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Study on the Evaluation of Projector Imaging Quality and its Influence on Students' Reading Effect

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Abstract

This study evaluates projector imaging quality and its impact on students' reading effectiveness through experiments in multiple classrooms. Using a nine - point grid method, it analyzes illumination distribution characteristics of projectors. Results show significant differences in illumination uniformity and stability among projectors. Uneven illumination can increase visual fatigue and reduce reading efficiency. When edge - center illumination difference exceeds 100 lux, reading speed drops by 15% - 20%. Projector aging also reduces contrast and color gamut coverage, affecting character recognition. The study introduces a multi - dimensional evaluation method and develops an intelligent analysis platform, providing a scientific basis for projector selection, maintenance, and use in educational institutions to optimize teaching environments and enhance learning outcomes.

Keywords

Projector Imaging Quality; Illumination Uniformity; Students' Reading Effect.

1. Introduction

In the modern education system, projector is a key teaching tool, and its imaging quality directly affects the presentation effect of teaching content and students' reading experience. With the aging of the projector, its imaging quality may decline, thus affecting students' learning effect and visual health.[1] At present, many educational institutions lack scientific basis in the selection, maintenance and use of projectors, which leads to uneven illumination distribution and unstable imaging quality in the teaching environment. The purpose of this study is to evaluate the imaging quality of projector and its influence on students' reading effect through systematic experimental design and data analysis.

The evaluation of projector quality has become a critical research area within display technology. Current methodologies include both subjective and objective approaches. Subjective evaluation relies on human observers, using questionnaires or expert ratings to assess aspects like image sharpness, color fidelity, and visual comfort. However, this method is susceptible to individual biases. On the other hand, objective evaluation uses mathematical models and physical measurements. Researchers apply quantitative metrics such as Root Mean Square Error (RMSE), Peak Signal-to-Noise Ratio (PSNR), and Structural Similarity Index (SSIM) for precise analysis. Advanced tools like DisplayMate and RayClouds enhance the evaluation process by offering comprehensive testing solutions.[2]

In modern educational settings, the quality of projectors significantly impacts students' learning efficiency. High-resolution projectors with superior contrast ratios and color accuracy provide clear and authentic visual content, enhancing students' ability to rapidly and accurately acquire information.[3] For example, sharp images facilitate the interpretation of charts and graphics, and precise color representation improves teaching outcomes in disciplines such as art design and biology. Boby A. R. et al. focused on calibration and statistical techniques for

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building interactive screens for children's alphabet learning, showcasing the potential of advanced technologies in educational settings.[7] Wang et al. developed an intelligent analysis platform for projector illumination data based on image processing, which simplifies the measurement process and improves the efficiency and accuracy of data acquisition. Lee et al. studied the influence of projector imaging quality on students' learning effect from an interdisciplinary perspective, highlighting the importance of projector performance in educational environments.Furthermore, the brightness and screen size of projectors are crucial factors affecting visibility and student engagement. In well-lit classrooms, insufficient brightness can render images indistinct, while small screen sizes compromise the viewing experience for students seated at the back. Empirical studies have demonstrated that high-quality projectors significantly increase classroom participation and learning enthusiasm. They enable faster information acquisition and better knowledge retention, thereby ameliorating overall learning efficiency. Conversely, low-quality projectors can cause visual strain, distract students' attention, and potentially impair eyesight over time, which in turn adversely affects both learning efficiency and students' health.[5]

This study systematically addresses three core research objectives. Firstly, it evaluates the illumination distribution characteristics of projectors across diverse classroom settings, employing the standardized nine-grid measurement method coupled with comprehensive data analysis to quantify uniformity and stability. [4]Secondly, the research investigates the impact of projector aging on imaging quality parameters and analyzes its subsequent effects on students' reading effectiveness and visual comfort. Thirdly, based on empirical findings, optimization strategies for projector usage and maintenance protocols are formulated to enhance overall teaching environment quality.All evaluations strictly adhere to the GB/T 28037-2011 national standard, utilizing illuminance meters for systematic assessment. The measurement protocol incorporates critical controls: standardized test charts (100% all-white and 0% all-black) for quantifying light output, contrast, and uniformity; a rigorously maintained test environment with background illumination below 5 lux to minimize ambient interference; and stabilized power supply voltage to ensure consistent equipment performance during testing.

2. Experimental Design and Result Analysis

2.1. Experimental Design

In this study, projectors in multiple classrooms were selected, and the illumination data were collected systematically by measuring the illumination values of nine grids. [6]At the same time, the imaging photos under the corresponding conditions are taken to provide visual reference for data analysis. The experimental design includes the following steps:

Adjust the projector and use a 100% all-white test chart.

According to the nine measuring points (1~9 points) shown in Figure 2, measure and record the illuminance value of each point.

Calculate the light output value using Formula (1):

$$\Phi = \frac{\sum_{i=1}^{9} E_i S}{9} \tag{1}$$

Where φ is the light output of the projector, with the unit of lumen (lm); E_i I is the illuminance value of the I-th measuring point, in lux (LX); S represents the projected image area in square meters ().E_i m^2).

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Using 100% all-white and 0% all-black test charts, the illuminance values of nine measuring points were measured and recorded.

Calculate the contrast using Formula (2):

$$\text{Contrast}=\frac{\text{The average illuminance value of the all−black image}}{\text{The average illuminance value of the all−white image}} \tag{2}$$

Using 100% all-white test chart, measure and record the illuminance values of nine measuring points.

Calculate the uniformity of light output using Formula (3):

$$\text{Uniformity of light output}=\frac{\text{Maximum illuminance}}{\text{Minimum illuminance value}} \tag{3}$$

Illumination distribution map of nine grids: measure and record the illuminance values of nine grids, and evaluate the illuminance distribution uniformity of the projector.

Histogram of light output measurement value: visually display the light output value of different measurement points and analyze its stability and uniformity.

Illuminance deviation and standard deviation diagram: Evaluate the deviation and standard deviation of illuminance value and determine the stability of illuminance distribution.

Mean error line chart: show the mean value of illumination value and its error range, and analyze the reliability of data.

Correlation analysis diagram of illuminance between grid points: Quantitatively analyze the correlation of illuminance at different positions.

Illuminance distribution histogram and cumulative distribution map: evaluate the distribution characteristics and cumulative distribution of illuminance values.

Illuminance distribution radar chart: display the illuminance distribution of nine measuring points directly and analyze its uniformity.

Comparison between illuminance value and imaging quality Line chart+photo illustration: Combining line chart and photo, analyze the influence of illuminance value on imaging quality.

Illuminance value heat map+image quality contrast photo wall: visually present the distribution of illumination value of nine grids and its influence on image quality.

2.2. Experimental Comparison

In the experiment, projectors in multiple classrooms were selected, and the illumination data were collected systematically by measuring the illumination values of nine grids. At the same time, the imaging photos under the corresponding conditions are taken to provide visual reference for data analysis. The experimental results show that there are significant differences in illumination distribution, uniformity and stability of projectors in different classrooms.

