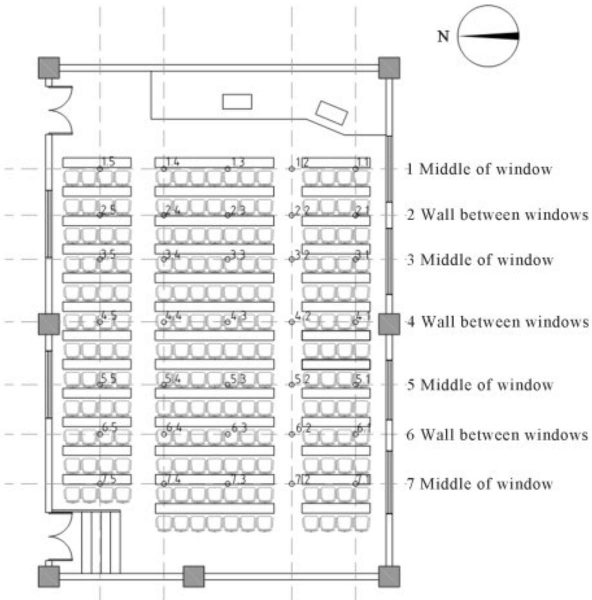


*Figure 1: Distribution of points for natural lighting.*

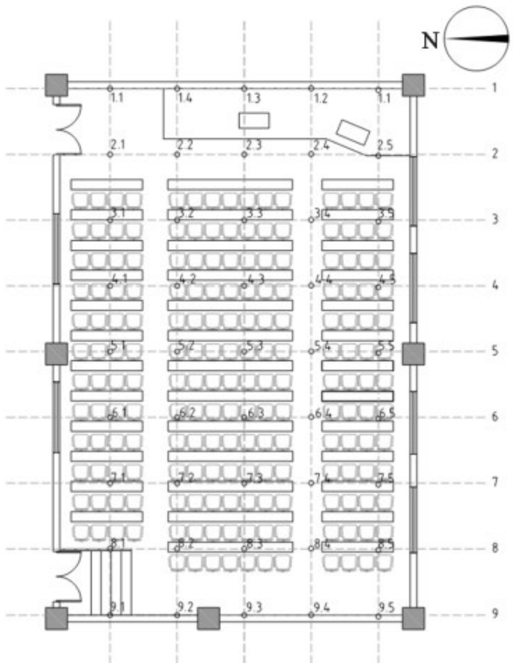


*Figure 2: Artificial lighting measurement points.*

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*Figure 3: Artificial lighting fixture distribution.*

## 3. Subjective and Objective Analysis of the Light Environment in the Classroom

### *3.1. Objective Analysis*

#### *3.1.1. Natural Lighting*

Under natural lighting conditions, the lighting environment of the classroom is evaluated according to GB 50033-2013 Architectural Lighting Design Standards [15]. Through the calculation and statistics of experimental data, it is concluded that under natural lighting conditions, the average lighting coefficient is Cav=3.35%, which is close to and meets the standard value of 3.00%. However, the measured average illuminance of the classroom under natural lighting conditions is Eav=267.4 lx, which is much smaller than the standard value of indoor natural illuminance of 450 lx, and the illuminance uniformity U=0.21. Natural lighting in the classroom is difficult to meet the natural lighting standards in the classroom, so the illumination distribution law under natural lighting conditions should be deeply explored, and certain methods should be used to improve lighting.

Compared with the horizontal and longitudinal profile of the color scale of the classroom (Figure 4), it is found that with the increase of the distance from the outer window, the lighting coefficient of each column of measurement points is getting smaller and smaller, and only if it is closer to the window can meet the needs of the light environment. At the same time, the lighting coefficient of the window wall is less than that of the window, it can be seen that there is no direct lighting place (such as the window wall) to the working face. Illuminance has a significant impact. To sum up, the illumination level and uniformity in the classroom under natural lighting are not optimistic.

