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The Impact of Lighting Design on Visual Comfort in Architectural Design Studios

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Abstract

Lighting design, including both daylight and artificial light, significantly influence visual comfort and productivity of users, particularly in educational environments. Architecture students, for instance, spend most of their time in the studio, engaging in various activities. Each of these activities requires adequate illumination, especially for drawing and painting tasks. This study aims to evaluate the lighting quality in two design studios within the Department of Architecture at Umm Al-Qura University in Makkah, Saudi Arabia. In addition, it aims to realize the relationship between the illuminance design and the visual perception of the students. Data were collected through observation to obtain physical studio data and existing lighting design. DiaLux evo 12.1 software is used to simulate the lighting performance. User perception of the studio quality was obtained through a questionnaire distributed to students. The results show that the below-standard illumination level reflects on the students' responses. The study concluded that to create visually comfortable learning environments, task lighting should be utilized to ensure uniformity, and sunshades should be installed to mitigate harsh sunlight.

Keywords: Daylight – Artificial light - Glare - Architecture Design Studio - Visual Comfort

1. Introduction

Proper illumination is extremely important in architectural design studios as various activities are carried out throughout the day, which include reading, writing, hand drafting, use of laptops, teaching using a projector and whiteboard, and model making. Each of these activities requires proper illumination as per the ideal working environment situations. Poor lighting can lead to fatigue and decreased productivity, highlighting the importance of thoughtful lighting design from the outset of building construction [1].

A study found that proper lighting in classrooms is crucial for enhancing the learning experience and academic success of elementary students, with significant correlations between lighting quality and student performance [2] Inadequate lighting has been linked to neurological and learning problems, as well as musculoskeletal injuries among students [3].

Concerning health implications, poor lighting conditions can cause physical discomfort, such as eye strain and headaches, which detrimentally affect concentration and productivity [4]. The lack of adequate illumination can also increase accident rates, further compromising student safety and well-being [4].

On the other hand, daylight plays a crucial role in the educational environment especially in schools of architecture. It enables better performance and learning rates, and significantly impacts the visual comfort of the students and educators [5]. Studies indicate that appropriate daylight levels can enhance motivation and reduce fatigue [6]. Research shows that classrooms with optimal daylight conditions improve student performance and satisfaction [7].

In addition to promoting a state of calm contemplation, daylight also makes large energy savings feasible. Daylight significantly lowers energy consumption in educational buildings, which are among the highest consumers of energy after residential and office spaces [8]. Implementing effective daylighting strategies can minimize the need for artificial lighting, thus reducing electricity costs and environmental impact [9].

Architectural strategies must integrate daylighting effectively, considering factors like window placement and building orientation to maximize natural light intake [7]. Standards such as the European standard EN 17037, the UK standard CIBSE, and the American standard IESNA provide guidelines for assessing daylight performance, ensuring educational spaces meet necessary visual comfort criteria [8].

While the benefits of daylight in educational settings are well-documented, challenges such as glare discomfort must be addressed to fully realize its potential. Balancing these factors is essential for creating optimal learning environments. Glare occurs because the amount of light entering the eye is greater than the eye's ability to process it [10]. The impact of daylight glare on architecture students is significant, influencing their visual comfort, productivity, and overall well-being. Research indicates that while natural light is essential for enhancing learning environments, uncontrolled glare can lead to discomfort and hinder performance. A study found that 49% of architecture students reported visual discomfort due to daylight glare, which affected their ability to perform tasks effectively [11].

An abundance of natural light that is distributed unevenly such as inadequately sized windows [12] may result in glare and excessive solar gain. The perception of visual comfort is influenced by factors such as window orientation, [5], illuminance level, colour rendering, modelling, luminance distribution, etc. [13].

The integration of sunshade elements in minimalist facades decreases glare by controlling sunlight penetration, which is crucial in the hot climates. Implementing tubular daylight guidance systems and movable shading devices has shown to improve daylight availability while reducing glare in deep-plan classrooms [14]. In addition, making a cantilever, plant trees on the facade area, installing curtains, lay out away from light sources, finishing the room is in a shaded colour, and Install shading on the façade are means that could reduce glare.

2. Lighting Design consideration of architectural design studios

As shown in the next table, higher levels of illumination E_m (750–1,000 lux) are necessary for tasks that require precision, such as drafting, model-making, and detail work.