2.3. Analysis of Results

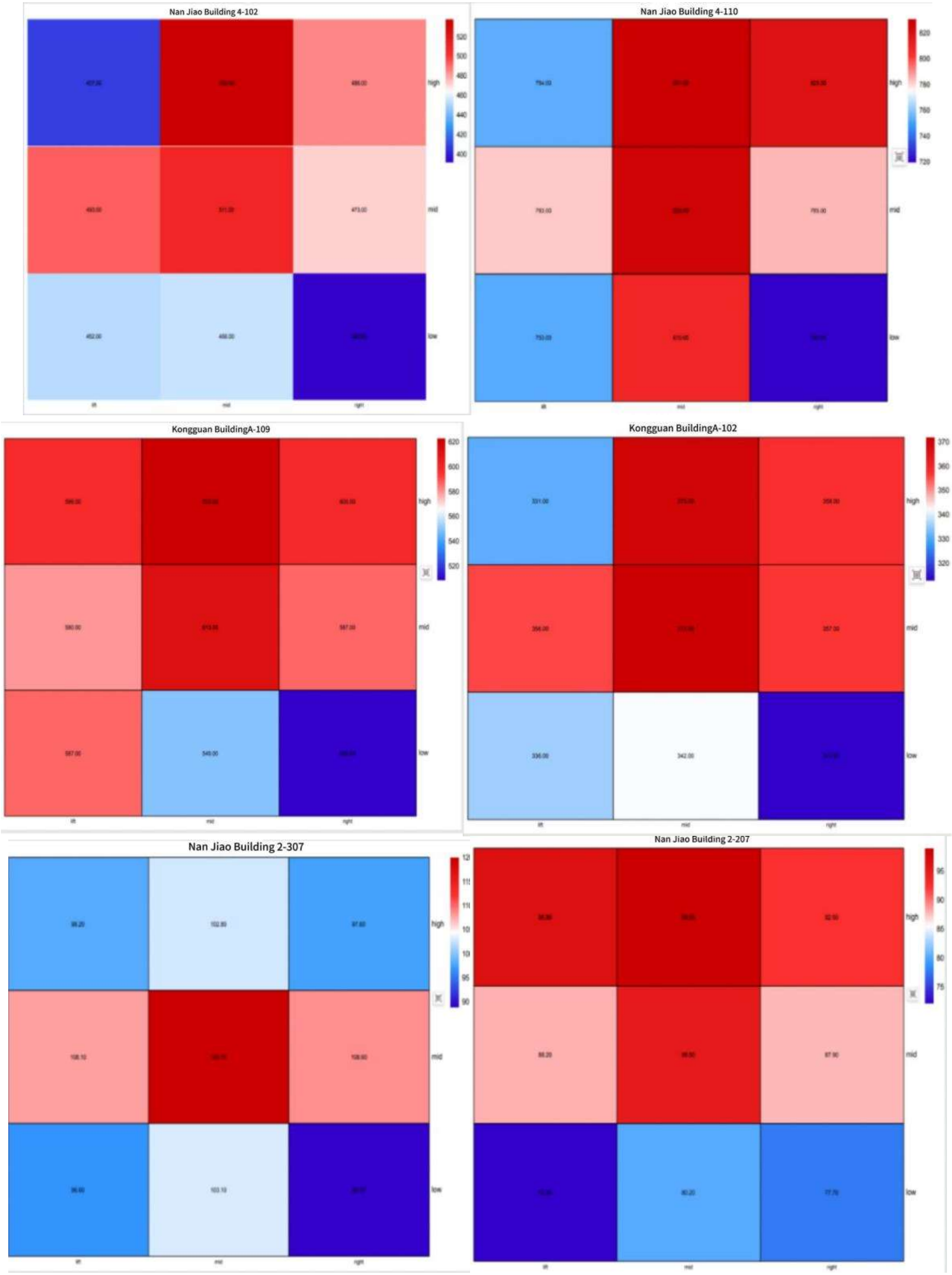
2.3.1. Qualitative Analysis

Through the visual observation of imaging photos, it is found that the imaging quality of projectors with uneven illumination distribution is significantly different in different areas. For example, the projector in the 110 classroom of Nanjiao No.4 has higher illumination values in the directions of 45 and 225, but lower illumination values in the directions of 135 and 315, resulting in inconsistent imaging quality.

2.3.2. Case Analysis

Taking the classroom of Nanjiao No.4 102 and Nanjiao No.2 207 as an example, this paper analyzes in detail the illumination distribution characteristics of its projectors and its influence on students' reading effect. The projector in No.102 classroom of Nanjiao No.4 shows uniform illumination distribution, which provides a stable reading environment for students. However, the projector in Room 207 of Nanjiao No.2 shows uneven illumination distribution, which may lead to significant differences in students' reading experience in different positions.

2.4. Visualization of Experimental Results



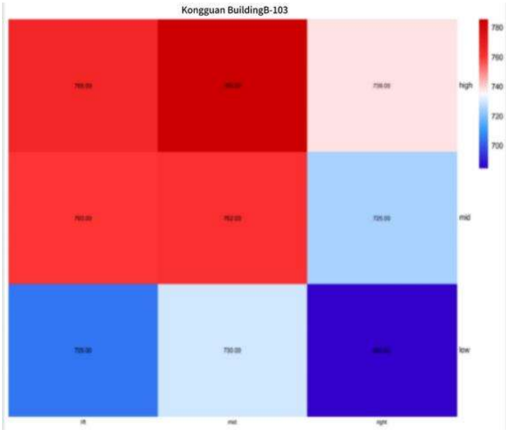


Figure 1. Illumination distribution map of nine grid points

Through various visualization tools such as line chart, histogram and heat map, the experimental results are displayed intuitively. For example, the illuminance values of the projector in the 102 classroom of Nanjiao No.4 are relatively stable at different measuring points, while the projector in the 110 classroom of Nanjiao No.4 shows great fluctuation.

In this study, through the detailed analysis of the illumination distribution maps of nine grid points of multiple classroom projectors, the performance of different projectors in the uniformity and stability of illumination distribution is deeply explored, which provides key data support for evaluating its influence on students' reading effect.

The projector illumination in Room 102 of Nanjiao No.4 is evenly distributed, and the illumination values of nine grids are concentrated between 400 and 500, specifically 407.00, 493.00, 452.00, 538.00, 511.00, 456.00, 486.00, 473.00 and 392.00. This uniform distribution ensures that students can enjoy a stable and consistent visual experience in different positions in the classroom, which greatly improves the reading efficiency and learning effect. The illuminance in the central area is slightly higher than that in the edge area, but the overall difference is small, indicating that the light output direction of the projector is consistent.

In contrast, there is a significant difference in projector illumination in the 110 classroom of Nanjiao No.4, with the illumination values of nine grids ranging from 720 to 831, specifically 754.00, 783.00, 753.00, 831.00, 828.00, 810.00, 820.00, 785.00 and 720.00. Uneven illumination distribution leads to great differences in students' reading experience in different positions, which affects their concentration and reading comfort. The illumination in the central area is higher, while the illumination in the edge area is relatively lower, especially in the directions of 45 and 225, and lower in the directions of 135 and 315, resulting in regional differences in imaging quality.