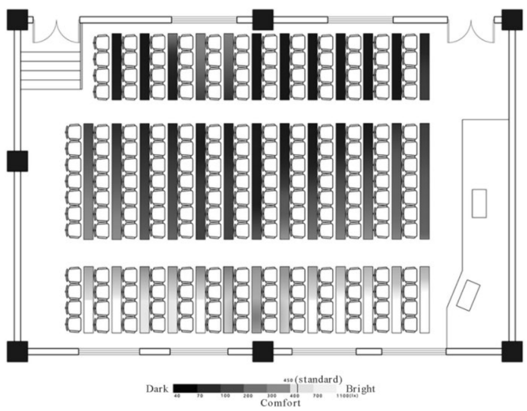


*Figure 4: Average illuminance level diagram of natural lighting working surface.*

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#### *3.1.2. Artificial Lighting*

Under artificial lighting conditions, according to GB 50034-2013 Architectural Lighting Design Standard [16], the uniformity of classroom desktop illumination shall not be less than 0.6, and the desk illumination of the classroom should not be less than the standard value of 300 lx. Through the calculation and statistics of experimental data, it is concluded that the average illumination of the classroom Eav=137.114 lx and the uniformity U=0.519 do not meet the requirements of the specification.

Compared with the average illuminance data of each measurement point in the color scale of the classroom, it is found from Figure 5 that with the rise of the seats in the ladder classroom, the relative position of the lamps and the working face decreases, and the illuminance of the working face is significantly enhanced, indicating that a reasonable lamp height can improve the lighting environment to a certain extent.

Compared with the average illuminance data of each measurement point in the cross-section of the classroom color scale diagram, it is found that the illuminance and uniformity of the position in the middle of the classroom is relatively high, and the illumination of the positions on both sides are low and the uniformity is poor. Therefore, under the condition of manual lighting, the middle of the classroom with double-sided light source lighting has the highest illumination, and the surrounding position of the classroom with only one-sided light source lighting is relatively small, which also provides a reference basis for students to choose their seats and the layout design of the working face.

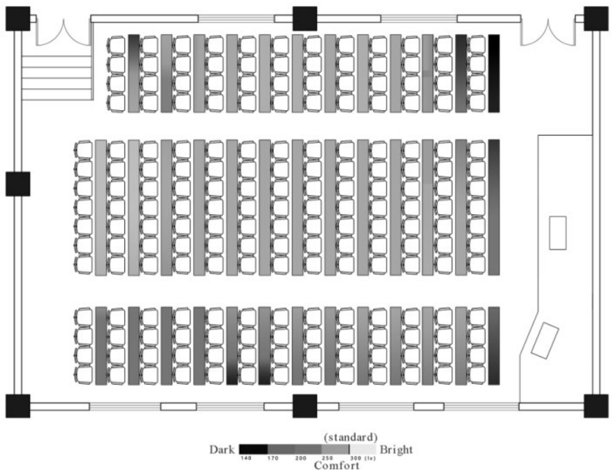


*Figure 5: Average illuminance level diagram of artificial lighting working surface.*

### *3.2. Subjective Analysis*

This subjective analysis uses an online questionnaire. The problem revolves around the uniformity and comfort of light in the classroom. The survey object is all teachers and students on the North Campus of Henan University of Technology. A total of 236 questionnaires were received and 208 valid questionnaires were screened, with an efficiency of 88.14%.

#### *3.2.1. Natural Lighting*

Under natural lighting conditions, the voting results of subjective satisfaction of the classroom lighting environment are shown in Figure 6. Among the people who participated in the voting, the proportion of students who were satisfied with the overall light environment of the classroom, the blackboard and the desk of the class were less than 5.00%, while those who felt moderate were more than 50.00% were dissatisfied. The proportion of students is from 40.00% to 50.00%.

In response to the question of whether natural lighting meets the needs of students, the source of the analysis questionnaire shows that the seats of students who are acceptable or satisfied with the lighting in the classroom are located on the side of the outer window in the middle, which can get enough light and will not be dazzling by direct sunlight. Most of the students who are dissatisfied are located on the outermost side and near the inner porch, and the light will be too dazzling or dim. Among them, the seats of students who think that the classroom are too dark are mainly located on the side of the internal corridor far away from the outer window, and they can receive less natural lighting; those who think

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that the classroom seats are too dazzling are mainly located near the outer window. On the side, too much outdoor natural lighting is obtained before and after noon.

It can be seen that classroom 2501 needs to increase the amount of natural lighting, improve the brightness of the working face, blackboard and even the classroom; ensure the uniformity of lighting and reduce direct outdoor light, and further borrow appropriate lighting assistance to build a comfortable light environment.