Table 1. General and task lighting in design studios according to variable standards

	IESNA (Illuminating Engineering Society of North America)	EN 12464-1 (European Standard for Lighting of Indoor Workplaces)	CIBSE (Chartered Institution of Building Services Engineers)	Saudi Building Code (SBC) and Saudi Standards (SASO)
General Lighting in Design Studios	300-500 lux	500 lux	300-500 lux	300-500 lux
Task Lighting (Drafting, Drawing, and Detailing)	750-1,000 lux	750-1,000 lux	750	750-1,000 lux

All standards encourage the use of natural lighting where possible, as it can enhance the overall lighting quality and reduce energy consumption. However, they emphasize the importance of reducing glare, especially for areas where students are using computers or working on detailed drawings. For design studios, a UGR_L (Unified Glare Rating) of 16 is a perceptible glare.

The following formula is used to calculate UGR_L:

$$UGR = 8\log_{10}\left(\frac{0.25\sum\left(\frac{L_b \times L_s \times \omega}{p^2}\right)}{L_b}\right)$$

Where:

- L_b: Background luminance (in cd/m²)
- L_s: Luminance of the light source in the direction of the observer's eye (in cd/m²)
- ω: Solid angle of the luminaire (in steradians) from the observer's position
- p: Position index that accounts for the relative position of the light source to the line of sight of the observer
- ∑: Sum over all visible luminaires in the field of view

On the other hand, all standards require uniform lighting throughout the studio. A common Uniformity Ratio (Uo) for lighting in workspaces using the following formula is 0.6 or higher (closer to 1.0) to avoid uneven light distribution.

$$Uo = \frac{E_{\min}}{E_{\text{avg}}}$$

Where:

- E_{min} = Minimum illuminance level measured in the area (in lux)
- E_{avg} = Average illuminance level measured in the area (in lux)

In addition, a Colour Rendering Index (R_a) value of 80 or higher is recommended to ensure accurate color perception, which is critical for architectural design studio. Moreover, a Correlated Colour Temperature (CCT), of 5000-7000 K is recommended to ensure bright white or daylight white atmosphere.

3. Methodology

On reviewing some of the research works on similar grounds that took place around the world for understanding the subject matter, the results and conclusion gave way to the research gap for future studies. To address the gap, a case-specific study has been conducted to relate the onsite illuminance readings to the simulation-based study and the student's visual comfort in the design studios of the architecture schools.

An architecture department in Umm Al-Qura University, Makkah, Saudi Arabia was selected to conduct the fieldwork. The main classroom in any school of architecture is the design studio. Design studio is where the students spend most of their time working and conducting various activities hence analyzing and addressing the need for the appropriate light is necessary. The department has 10 design studios, three of which were recently renovated. Most of the studios are oriented towards the southeast, so they are not affected by the sun's rays in the morning, as work in the studio starts at 10:00 am. However, only two studios were considered as part of the study.

Onsite observations were conducted using a Mastech MS6300 luxmeter, while light analysis was performed using simulation software, DIALux evo 12.1. The study was conducted to analyze the light readings for the two design studios within the selected architectural building. The analysis was done at three different time within the studio timings.

A questionnaire was conducted for students who spent their whole day doing drawing activities. Students were asked about visual comfort, and the ability to work with daylight conditions at specific times. Their answers were analyzed to understand the students' satisfaction which further gave way to the results and conclusion.

4. Scope and Limitations

The study limited to only two architecture design studios in the Department of Architecture, Umm Al-Qura University, Makkah. The onsite observation and questionnaire were conducted in August and September 2024 respectively, during the studio's working hours, from 10:00 am to 5:00 pm The simulation analysed the lighting three times on the first day of each season.

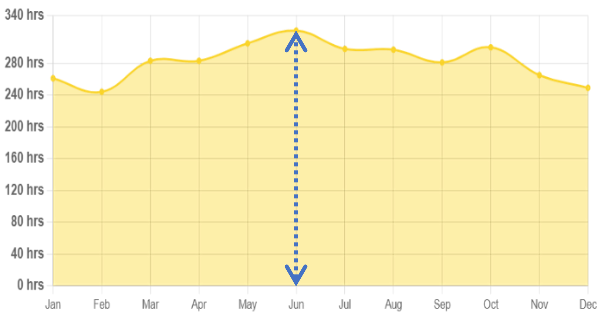
5. Case Study

5.1 Factors affected light design in Makkah

Department of Architecture is located in Makkah, Saudi Arabia. In Makkah, the summers are long, sweltering, arid, and partly cloudy and the winters are short, comfortable, dry, and mostly clear. Over the course of the year, the temperature typically varies from 16°C to 42°C and is rarely below 12°C or above 44°C [15].

Figure 1 shows the average number of hours per month that Makkah receives direct sunlight. It illustrates that on average, June is the sunniest month with 321 hours of sunshine. February has on average the lowest amount of sunshine with 244 hours. On average, the total annual amount of sun is 3399 hours [15].