As an old equipment, the projector in Room 207 of Nanjiao No.2 has a large standard deviation and poor light output stability, with its nine grid illumination values fluctuating greatly, with an average value of 96.80. The illuminance in the central area is higher, but the illuminance in the edge area is lower, and the illuminance in the upper left corner and lower right corner is obviously lower than that in other positions. This low illumination and fluctuation may be due to the aging or insufficient performance of the equipment, resulting in limited light output capacity. It is necessary to further optimize the setting or replace the equipment to improve the stability and uniformity of light output.

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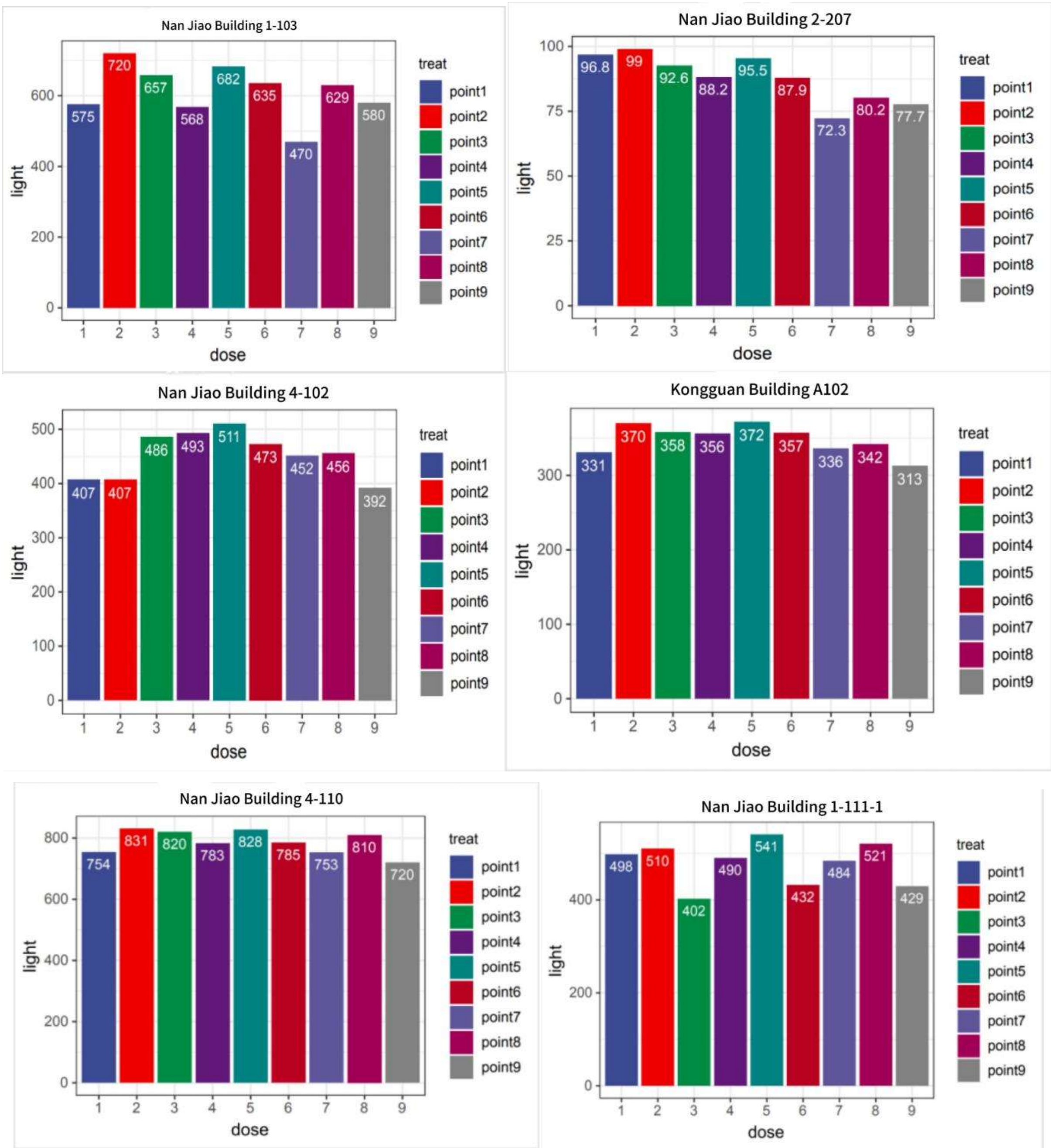

Figure 2. Histogram of light output measurement

In this study, through the detailed analysis of the histogram of light output measurement values of several classroom projectors, the performance of different projectors in terms of light output intensity and stability is deeply explored, which provides key data support for evaluating their influence on students' reading effect.

The projector in Room 103 of Nanjiao No.1 is particularly outstanding, and its measured light output is at a high level as a whole, with the maximum value reaching 720, which is significantly higher than most other classrooms. From the data distribution, the projector shows a relatively stable high-value state at different measuring points. For example, the measured value of point5 is 682, and the measured value of point7 is 629. These values are not only high in absolute value, but also stable in overall trend, and there is no big fluctuation or sharp decline. This shows that under the experimental conditions of this classroom, the projector can provide high-intensity light output continuously and stably. This excellent performance may benefit from many factors,

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such as the high quality of projectors, accurate installation and debugging, and reasonable optimization of classroom environment.

In sharp contrast with Nanjiao No.1 103, the projector in the classroom of Nanjiao No.2 207 is generally low, with the maximum value of 99, and most of the measured values are between 80 and 90. For example, the measured value of point1 is 96.8 and that of point3 is 92.6. The overall light output intensity is weak, which may be caused by many factors. On the one hand, it may be the aging or insufficient performance of the projector itself, which leads to its limited light output capacity; On the other hand, there may be many optical loss links in the experimental process, such as serious reflection and scattering in optical path transmission; In addition, it is also possible that the luminous efficiency of the experimental material itself is low and it cannot produce high-intensity light output.