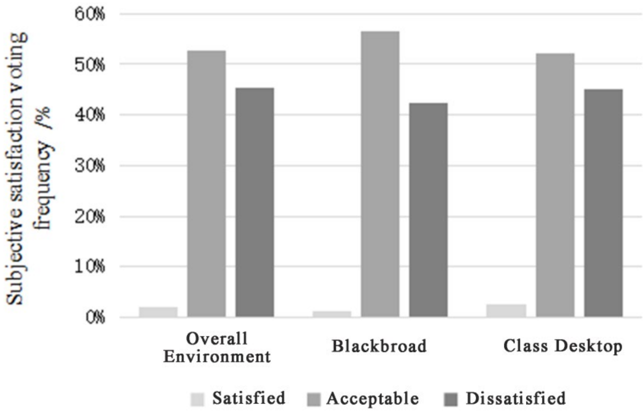


*Figure 6: Subjective satisfaction poll of light environment.*

### *3.2.2. Artificial Lighting*

Under the conditions of manual lighting at night, as shown in Figure 7, 56% of students think that the subjective feeling of the light environment in the classroom is poor, 48% think that the color development of the lamps is poor, and only about 20% think that the light environment and color development are better, which has little impact on the learning state. When voting on the subjective expectation of artificial light brightness, 42% of students believed that the overall light environment of the classroom was dim and needed to improve the overall brightness.

The source of the questionnaire found that the seats of the satisfied students are in the middle of the classroom, and the overall vision and lighting brightness are better; while students with dark evaluations, their seats are basically close to the outer window or the side of the inner corridor, and the light source is insufficient. Students who have a brighter evaluation of the classroom lighting environment, their seats are basically in the middle of the classroom, and the light from the surrounding lamps superimposed to form an overly bright local area. It can be seen that under the subjective night artificial lighting conditions, 2501 classroom needs to improve the overall brightness of the classroom while ensuring the uniformity of classroom lighting.

In addition, from its management point of view, the lamps in the classroom are not often replaced or repaired, so it can be considered that the lamps are aging due to excessive service life or insufficient illumination in the classroom due to long-term unclean ash accumulation.

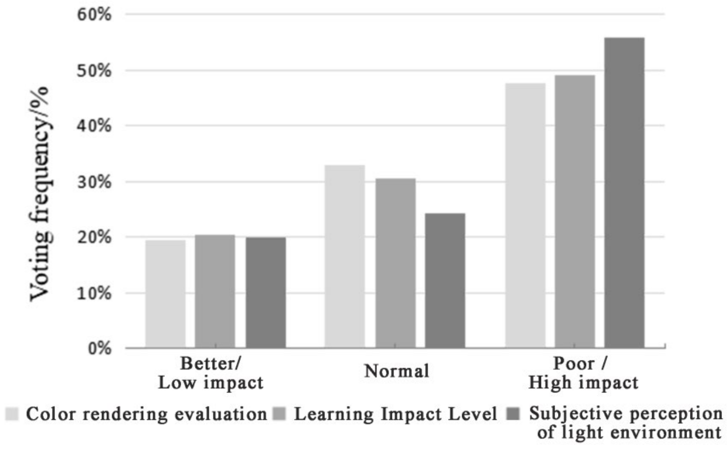


*Figure 7: Classroom artificial lighting use evaluation frequency distribution.*

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To sum up, the subsequent improvement of indoor lighting environment can not only start with the overall brightness and uniformity of the classroom in the morning and evening, but also give due consideration to the lighting parameters of the classroom itself, artificial lighting parameters and lamp management.

## 4. Optimization Strategy Simulation based on DIALux Software

In order to further and accurately analyze the current situation of the classroom light environment, based on the existing classroom and lighting information, the DIALux software simulation of classroom 2501 was carried out. Under the condition of ensuring the feasibility of simulation, a reasonable optimization strategy is summarized through the analysis of experimental data. At the same time, the corresponding simulation of the optimization strategy is carried out to make the indoor light environment meet the standard while achieving more energy-saving.

### *4.1. Simulation Construction*

Before the simulation, the light reflection ratio ρ and light transmission ratio ζ are measured on various materials in the classroom (see tables 1 and 2 for experimental data), and according to the experimental data, materials are given to the desktop, floor, etc. in DIALux software to make them more consistent with the actual classroom parameters.