Figure 2 shows the mean percent of sun hours during the day in Makkah. The sun shines on average 82.0% in June making it the sunniest month. On average, April has the lowest percentage of sunshine with 72.0%.



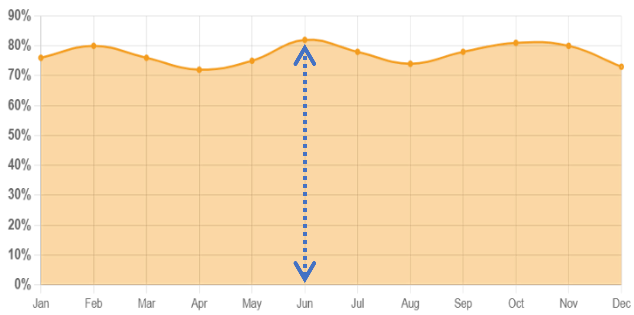


Figure 1. Average number of direct sunlight hours per month in Makkah (left)

Figure 2. The mean percent of sun hours during the day in Makkah (right)

Considering clouds, the average percentage of the sky covered by clouds experiences significant seasonal variation over the course of the year. The clearer part of the year in Makkah begins around October 17 and lasts for 8.3 months, ending around June 27. The clearest month of the year in Makkah is November, during which on average the sky is clear, mostly clear, or partly cloudy 84% of the time. The cloudier part of the year begins around June 27 and lasts for 3.7 months, ending around October 17. The cloudiest month of the year in Makkah is September, during which on average the sky is overcast or mostly cloudy 37% of the time [15].

Table 2. The percentage of time spent in each cloud cover band, categorized by the percentage of the sky covered by clouds.

Fraction	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Cloudier	19%	19%	20%	17%	18%	25%	36%	30%	37%	31%	16%	21%
Clearer	81%	81%	80%	83%	82%	75%	64%	70%	63%	69%	84%	79%

The following graph illustrates solar elevation and azimuth over the course of the year 2024. The black lines are lines of constant solar elevation (the angle of the sun above the horizon, in degrees). The background colour fills

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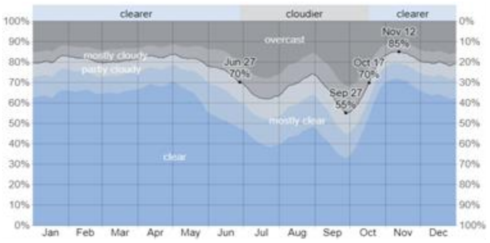
indicate the azimuth (the compass bearing) of the sun. The lightly tinted areas at the boundaries of the cardinal compass points indicate the implied intermediate directions (northeast, southeast, southwest, and northwest).



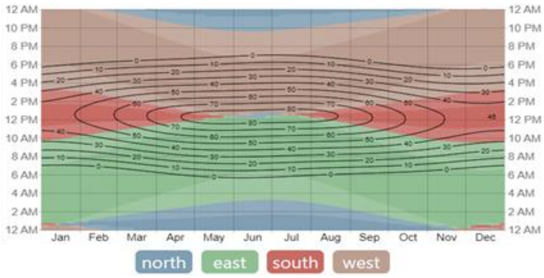


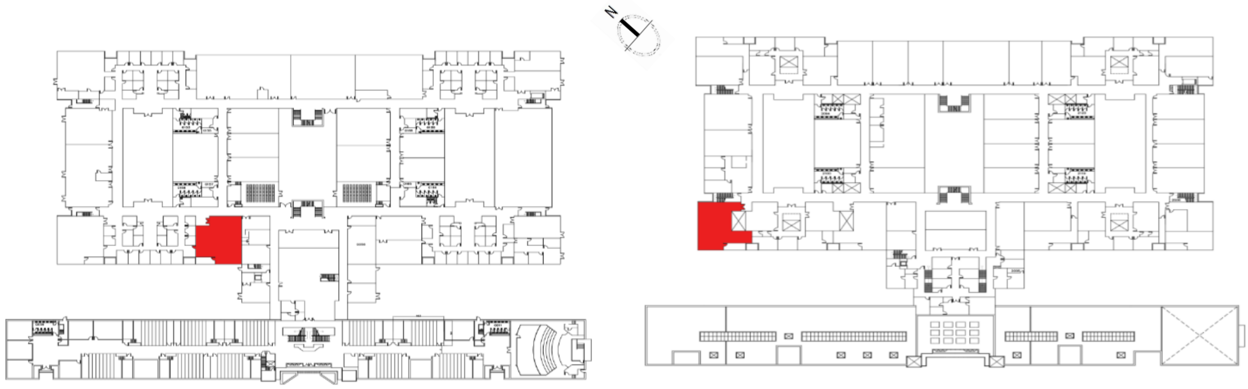
Figure 3. Percentage of the sky covered by clouds in Makkah (left)

Figure 4. Solar Elevation and Azimuth in Makkah (right)

5.2 Case Study Studios: The two studios are assigned to first-year students. The first is an older studio situated on the ground floor, with an area of approximately 200 m². The second is a renovated studio on the second floor, covering around 195 m² with a ceiling height of 3m for all design studios. The old and renovated studios can accommodate 40 and 30 students, respectively.