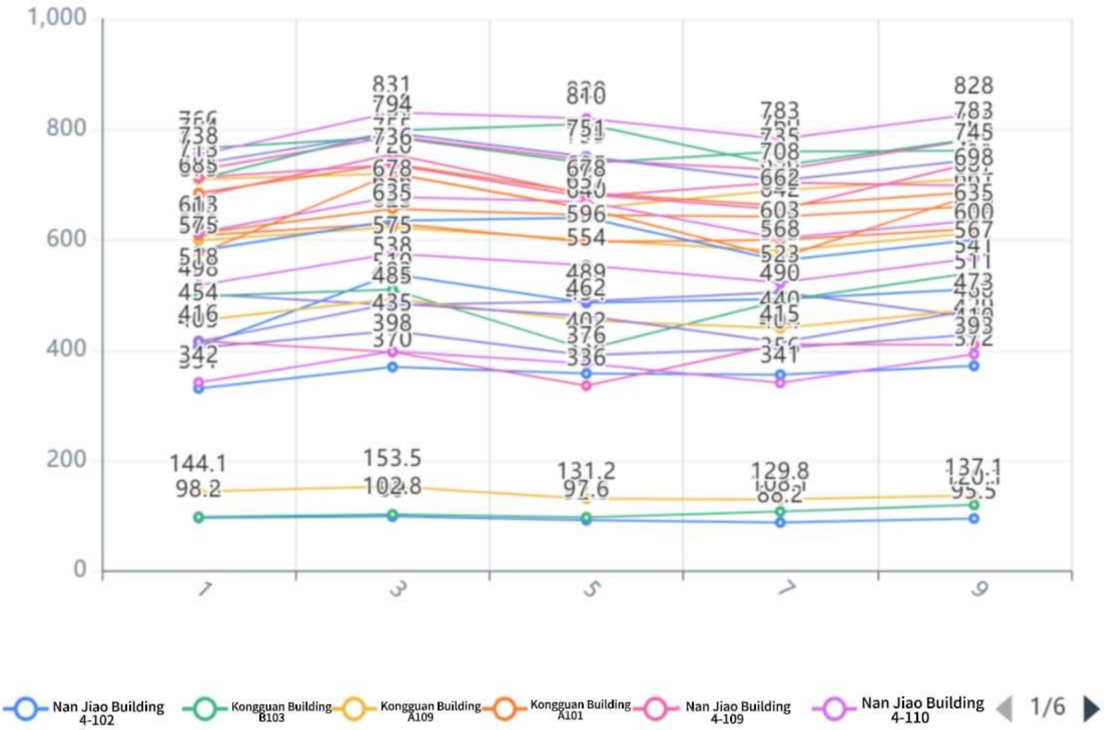

Figure 3. Light output uniformity line chart

Combined with the analysis results of light output uniformity line chart, the performance of projectors in different classrooms can be evaluated more comprehensively. The projector in Room 102 of Nanjiao No.4 provides students with a high-quality reading environment with its stable light output. However, the projectors in Room 110 and Room 207 of Nanjiao No.4 and Nanjiao No.2 may affect students' reading experience because of their large fluctuations in light output, so improvement measures should be taken. As an old equipment, classroom 207 in Naner is limited in light output capacity, so it is recommended to update or maintain it. Projectors in other classrooms also have their own characteristics, and some need to optimize the setting or adjustment of ambient light conditions to improve the stability and consistency of imaging quality and ensure that students can enjoy a good reading experience in different positions. These findings provide an important reference for educational institutions in the selection, maintenance and use of projectors, which is helpful to optimize the teaching environment and improve the learning effect of students.

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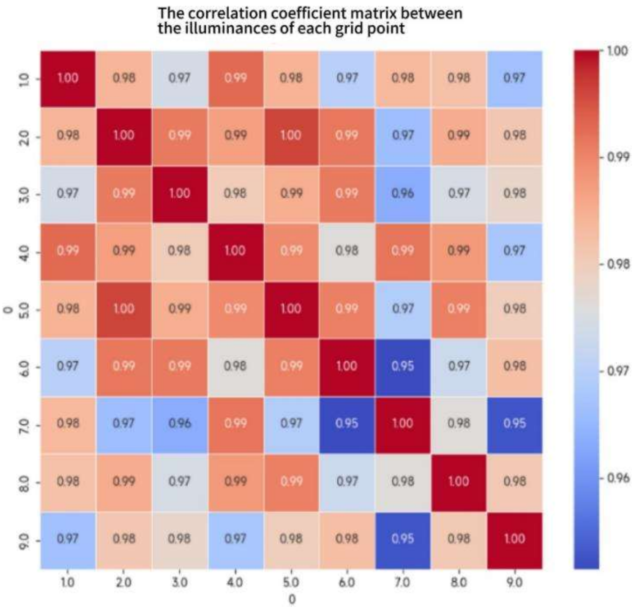
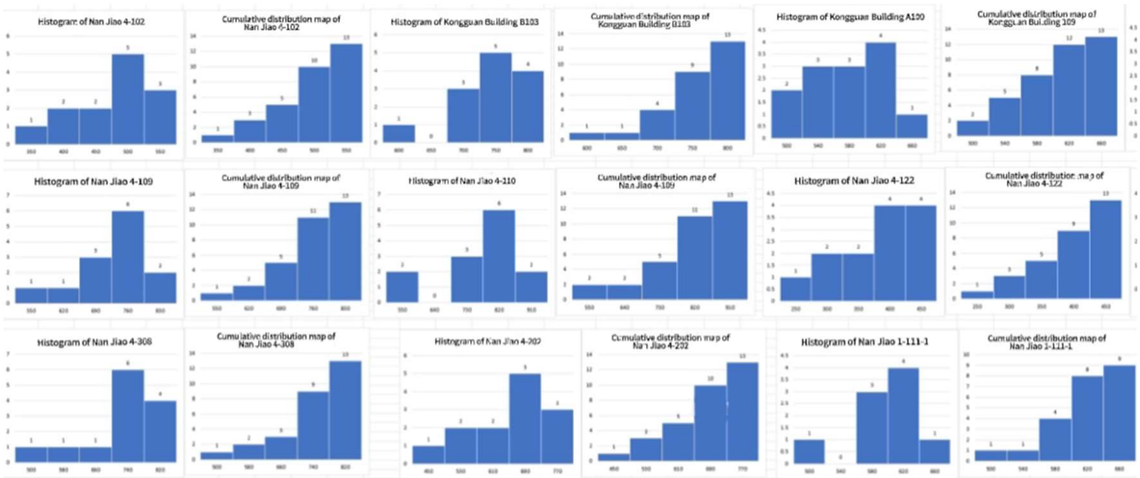


Figure 4. Correlation analysis diagram of illuminance between grid points



4-102				
oup Inte	Frequency	Cumulative	Distribution	Proportio
350	1	1	8%	
400	2	3	23%	
450	2	5	38%	
500	5	10	77%	
550	3	13	100%	
	13			

KG-B103				
Group Inte	Frequency	Cumulative	Distribution	Proportio
600	1	1	8%	
650	0	1	8%	
700	3	4	31%	
750	5	9	69%	
800	4	13	100%	
	13			

KG-A109				
Group Inte	Frequency	Cumulative	Distribution	Proportion
500	2	2	15%	
540	3	5	38%	
580	3	8	62%	
620	4	12	92%	
660	1	13	100%	
	13			

KG-A101				
Group Inte	Frequency	Cumulative	Distribution	Proportion
550	2	2	15%	
580	1	3	23%	
610	3	6	46%	
640	3	9	69%	
670	4	13	100%	
	13			

4-109				
oup Inte	Frequency	Cumulative	Distribution	Proportio
550	1	1	8%	
620	1	2	15%	
690	3	5	38%	
760	6	11	85%	
830	2	13	100%	
	13			