*Table 1: Experimental data on light reflectance of various materials.*

| Material | Color | Light reflection ratio ρ average |
|---|---|---|
| Blackboard | Black | 0.092 |
| Wooden table top | Yellow | 0.194 |
| Terrazzo flooring | Black, white and grey | 0.258 |
| Wooden door | Red | 0.177 |
| Plastered wall | White | 0.626 |

*Table 2: Experimental data on the transmittance ratio of glass materials.*

| Material | Color | Light transmission ratio ζ average |
|---|---|---|
| Glass window | Transparent | 0.779 |

According to the research data, the classroom lamp adopts a Foshan-illuminated LED LINEAR LIGHT lamp, model FSB143S-36, and the lamp distribution map is shown in Figure 8. The lighting curve and related parameters of lamps available from DIALux lamp network are shown in Figure 9. The luminaire used is rated at 2×18 W, with a total luminous flux of 2700 lm and a length, width and height of 1200 mm, 70 mm and 70 mm, respectively. According to the actual situation of the site, the lighting environment of the classroom is simulated (see Figure 10).

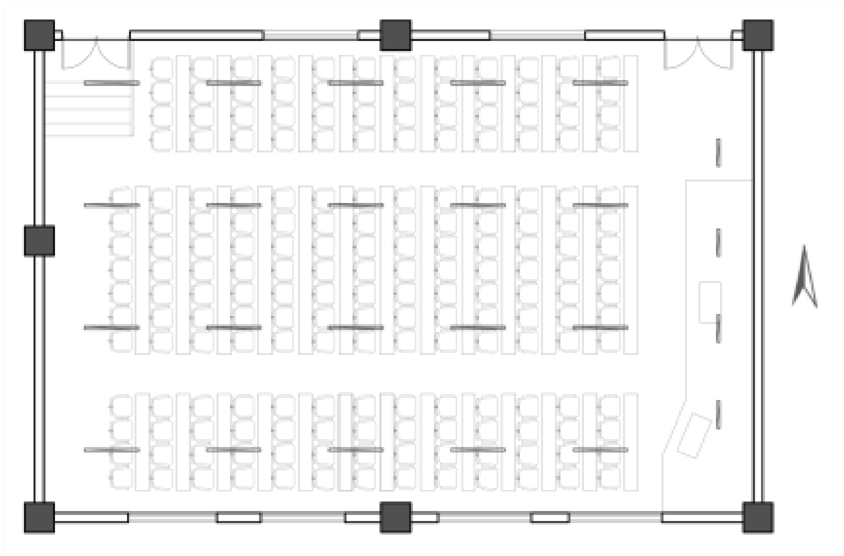

*Figure 8: Layout of classroom lighting environment for simulations.*

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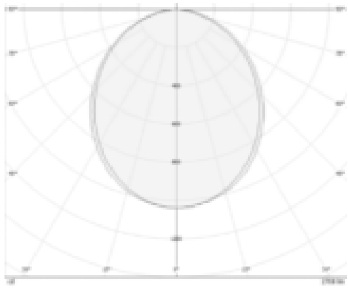

| Type | Power Rating | Total luminous flux | Light effects | CCT | CRI |
|---|---|---|---|---|---|
| LED | 36W | 2600lm | 75lm/W | 6000K | 80 |

*Figure 9: Light distribution curves and related parameters.*

*Figure 10: 3D diagram of classroom lighting environment for simulations.*

By comparing the measured and simulated color scale diagrams, it is found that the measured natural lighting and artificial lighting conditions of the working face illumination color scale map (see Figures 4 and 5) are basically consistent with the distribution trend of the working face illuminance color scale map (as shown in Figures 11 and 12) under the same conditions obtained by software simulation. Therefore, DIALux approximation can be used instead of measured data for simulation analysis.