Both studios have openings facing the southwest. However, the renovated one (Studio 2) has long northwest openings. Each studio has a 3.5 x 7 m courtyard covered with a barrel vault, allowing natural light to enter.

There are no other higher buildings that provide shade from the sun exposure received by the mass building. All windows had clear glass with white aluminium frames covered with curtains in studio 2. All the walls are painted light beige, and the floors are covered with matte vinyl. The ceiling in Studio 1 consists of 60 x 60 cm false ceiling tiles, while in Studio 2, it is a combination of white gypsum board and brown tiles. The drafting tables have stainless steel supports and medium-density white or wood pattern fibreboard tops.



Ground floor plan (Studio 1) 2nd floor plan (Studio 2)

Figure 5. Ground and 2nd floor plans with marked design studios [Authors]

6. Results and Discussion

6.1 Onsite Observations by Authors

Studio 1 is equipped with 23 fluorescent louver tube light fixtures, each measuring 120 x 60 cm, designed to reduce glare. It also includes eight recently added wall-mounted fluorescent lamps to enhance illuminance. In contrast, Studio 2 features 17, 120 x 60 cm, recessed-mounted fixtures with opal covers, providing more comfortable and glare-free lighting. It also equipped with 24 recessed spotlights. Despite the difference in the illuminator types, the lighting temperature in both studios is suitable for drawing and colouring tasks.

In Studio 1, students preferred to keep the artificial lights on throughout the day due to the lack of natural light. However, the students placed black cardboard over the top of the window, indicating that they experienced glare, prompting them to use this solution. As for Studio 2, the overall lighting appears to be sufficient. However, students lower the new sunshades in the afternoon due to increased glare.

Figure 6. Photos of Studio 1 (left) and Studio 2 (left) [Authors]

A number of measurements were taken at 10:00 in both studios using a luxmeter (Mastech MS6300). Specific positions were fixed, and reading was taken in the two studios with and without artificial lighting. The results were as follows:

Figure 7. Position of luxmeter readings [Authors]

Table 3. Onsite results of the two studios

Studio 1			Studio 2		
Point No.	Daylight (Lx)	Day and Artificial lighting (Lx)	Point No.	Daylight (Lx)	Day and Artificial lighting (Lx)
1	23	300	1	111	751
2	22	400	2	157	638
3	50	430	3	295	845
4	140	530	4	594	810

5	28	440	5	209	900
6	115	310	6	298	718
7	40	425	7	615	1300
8	118	405	8	152	644
9	30	380	9	238	930
10	38	405	10	600	1130
11	77	480	11	100	750
12	85	385	12	180	805
13	105	380	13	155	556
14	150	550	14	180	457
15	30	280	15	195	678
16	80	480	16	193	440
Average	71	411	Average	267	772

The results show that average illumination level in Studio 1 is 71 lux (daylight only) and 411 Lux (both daylight and artificial light). This value is extremely below the standard (750 -1000 Lux). However, lighting uniformity Uo= 0.68 means that the lighting in the studio has acceptable uniformity.

On the other hand, the results also show that the average illumination level in Studio 2 is 267 lux (daylight only) and 772 Lux (both daylight and artificial light). This value is consistent with the standard (750 -1000 Lux). lighting uniformity Uo= 0.57 means that the lighting in the studio has moderate uniformity. The shortage occurred in a small corner of the studio, which housed four drafting tables and has a small window. This indicates a need for improvement in the lighting design to achieve a more even distribution of light.

Due to windows size and orientation, and the high floor level of Studio 2, the average daylight illuminance in Studio 2 exceeded the average illuminance in Studio 1.