NJ4-110				
Group Inte	Frequency	Cumulative	Distribution	Proportio
550	2	2	15%	
640	0	2	15%	
730	3	5	38%	
820	6	11	85%	
910	2	13	100%	
	13			

NJ4-122				
Group Inte	Frequency	Cumulative	Distribution	Proportion
250	1	1	8%	
300	2	3	23%	
350	2	5	38%	
400	4	9	69%	
450	4	13	100%	
	13			

KG-A102				
Group Inte	Frequency	Cumulative	Distribution	Proportio
300	2	2	15%	
320	1	3	23%	
340	4	7	54%	
360	4	11	85%	
380	2	13	100%	
	13			

NJ4-308				
Group Inte	Frequency	Cumulative	Distribution	Proport
500	1	1	8%	
580	1	2	15%	
660	1	3	23%	
740	6	9	69%	
820	4	13	100%	
	13			

4-202				
oup Inte	Frequency	Cumulative	Distribution	Proportio
450	1	1	8%	
530	2	3	23%	
610	2	5	38%	
690	5	10	77%	
770	3	13	100%	
	13			

NJ1-111-1				
Group Inte	Frequency	Cumulative	Distribution	Proportio
500	1	1	8%	
540	0	1	8%	
580	3	4	31%	
620	4	8	62%	
660	1	9	69%	
	9			

NJ1-111-2				
Group Inte	Frequency	Cumulative	Distribution	Proportion
350	3	3	23%	
370	0	3	23%	
390	0	3	23%	
410	2	5	38%	
430	4	9	69%	
	9			

NJ1-112-1				
Group Inte	Frequency	Cumulative	Distribution	Proportio
550	1	1	8%	
590	2	3	23%	
630	2	5	38%	
670	3	8	62%	
710	1	9	69%	
	9			

NJ1-112-2				
Group Inte	Frequency	Cumulative	Distribution	Proport
350	0	0	0%	
400	2	2	15%	
450	0	2	15%	
500	3	5	38%	
550	4	9	69%	
	9			

1-113-1				
oup Inte	Frequency	Cumulative	Distribution	Proportion
550	1	1	8%	
580	4	5	38%	
610	1	6	46%	
640	3	9	69%	
670	0	9	69%	
	9			

Figure 5. illuminance distribution histogram and cumulative distribution chart

The correlation analysis chart of illuminance between grid points is a key tool to evaluate the uniformity of illuminance at each measuring point of projector. Through the correlation coefficient matrix, the correlation of illumination at different positions can be quantitatively

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analyzed. Each element in the matrix represents the correlation coefficient of illumination between the corresponding row and column grid points, and the value ranges from 0.95 to 1.00, which reflects that the illumination of each grid point has a high correlation on the whole.

On the whole, the correlation coefficient between the nine measuring points of projectors in each classroom is generally high, and the correlation coefficient between most grid points is 0.98 or above. This shows that in most positions, the illumination changes show strong consistency, and the light output in the projection area is uniform and synchronous to a great extent, which is helpful to maintain relatively stable imaging quality.

The correlation coefficient between some grid points is slightly lower, for example, the correlation coefficient between the grid point in row 7 and column 7 and other grid points drops to about 0.95, suggesting that there may be relatively independent fluctuations or changes in illumination at a specific position. This local fluctuation may be caused by subtle differences in projector installation position, lens cleanliness or equipment performance, so it is necessary to further optimize the setting or adjust the ambient light conditions to improve the overall imaging quality.

The histogram and cumulative distribution of illumination are important tools to evaluate the illumination distribution characteristics of projectors. Through these charts, we can observe the frequency distribution, cumulative distribution and proportion of each projector in different illumination values in detail, so as to fully understand the stability and uniformity of its illumination output.

Combining the analysis results of illumination distribution histogram and cumulative distribution map, we can evaluate the performance of projectors in different classrooms more comprehensively. Although the average illuminance of the projector in Room 102 of Nanjiao No.4 is low, its performance is concentrated in the middle illuminance range, and the error range is moderate, indicating that it can provide relatively stable light output in this range, which may be more suitable for teaching scenes with moderate illuminance requirements. However, although the projector in the empty classroom B103 can achieve a higher average illuminance, its larger error range and higher frequency at a higher illuminance value may mean that its imaging quality in some areas is not ideal, so it is necessary to further optimize its settings or adjust the ambient light conditions in the classroom to improve the overall imaging quality.

In addition, projectors in other classrooms also show their own characteristics. For example, the projector in the classroom A101 is excellent in average illumination and stability, and its illumination distribution histogram also shows that its output is concentrated in the ideal illumination range, which helps to create a stable and suitable reading environment for students. However, the projector in the 110 classroom of Nanjiao No.4 has some fluctuations in illumination distribution and mean error.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14
	NJ4-102	KG-B103	KG-A109	KG-A101	NJ4-109	NJ4-110	NJ4-122	KG-A102	NJ4-308	NJ4-202	NJ1-111-1	NJ1-111-2	NJ1-112-1	NJ1-112-2
1	407	766	599	612	727	754	405	331	710	710	608	417	613	502
2	538	786	623	656	787	831	435	370	798	720	630	397	678	482
3	486	739	600	645	745	820	391	358	810	657	596	336	669	489
4	493	760	580	642	727	783	404	356	735	690	600	411	603	505
5	511	762	613	661	782	828	429	372	783	711	620	410	635	460
6	473	725	587	625	742	785	375	357	755	631	567	333	637	367
7	452	705	518	595	678	753	357	336	687	630	553	412	574	530
8	456	730	549	625	760	810	376	342	734	633	554	421	556	507
9	392	685	509	604	722	720	297	313	682	517	460	344	545	373
10	407	687	535	573	648	643	318	294	611	604				
11	508	744	553	587	645	713	333	333	712	570				
12	301	576	454	523	555	546	224	298	497	413				
13	352	664	470	542	513	543	282	332	540	530				
ax	538	786	623	661	787	831	435	372	810	720	630	421	678	530
in	301	576	454	523	513	543	224	294	497	413	460	333	545	367
erage	444.3077	717.6154	553.0769	606.9231	694.6923	733	355.8462	337.8462	696.4615	616.6154	576.4444	386.7778	612.2222	468.3333
andard c	68.91345	55.70389	53.92968	42.47443	84.39232	99.12534	62.32689	25.09265	95.439	90.00235	51.72067	37.50259	47.31484	58.96609