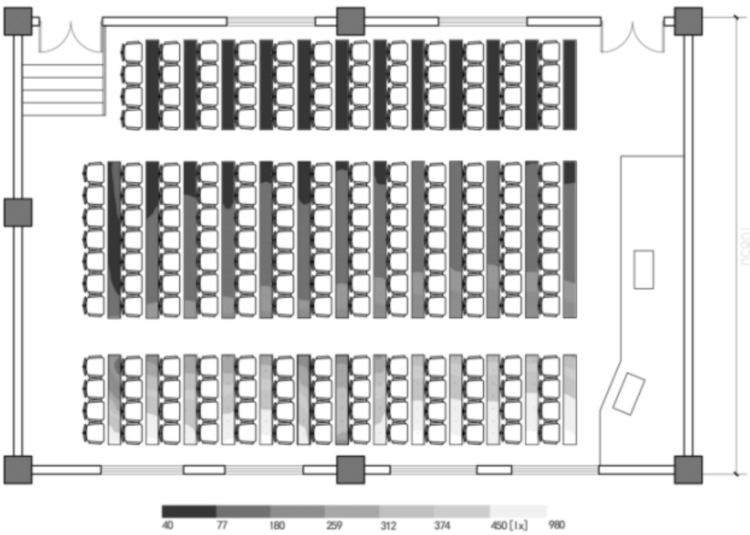


*Figure 11: DIALux simulates classroom illumination in natural lighting.*

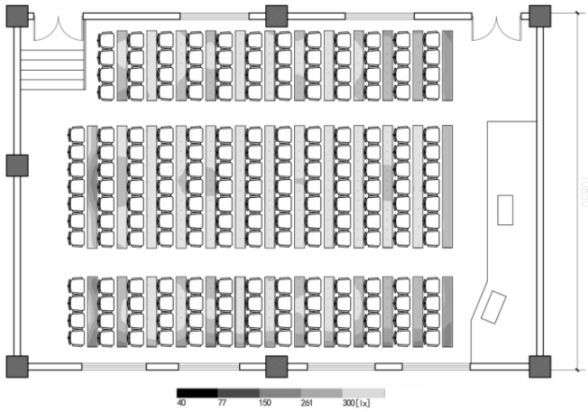

*Figure 12: DIALux simulates classroom illumination under artificial lighting.*

In the actual calculation of 2.1, it can be seen that under natural lighting and artificial lighting conditions, the average illuminance of the classroom is 267.4 lx and 137.1 lx respectively. The current situation simulation calculation using DIALux shows that the average illumination of the classroom under natural lighting and artificial lighting conditions is 342 lx and 290 lx. Through analysis, it can be seen that the lighting environment of the classroom may be affected by glass ash and light changes under natural lighting conditions, so that the measured and simulation results are different, but the gap is relatively small. Under artificial lighting conditions, it may be affected by management problems such as falling ash and aging of lamp tubes, so that the actual measurement and simulation results are quite different, but even if under such ideal circumstances, the average illumination still does not meet the normative requirements. To sum up, the light environment of the classroom does not meet the standard requirements under the condition of natural lighting and artificial lighting, and it urgently needs to be improved.

At the same time, it can be seen from Figures 11 and 12 that the classroom has certain defects in terms of illumination uniformity and intensity.

(1) Under natural lighting conditions, the indoor illuminance attenuates too much along the direction of depth, the window-side area is too strong, and the middle and wall areas are dark. The uniformity of illumination and the intensity of the middle and wall areas urgently need to be improved.

(2) Under artificial lighting conditions, the light environment in the middle and back areas is relatively good, but the lighting on both sides and front rows is relatively weak, and the overall lighting uniformity of the classroom needs to be further improved.

### *4.2. Optimization Measures*

Based on the above subjective and objective analysis of the current situation of the light environment, DIALux simulation software is used to improve the indoor light environment from the design method level by changing the configuration of the light environment in the classroom, instead of meeting the standard by increasing the power of the light source in the traditional sense, so as to reduce energy consumption. The purpose. Through software simulation simulation, the changes of lighting indicators under different optimization measures are calculated [17] and their feasibility is analyzed.

#### *4.2.1. Window Wall*

Through the analysis of 3.1.1 natural lighting experimental data and the analysis of 3.2.1 natural lighting environment satisfaction, it can be seen that the window wall will make the illumination near the window uneven, which is easy to form natural lighting glare and affect the lighting quality of the classroom. If the optimization method of increasing the width of the window is adopted, the width of the window wall can be reduced while increasing the window-to-ground ratio. The size of the window-to-ground ratio is directly proportional to the indoor illuminance and uniformity of the building. Generally speaking, the larger the window-to-ground ratio, the more conducive it is to indoor lighting. In order to verify the feasibility of this optimization measure, the optimized scenario is simulated and compared with the current simulation results before optimization (the data comparison results are shown in Table 3, and the color scale diagram comparison is shown in Figure 13).