6.2 Calculating result using DiaLux evo 12.1 software

Simulations using the DiaLux evo 12.1 software were carried out to obtain lighting illumination data, daylight factor values, light distribution, and possible direct glare disturbances from sunlight. The R_a was adjusted as 80 and CCT was adjusted as 6500k. Three lighting scenes were analysed throughout the first day of each season for each studio. The results were as follows:

Table 4. Simulation results of the two studios

		10:00 AM		**3:00 PM**		**5:00 PM**	
	Cloud Condition	Illuminance (LUX)	Uniformity (Uo)	Illuminance (LUX)	Uniformity (Uo)	Illuminance (LUX)	Uniformity (Uo)
Studio 1							
21st March	Clear	374	0.48	1776	0.19	1289	0.24
21st June	Cloudy	396	0.46	830	0.29	714	0.32
21st September	Overcast	408	0.45	400	0.46	360	0.50
21st December	Clear	373	0.49	1984	0.18	373	0.49
Studio 2							
21st March	Clear	868	0.41	3145	0.13	3020	0.16

21st June	Cloudy	1014	0.33	2943	0.15	2614	0.17
21st September	Overcast	939	0.34	889	0.33	648	0.29
21st December	Clear	870	0.41	3064	0.13	1079	0.35

Consistent with the findings from the onsite observation, Studio 2 consistently exhibits higher illuminance values across all measurements compared to Studio 1. For example, at 3:00 PM, Studio 2 records 3145 LUX, while Studio 1 only has 1776 LUX. This suggests that Studio 2 is better designed to capture and utilize natural light, and its artificial lighting is also more effectively integrated. In addition, Studio 2 demonstrates more stable illuminance values across the months, suggesting a more reliable light source or design.

Consistent with the onsite observations, the highest illuminance average in all studios occurs at 3:00 pm, while the lowest is recorded at 10:00 am. At 3:00 PM, the sun is lower in the sky, with more direct rays enhancing illuminance in southwest-oriented studios. The longer daylight hours in the afternoon, especially during spring and summer, contribute to increased light levels. While morning conditions may be hazy, clearing atmospheric conditions later in the day allows for greater sunlight penetration.

Given that higher illuminance can lead to glare, especially during peak sun hours, glare in both Studios is particularly high in December at 3:00 PM. At this time, the sun is generally lower in the sky, which can lead to increased direct sunlight entering the studios, significantly raising illuminance levels, especially in clear conditions. While Studio 2 is equipped with sunshades, Studio 1 may need such sunshades to minimize discomfort from excessive brightness while maintaining adequate lighting levels.

On the other hand, the results indicates that the lowest illuminance average in all studios occurs in March and June at 10:00 am, while it occurs in September at 5:00 pm. In December, Studio 1 experiences the same low illuminance values at 10:00 am and 5:00 pm.

Studio 1 shows significant changes in illuminance levels throughout the year. For instance, it has the highest value of 1984 LUX in December at 3:00 PM but drops to 400 LUX in September at the same time. This indicates how different seasons impact light availability. The lowest illuminance is recorded in Studio 1 during September at 5:00 PM (360 LUX). This may occur because the type of cloud cover (clear, cloudy, overcast) significantly impacts natural lighting. For instance, overcast days in September result in diffused light, leading to lower illuminance levels. In addition, September marks the transition into autumn, resulting in shorter daylight hours compared to the summer months. This reduction in natural light can significantly impact the illuminance levels in the studio.

Studio 2 shows the highest illuminance at 3:00 PM in both March (3145 LUX) and June (2943 LUX). The afternoon sun in March and June can provide intense direct light, particularly in the southwest orientation of Studio 2, maximizing the amount of daylight entering through the long windows. Both March and June are spring and summer months, respectively, characterized by longer daylight hours. More available sunlight during these months contributes to higher illuminance levels. During these months, the sun's intensity is stronger, especially in June when the sun is at its peak height in the sky. This can lead to higher illuminance levels compared to the autumn and winter months.

Studio 1 shows uniformity values (Uo) that vary from 0.18 to 0.49, while Studio 2 has lower uniformity values, ranging from 0.13 to 0.41. This suggests that while Studio 1 has higher potential uniformity, it may also experience significant differences in light distribution at times, particularly in the afternoon. This result aligns with the findings from the onsite observation.

The results indicates that uniformity values generally decrease as illuminance increases, especially noticeable in Studio 2's afternoon measurements. This might imply that while the studio is brighter during peak times, the quality of light distribution suffers, affecting the visual comfort of the space.