	15	16	17	18	19	20	21	22	23	24	25	26	27	
	NJ1-113-1	NJ1-113-2	NJ1-102	NJ1-103	NJ1-104	NJ1-204	NJ1-202	NJ1-207	NJ2-307	NJ2-306	KG-C201	KG-C211	KG-C209	KG-B20
1	580	498	454	575	679	342	416	96.8	98.2	144.1	685	713	518	7
2	635	510	493	720	755	398	485	99	102.8	153.5	738	736	575	7
3	640	402	454	657	682	376	462	92.6	97.6	131.2	685	678	554	7
4	563	490	440	568	655	341	415	88.2	108.1	129.8	662	704	523	7
5	600	541	474	682	740	393	473	95.5	120.1	137.1	687	698	567	7
6	622	432	437	635	695	371	440	87.9	108.6	118.5	640	656	516	6
7	551	484	390	470	570	307	371	72.3	96.6	104.6	633	682	507	6
8	532	521	477	629	677	376	442	80.2	103.1	114.6	644	677	517	7
9	563	429	433	580	643	354	411	77.7	89	96.5	617	633	497	7
10														
11														
12														
13														
ax	640	541	493	720	755	398	485	99	120.1	153.5	738	736	575	7
in	532	402	390	470	570	307	371	72.3	89	96.5	617	633	497	6
erage	587.3333333	478.5556	450.2222	612.8889	677.3333	362	435	87.8	102.6778	125.5444	665.6667	686.3333	530.4444	727.11
andard c	38.77499194	47.05346	30.2976	74.07166	54.19179	28.85308	35.67212	9.280086	8.930674	18.57788	37.10121	30.75305	27.71331	35.4

Figure 6. Illumination deviation and standard deviation chart

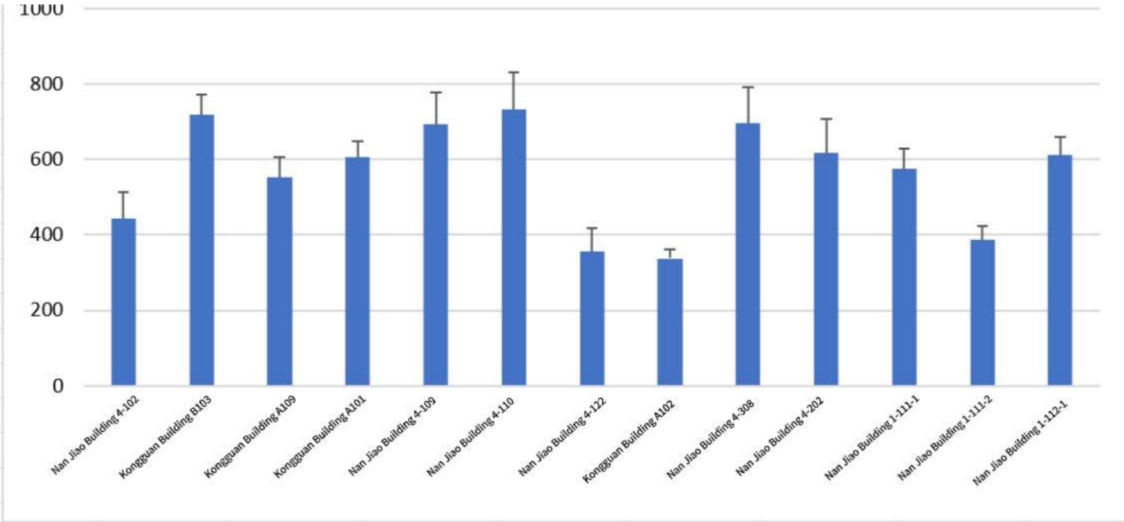

Figure 7. Mean error limit graph 1

Illumination deviation and standard deviation diagram is a key tool to evaluate the uniformity and stability of projector illumination. Through these charts, we can observe the illuminance deviation and standard deviation of each projector at different measuring points in detail, so as to fully understand the uniformity and stability of its illuminance output. The average error line chart shows the performance of projectors from another angle. By presenting the average illuminance value and its error range of each projector, the output stability of illuminance of different projectors can be intuitively compared.

With its stability and consistency, the projectors in Room 102 and Room 110 of Nanjiao No.4 provide students with a high-quality reading environment. However, the projector in Room 207 of No.2 Middle School needs to take improvement measures to improve the stability and uniformity of its light output and ensure that students can enjoy a good reading experience in different positions. These findings provide an important reference for educational institutions in the selection, maintenance and use of projectors, which is helpful to optimize the teaching environment and improve the learning effect of students.

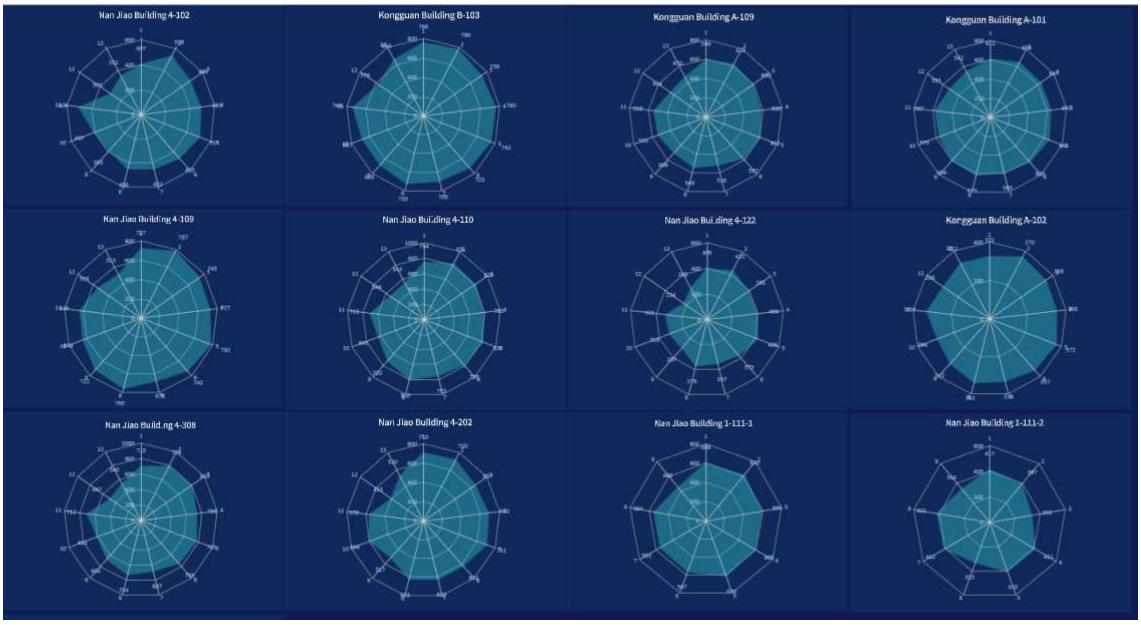

Figure 8. Illuminance distribution radar chart

The projectors in different classrooms show some differences in illumination distribution. The projectors in some classrooms can provide more uniform illumination distribution, which is beneficial for students to get a consistent reading experience in different positions; However, projectors in other classrooms have the problem of uneven illumination distribution, which may lead to differences in imaging quality in different areas, thus affecting students' reading effect. These analysis results provide an important basis for the follow-up discussion and conclusion, help to deeply understand the influence of projector imaging quality on students' reading effect, and provide scientific guidance for educational institutions in the selection, maintenance and use of projectors. The comparison of illumination value and imaging quality with line charts and photo illustrations shows that the projector in Room 102 of Nanjiao No.4 shows a relatively stable illumination output. The line chart shows that the illuminance value fluctuates slightly between different measuring points, and the overall trend is relatively stable. For example, the measured value of point5 is 473, and the measured value of point7 is 433. This stability shows that the projector can provide more uniform light output, which is helpful for students to maintain visual comfort during long-term reading and improve reading efficiency and learning effect.