Through comparison, it can be seen that reducing the width of the wall between the window can improve the indoor illumination and increase the uniformity of the illumination. However, with the increase of the size of the window, the illumination near the window will also be greater, and the problems caused by overheating and glare cannot be ignored. Therefore, changing the window size can optimize the indoor lighting quality to a certain extent, but it will also bring certain building energy consumption problems. Therefore, according to the actual situation, a relatively suitable window-wall ratio should be selected from the aspects of lighting and energy conservation.

*Table 3: Comparison of data before and after changing the window-to-wall ratio for natural lighting.*

| | Window size | Window-to-wall ratio | Window-to-ground ratio | Average illuminance/lx |
|---|---|---|---|---|
| Before Optimization | 2.4 m×2.3 m | 28% | 1/7 | 342 |
| After Optimization | 2.6 m×2.3 m | 30% | 1/6 | 412 |

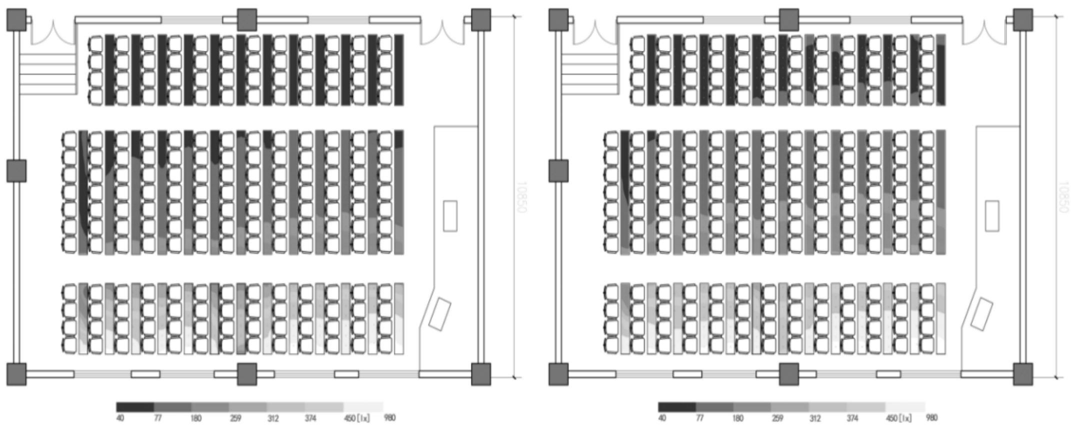

*Figure 13: Comparison of illumination color scale before (left) and after (right) changing the window-wall ratio when natural lighting is applied.*

***4.2.2. Lamp Height***

The article in 3.1.2 artificial lighting experimental data analysis mentioned that as the seat in the step classroom rises, the relative position of the luminaire and the working surface decreases, and the working surface illumination in significantly enhanced. It can be seen that if the relative position of the lamp and the working face is always maintained at a reasonable height, the lighting environment can be improved to a certain extent. In the software, the height of the lamp is adjusted according to the height of the working face, so that the vertical distance of the lamp to the desktop is equal, and the rationality of this measure is verified by simulation. Simulation calculations show that the average illuminance of the working face is Eav=305 lx >300 lx, and the illuminance color scale diagrams before and after optimization are compared (as shown in Figure 14). The results show that adjusting the height of the lamp has a certain effect on improving the average illuminance and illuminance uniformity, but it is not significant.

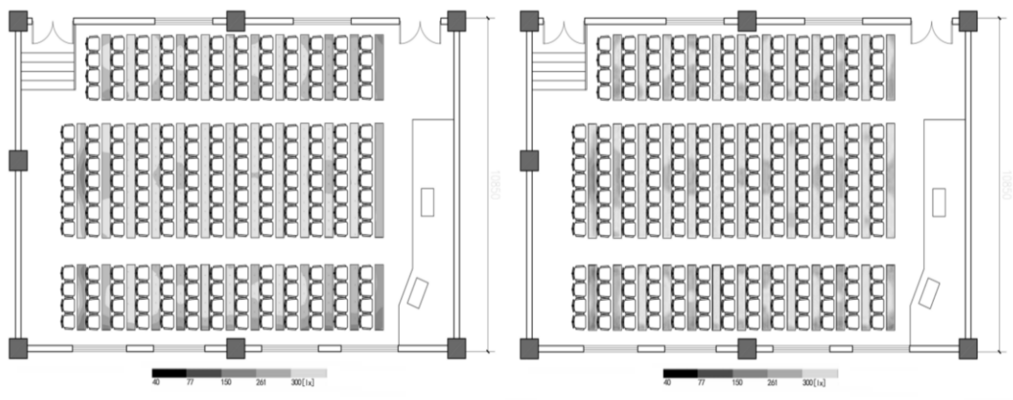

*Figure 14: Artificial lighting when adjusting the height of the lamps before (left) after (right) illumination color scale comparison chart.*