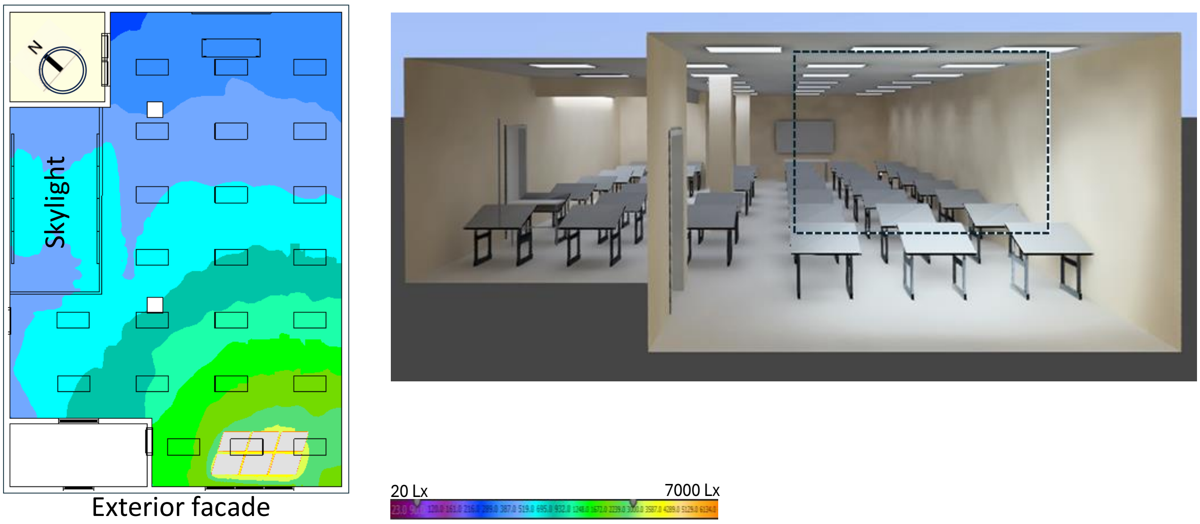


Figure 8. Low illumination and uniformity ratio in Studio 1 [Authors]

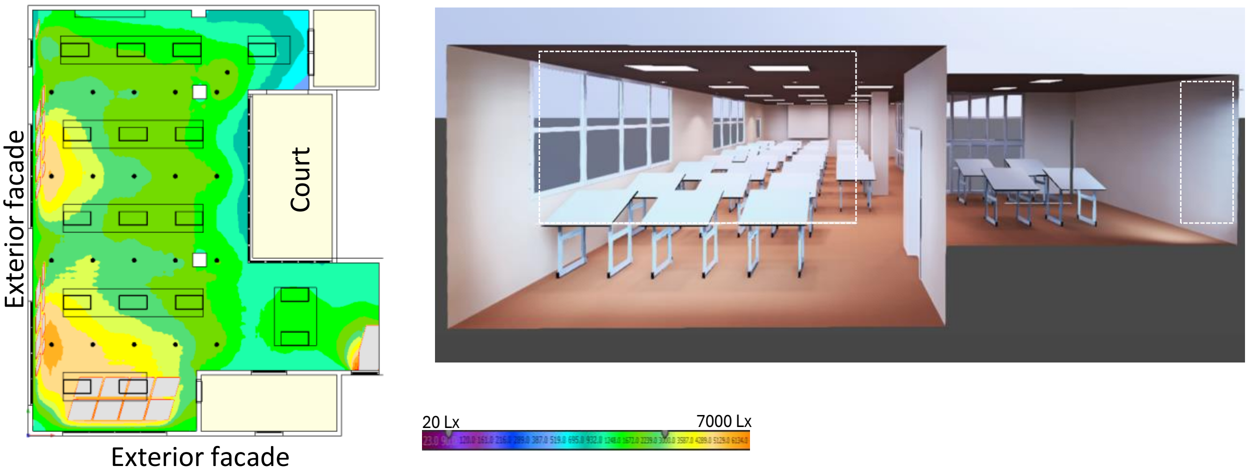


Figure 9. Low uniformity ratio and high glare in Studio 2 [Authors]

6.3 The questionnaire

A questionnaire with the following questions was conducted using Likert scale in order to understand students' perceptions of the lighting in the two studios:

Q1. How do you rate the overall intensity of the lighting in the studio?
Q2. How comfortable or uncomfortable do you feel in your position in the studio due to the lighting?
Q3. How satisfied are you with the color of the lighting in the studio?
Q4. How well can you concentrate on your work as a result of the lighting?
Q5. How much eye strain do you experience while working due to the lighting?
Q6. How would you rate the level of visibility in the studio?
Q7. How do you rate the intensity of lighting on the drawing board?
Q8. How visible are the fine details on the drawing board?
Q9. How distinct are the colors on the drawing board?
Q10. How much glare do you experience while working?

There were 30 participants, representing 75% of the student population in Studio 1, and 22 participants, representing 73% of the student population in Studio 2. Purposive sampling method was used, to ensure that respondents spread evenly in all seating positions.