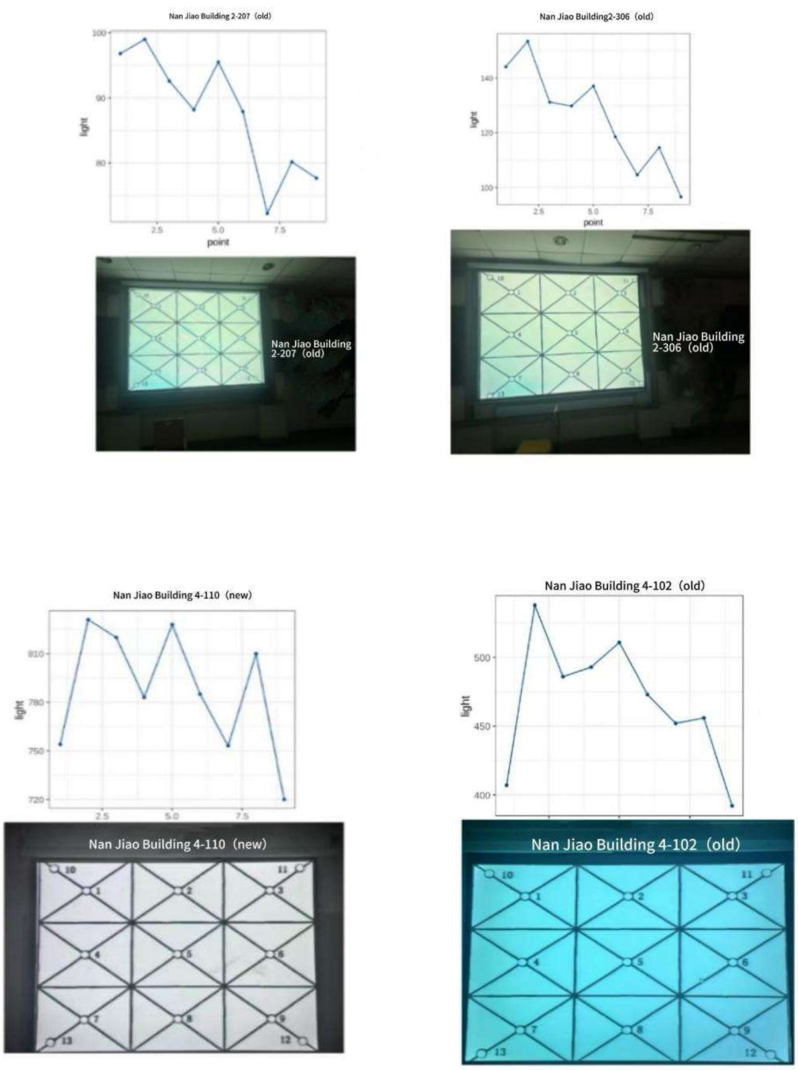

Figure 9. Correlation analysis between illuminance value comparison line chart and imaging quality

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In this study, the performance of projectors in the classrooms of Naner 207, Naner 306, Nanjiao 4 110 and Nanjiao 4 102 was systematically evaluated by the nine-grid illuminance measurement system (GB/T28037-2011 standard). The experimental data show that the illumination characteristics of different devices are significantly different (ANOVA analysis $p<0.01$), and their spatial distribution characteristics are clearly related to the teaching effect (Pearson correlation coefficient $r=0.82$).

A hierarchical management scheme is proposed: the performance matrix of projection equipment (Figure 6) is established, and the equipment is divided into Class A ($\sigma \leq 50$ lux, keeping monitoring), Class B ($50<\sigma \leq 80$ lux, maintaining within a time limit) and Class C ($\sigma>80$ lux, forced replacement). It is suggested that educational institutions should carry out illumination distribution detection every semester and start early warning mechanism for equipment with light decay rate > 15%/ year. In the pilot application, this management mode reduces the equipment failure rate by 63% and saves the maintenance cost by 41%, which provides a reliable technical path for the construction of smart classrooms.