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#### *4.2.3. Lighting Layout*

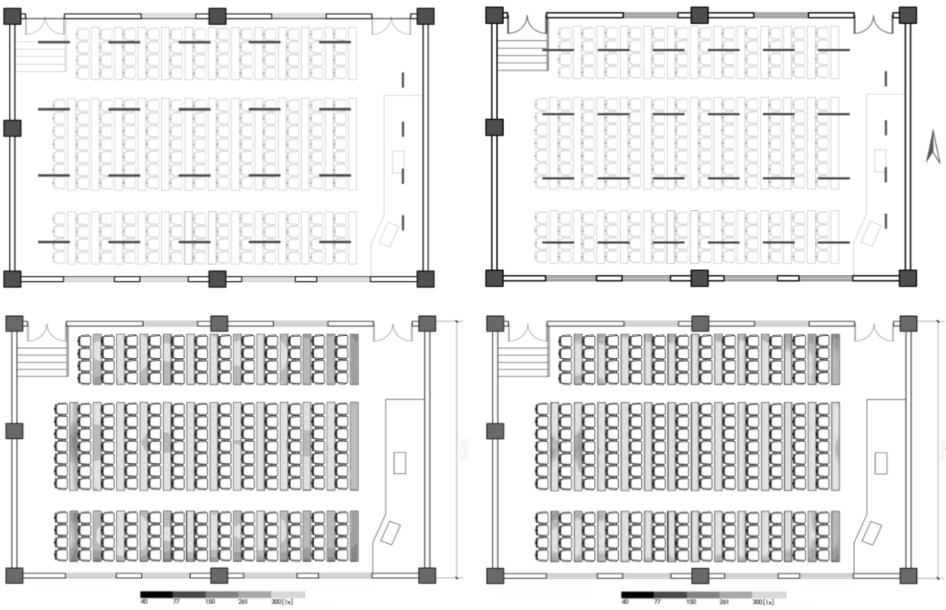

*Figure 15: Before (left) after (right) changing the distribution of lamps illumination color scale comparison chart.*

From the satisfaction of the artificial lighting experiment on 3.2.2 and the 3.2.2 artificial lighting environment, it can be seen that the position of the light source also has a certain impact on the indoor light environment, and different lighting layout methods will also bring people a different light experience. Tables and chairs in the classroom are usually arranged regularly. The lamps can be evenly arranged above the working face such as tables and chairs. The spacing and height between the lamps between the light sources should meet the height ratio, so as to ensure the illuminance and uniformity of the working face. In order to make the lamps more concentrated and evenly distributed above the working surface, shorter lamps can be selected. Use software to rearrange the lamps in the classroom (as shown in Figure 15) and calculate its feasibility through software simulation.

Using software to calculate, you can get the average illuminance of the working face before optimization. Eav=290 lx<300 lx does not meet the standard. After optimization, the average illuminance of the working face Eav=320 lx>300 lx meets the standard. By comparing the illuminance color scale diagram before and after optimization (as shown in Figure 15), the uniformity of the optimized working face has been greatly improved. Therefore, even if the number, power and color temperature of lamps do not change, the indoor lighting environment can be improved to a certain extent by improving the layout of lamps and making the lamps more evenly distributed on the working surface.

#### *4.2.4. Hybrid Lighting Optimization*

*Table 4: Minimum luminaire dimming factor value when meeting illumination standards.*

| Scene | | | Average illuminance/lx | Lamp dimming index/% | | |
|---|---|---|---|---|---|---|
| | | | | By window | Middle | By wall |
| Current status | No modification | Fully open | 581>450 | 100 | 100 | 100 |
| | | Partition adjustment | 508>450 | 0 | 90 | 100 |
| Optimization | Change window size | Fully open | 612>450 | 100 | 100 | 100 |
| | | Partition adjustment | 532>450 | 0 | 70 | 100 |
| | Change fixture arrangement | Fully open | 620>450 | 100 | 100 | 100 |
| | | Partition adjustment | 495>450 | 0 | 70 | 100 |