After gathering the results, they were analysed using ANOVA to test for significant differences between the mean responses to the questions based on the students' positions in each studio. The following table presents the questions, the mean responses from students for each studio, and the ANOVA results.

Table 5. ANOVA test for significant differences

		Valid	**Q1**	**Q2**	**Q3**	**Q4**	**Q5**	**Q6**	**Q7**	**Q8**	**Q9**	**Q10**	**Overall**
	Mean		3.6	3.9	4	3.7	3.6	4.2	3.5	3.5	3.9	3.7	3.79
Studio 1	Std. Dev.	30	0.93	0.96	0.94	0.98	1.16	0.71	0.89	1.16	1.06	1.09	
	Significance		0.17	0.29	0.15	0.15	0.65	0.28	0.11	0.09	0.006	0.49	0.114
	Mean		4.1	4.3	4.3	4.5	4.4	4.5	4.2	4.3	4.4	4.2	4.33
Studio 2	Std. Dev.	22	0.77	0.77	0.84	0.74	0.79	0.80	0.96	0.89	0.73	0.85	
	Significance		0.82	0.27	0.18	0.40	0.33	0.45	0.33	0.11	0.58	0.47	0.77

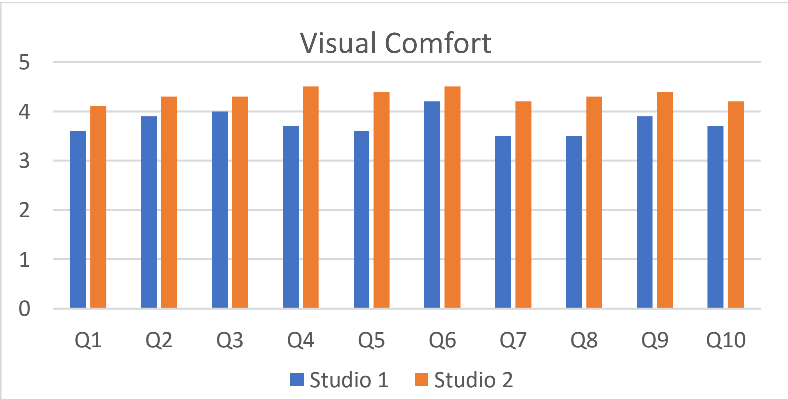


Figure 10. Lighting perception result: visual comfort of the two Studios [Authors]

As a result, it was seen that the students' perception had direct relation with results derived from the analysis of the lighting simulation. Overall, the results suggest that Studio 2 is better equipped to meet the lighting needs of the students, offering a more comfortable and functional environment, which could directly impact the students' workability and productivity. Considering the results of Studio 1, for a satisfaction scale (1 = Very Dissatisfied, 5 = Very Satisfied), 3.79 indicates moderate satisfaction. The main issues in this studio, from the students' perspective, are the lack of lighting on the drawing board and the poor visibility of fine details in their drawing projects. For Studio 2, a mean of 4.33 suggests that students are strongly satisfied with lighting in their studio.

The results show a clear difference in responses to lighting quality for visual comfort between the two studios. The largest gap between the two studios is seen in Q4, Q5, and Q8. Students in Studio 1 are more likely to experience eye strain, have difficulty seeing fine details on the drawing board, and become distracted from their work compared to those in Studio 2.

Glare control is better in Studio 2, with a score of 4.2 compared to 3.7 in Studio 1, suggesting that Studio 2's lighting is better designed to minimize glare using sunshades.

Based on the ANOVA analysis, there are no statistically significant differences between the arithmetic means of the questions attributed to the variable "Position of student in the studio" at the 0.05 significance level. In studio 1 and 2, the p-value obtained from the ANOVA test is 0.1135 and 0.770 respectively, which is greater than 0.05, indicating that the differences in means are not statistically significant and that any observed differences in means are likely due to random chance rather than a true underlying difference. This concludes that student's position in the studio does not influence his opinion on lighting in the two studios.

The primary recommendation for improving the lighting quality in Studio 1 is to install sunshades to prevent daylight glare. As for the two studios, it is recommended to add task lighting to the workspaces. Task lighting enhances contrast, increases illumination levels, and provides focused lighting for specific activities. It should also feature individual controls, allowing students to adjust the lighting based on the type of task and their personal preferences.

7. Conclusion

Since students spend most of their time in design studios, it is important to understand their perceptions, particularly regarding factors that impact their productivity, with a special focus on lighting.

The purpose of the study was to evaluate the lighting quality in architectural design studios and realize the relationship between the illuminance design and the visual perception of the students. After conducting instrument-based and simulation-based analyses, the results were confirmed by understanding the perception of the students.