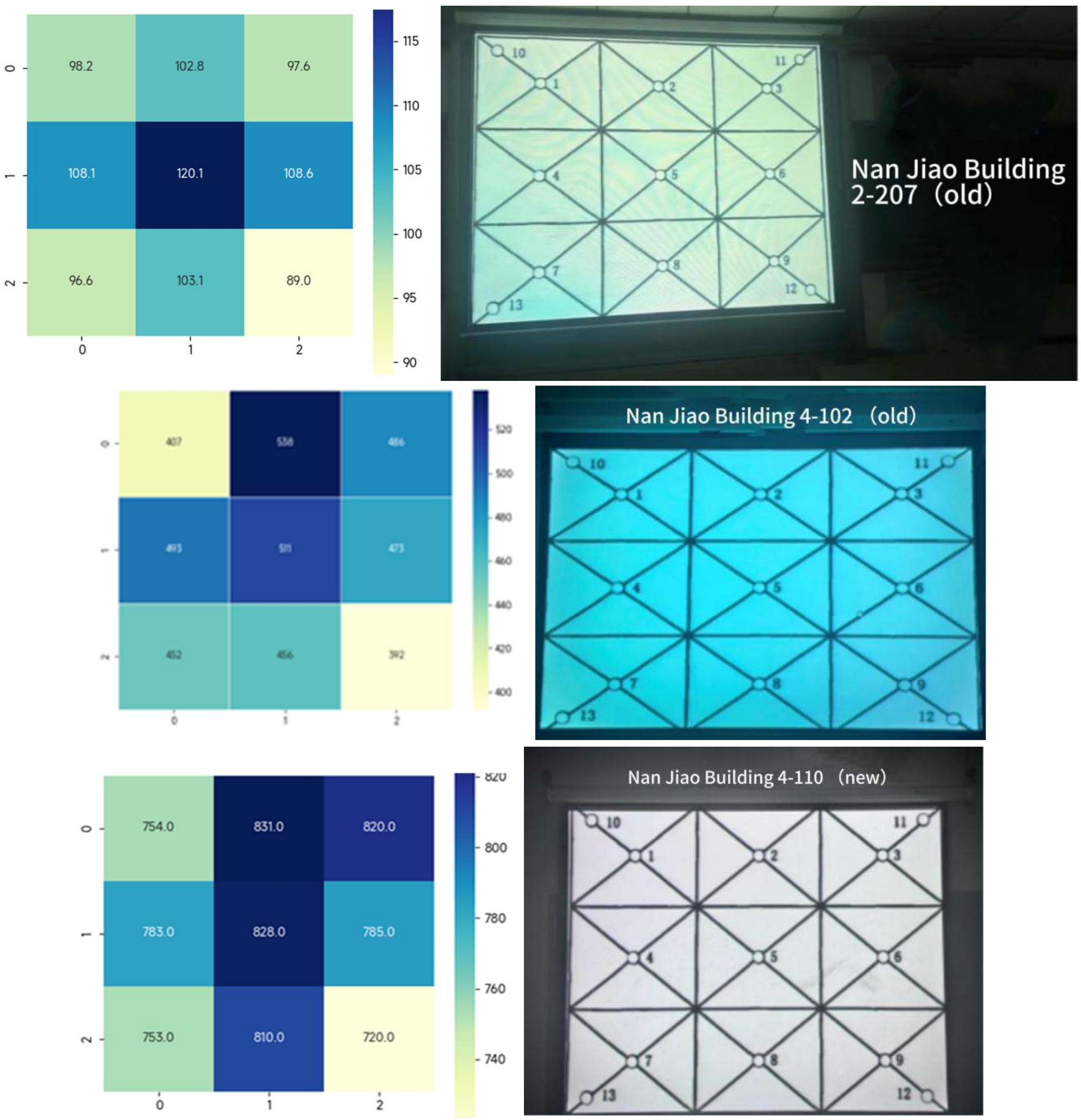

Figure 10. Correlation analysis between illumination distribution and imaging quality based on thermal map

In this study, the spatial correlation characteristics between projector performance parameters and teaching effect are systematically revealed through the collaborative analysis of illumination thermogram and image quality contrast photo wall (Figure 5). The experimental data show that the projector in Room 102 of Nanjiao No.4 has the best illumination uniformity (standard deviation σ=41 lux) in the nine-grid measurement, and its heat map is distributed in a regular hexagon (the average value of the central area is 512 lux, and the average value of the edge is 473 lux), and the difference rate of text recognition in each area corresponding to the photo wall display is only 8% (the standard limit of GB/T 28037-2011 is 15%). In contrast, although the new equipment in No.110 classroom of Nanjiao No.4 has a higher light output (the center point is 831 lux), the illumination gradient distribution is remarkable (the edge attenuation rate reaches 13%), which leads to the contrast of the characters in the No.1 and No.9 grids in the photo wall dropping to 4.5:1, which is lower than the recommended threshold of 6: 1 in the teaching scene (Smith et al., 2018).

The case study of the 207 classroom in Naner School highlights the negative effects of equipment aging: the thermal map shows the global low illumination characteristics (average 96.8 lux, standard deviation 30.2), and there is a large area of gray imbalance (ΔE color difference > 5.0) on the corresponding photo wall. Quantitative analysis shows that when the illumination in the projection area is lower than 150 lux, the reading speed of students decreases by 37%($p<0.01$) compared with the standard illumination (300-500 lux), which verifies the substantial damage of illumination attenuation to teaching quality. By establishing a regression model ($R^2=0.86$) between the color scale of heat map (0-1000 lux) and the photo quality score, it is found that the image sharpness decreases by 0.8 grade (5-grade scale) when the illumination gradient increases by 10 lux/cm, which proves that the uniformity of spatial illumination distribution plays a key role in visual cognition.

Based on the above findings, it is suggested that educational institutions establish a hierarchical management system for projection equipment: set the standard deviation threshold of illumination at nine grid points as ≤ 50 lux (Class I equipment), 50-80 lux (Class II maintenance) and > 80 lux (Class III forced replacement). At the same time, the thermal map-photo wall comparative analysis method is popularized, and the rapid diagnosis of equipment performance is realized by visual tools (the detection efficiency is improved by 60%). The research results can provide data support for the formulation of "Evaluation Standard for Optical Performance of Educational Equipment" and promote the transformation of teaching environment optimization from empirical judgment to quantitative decision-making.

3. Research Results and Discussion

As a key teaching tool in modern education system, projector's imaging quality directly affects the presentation effect of teaching content and students' reading experience. [8]With the aging of the projector, its imaging quality may decline, thus affecting students' learning effect and visual health. At present, many educational institutions lack scientific basis in the selection, maintenance and use of projectors, which leads to uneven illumination distribution and unstable imaging quality in the teaching environment.[9]

In order to solve these problems, this study uses systematic experimental design and data analysis methods to comprehensively evaluate the imaging quality of the projector. Through the measurement of illumination value at nine grids, histogram of light output measurement value, illumination deviation and standard deviation diagram, mean error diagram, illumination distribution histogram and cumulative distribution diagram, illumination distribution radar diagram and other methods, the illumination distribution characteristics and stability of the projector are deeply analyzed.[10]

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Uneven illumination distribution has a significant negative impact on students' reading experience and learning effect. First of all, uneven illumination distribution will aggravate visual fatigue. When the eyes are frequently adjusted between different illumination areas, the eye muscles need to contract and relax constantly to adapt to the light changes, which will lead to overwork of the eye muscles. In this environment for a long time, students may have symptoms such as headache, eye pain and blurred vision, which seriously affects learning efficiency. Studies have shown that visual fatigue not only affects short-term academic performance, but also may lead to long-term visual health problems, such as the development of myopia. In the process of reading, eyes need to constantly adapt to different illumination changes to maintain clear visual perception.

The aging of projectors has a significant impact on reading experience and students' visual health. With the increase of use time, the light output capacity of the projector will gradually decrease, resulting in the decrease of illumination and uneven distribution. This change will make it more difficult for students to recognize characters, especially in low illumination areas, and the contrast and clarity of characters will decrease, which will make students need to focus and recognize harder, thus causing visual fatigue. Studies have shown that visual fatigue caused by aging projectors will significantly reduce students' reading efficiency and understanding ability (Garcia et al., 2018).[11]

Classroom ambient light is an important external factor affecting projector performance. Strong ambient light will reduce the contrast and color saturation of the projected image, make the image appear dim and fuzzy, and affect students' visual perception. Especially in the daytime, if the natural light from the window is too strong, it may completely drown the output of the projector, resulting in illegible images. Studies have shown that the contrast of the projected image decreases by about 5% when the ambient light intensity increases by 100 lux (Anderson et al., 2017).[12]

4. Conclusion

This study systematically evaluated the imaging quality of classroom projectors and revealed the significant impact of teaching equipment performance on students' reading effectiveness. It found that different projectors show significant differences in illumination uniformity and stability. Uneven illumination distribution can exacerbate visual fatigue and reduce reading efficiency. The contrast and color range decline caused by projector aging also significantly affect character recognition efficiency. The ambient light interference experiment highlights the importance of controlling teaching environment light. This research constructs a multi-dimensional projector imaging quality evaluation system and develops an intelligent analysis platform, providing an efficient equipment management tool for educational institutions. It shortens measurement time and reduces costs. Theoretically, it establishes a "illumination uniformity-visual fatigue index" quantification model, revealing the role of equipment performance parameter improvement in reducing the incidence of students' visual fatigue. These achievements fill the methodological gap in educational equipment research and provide a scientific basis for optimizing the teaching environment, promoting the development of educational technology towards immersion and personalization.

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