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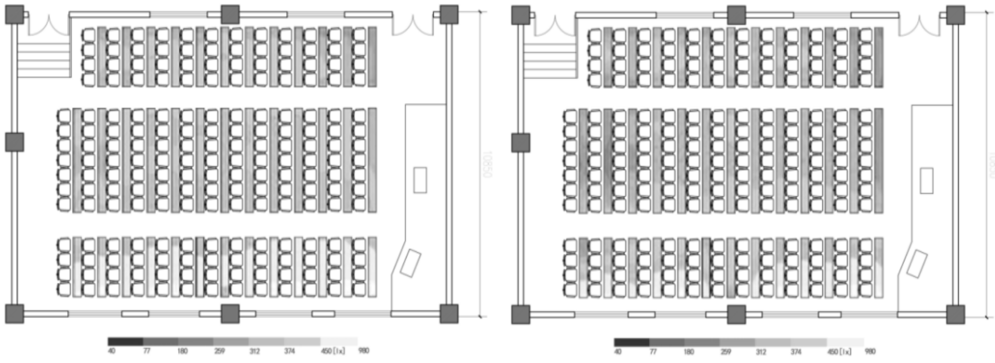

*Figure 16: Mixed lighting when the light is fully open (left) and light partition adjustment (right) illumination color scale comparison chart.*

Under natural lighting conditions, the illuminance standard value required by the national standard is 450 lx, and the calculation of 2.1 and the questionnaire survey results of 2.2 show that natural lighting alone generally cannot meet the standard, so mixed lighting is often used to supplement certain manual light during the day. The existing light switching group is the blackboard area along the opening direction and the front, middle and rear four areas. Under the mixed lighting conditions that need to be filled during the day, the light switch group that still adopts the opening direction obviously does not meet the trend of illuminance attenuation, so it can be adjusted to the light switch group in the window, middle and wall along the depth direction for manual. Make up the light. When supplementing light, it can be partitioned and supplemented regularly according to the trend of illuminance attenuation, so that the energy consumed in each inch can achieve maximum benefit.

Under the condition of mixed lighting, through simulation of full light on and partition light supplementation in various scenes, it can be seen from the comparison between the data (see Table 4) and the color scale diagram (as shown in Figure 16), zoning can improve the quality of the light environment in the classroom in a more accurate and energy-efficient way, and can effectively improve the uniformity of illumination caused by the side windows to meet the needs of teaching and self-study.

#### *4.2.5. Management and Maintenance*

By comparing the results of the 3.1 experimental data with the simulation calculation of the current situation of 4.1, it can be seen that regular cleaning can greatly improve the light environment of the classroom. This shows that in terms of management and maintenance, serious dusty windows, broken lamps, and serious dust pollution of lampshades should be replaced in time. Users should standardize and manage the use of lamps, eliminate lamps at any time, increase the service life of lamps, reduce energy consumption, and improve the quality of classroom lighting environment.

## 5. Conclusion

Through objective on-site measurement, subjective questionnaire survey and software simulation, this study evaluated the light environment of classroom 2501 of Henan Polytechnic University. From subjective and objective analysis and software simulation results analysis, a variety of feasibility optimization strategies were obtained, so as to achieve the standard of comfortable and energy-saving classroom light environment and improve the university classroom. Directions and measures provide reference.

Under the condition of natural lighting, according to the law of illuminance attenuation under single-sided window lighting, indoor illuminance uniformity and average illuminance can be improved by adjusting the wall, partition light supplementation and other methods, so that sunlight can be fully utilized, and manual light supplementation can also be controlled at different times, so as to reduce energy consumption. Under artificial lighting conditions, the indoor lighting environment can be improved by adjusting the height of lamps and the layout of lamps. Under the condition of not changing the power of lamps, the indoor environment can meet the standard requirements. In addition, it is necessary to strengthen the maintenance and management of facilities at all times, improve the indoor lighting environment, and maximize the service life of lamps.

To sum up, by making full use of natural and artificial light, choosing more reasonable classroom parameters and artificial lighting schemes, we can optimize the comfort of the classroom light

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environment and create a good learning environment for students. At the same time, in terms of energy conservation and emission reduction, it can also improve the utilization rate of natural lighting and artificial light, reduce the energy consumption of lighting, improve the energy utilization efficiency of buildings, and contribute to China's energy conservation and emission reduction.

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