The results of the study indicated that the low illuminance levels within the design studios highly affect the workability and interest of students. Appropriate orientation and window size of the design studio are the most important factors to consider. Additionally, to create visually comfortable learning environments, task lighting should be used to ensure uniformity, and sunshades should be installed to prevent harsh sunlight. Future studies can focus on the impact of lighting design on the products of architecture students.

References

[1] R. Küller, "Planning for good indoor lighting", Dept. of Arch. and Built Env., Lund Univ., Sweden, 2004.

[2] A. Gilavand., M. Gilavand., S. Gilavand, "Investigating the Impact of Lighting Educational Spaces on Learning and Academic Achievement of Elementary Students", *International Journal of Pediatrics*, vol. 4, no. 5, May 2016, doi: https://doi.org/10.22038/ijp.2016.6768.

[3] B. Fouladi, Z. Mosavianasl, M. Shegerd, K. Poresh, and H. Sari, "The Intensity of Elementary Schools' Lighting in Ahvaz City Compared with the Standard Values in 2017," *Occupational Hygiene and Health Promotion*, vol. 3, no. 1, May 2019, doi: https://doi.org/10.18502/ohhp.v3i1.967.

[4] L. Arce Espinoza and J. Mónge-Najera, "Lighting and noise level in the central facilities of the Costa Rican Distance Education University: health implications for staff and students," *UNED Research Journal*, vol. 2, no. 1, pp. 63–68, Jun. 2010, doi: https://doi.org/10.22458/urj.v2i1.222.

[5] T. Kharat and N. Dhamankar, "Investigating Student's Perception of Visual Comfort in Architecture Studios and Its Impact on Their Work Output," in *Indoor Environmental Quality*, S. Chinthalal, P. Kumar, B. Aggarwa, and P. Kulshreshtha, Eds., 2023: Springer.

[6] M. Badeche and A. Benkhalifa, "Analysis of the Users' Perception of Daylighting in Newly Libraries of Algeria," *International journal of innovative studies in sociology and humanities*, vol. 7, no. 8, pp. 118–124, Jan. 2022, doi: https://doi.org/10.20431/2456-4931.070811.

[7] M. Othman, M. Yasin, A. Ajis, A. Jaafar, and K. Alauddin, "Students' Perception of the Natural Daylighting in Higher Education Design Studios," *International Journal of Business and Technology Management*, vol. 5, no. 52, Sep. 2023, doi: https://doi.org/10.55057/ijbtm.2023.5.s2.32.

[8] M. Baydoğan and V. Özkantar, "Evaluation of daylight performance metrics according to country guidelines: The case of educational buildings in Turkey," *Energy and Buildings*, vol. 297, pp. 113487–113487, Oct. 2023, doi: https://doi.org/10.1016/j.enbuild.2023.113487.

[9] G. Erdemir and A. Köknel Yener, "A Study on Daylight Performance Evaluation in Primary School Classrooms," *Orclever Proceedings of Research and Development*, vol. 1, no. 1, pp. 257–270, Dec. 2022, doi: https://doi.org/10.56038/oprd.v1i1.184.

[10] Y. Sim, I. Kim, A. Choi, and M. Sung, "A preliminary study of an evaluation method for discomfort glare due to light trespass," *Lighting Research & Technology*, vol. 49, no. 5, pp. 632–650, Mar. 2016, doi: https://doi.org/10.1177/1477153516636439.

[11] S. Abdelwahab and H. Sobh, "Visual Discomfort Analysis as a Tool to Support Façade Shading Design: A Case Study in the Architectural Design Studio," *Journal of Architectural Engineering*, vol. 28, no. 2, Jun. 2022, doi: https://doi.org/10.1061/(asce)ae.1943-5568.0000533.

[12] T. Muneer, *Windows in buildings: thermal, acoustic, visual, and solar performance*. Oxford; Boston: Architectural Press, 2000.

[13] F. Rahman, M. Tuhin, "Daylight impact on learning environment in classrooms of secondary high school at Ishwardi, Pabna, Bangladesh". *Int Res J Eng Technol (IRJET),* Vol. 6, no. 10, 2019.

[14] A. Kunduraci and E. Kizilörenli, "A Design Proposal for Improving Daylight Availability of a Deep-Plan Classroom by Using Tubular Daylight Guidance Systems and Movable Shading Devices," *Politeknik dergisi*, vol. 27, no. 4, Apr. 2023, doi: https://doi.org/10.2339/politeknik.1266467.

[15] "Average Weather in Mecca, Saudi Arabia, Year Round - Weather Spark," *weatherspark.com*, 2024. https://weatherspark.com/y/101170/Average-Weather-in-Mecca-Saudi-Arabia-Year-Round