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A COMPARATIVE ANALYSIS OF SUSTAINABILITY RATING SYSTEMS (COMFORTABLE LIGHTING ENVIRONMENT AS AN ASSESSMENT CRITERION)

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Abstract- LEED, BREEAM, Green Pyramid, and TARSHEED Rating Systems are incapable of maintaining the health and welfare of building occupants, so many claims have been against developers, engineers, and real estate owners, due to sick building syndromes (SBS) related to the poor design of the aspect. Many of the environment-related aspects directly contradict the health-related aspects. The S.R.A focuses on the sustainable aspects, regardless of the health impact of humans using this building. Light can affect human health through the systems visible and invisible to the eye and its impact on eyestrain and headache. Stress and depression are two of the most common psychological disorders and diseases in modern communities living in apartments and dark, narrow houses. As a result, it appears that the effect of light and spatial proportion in modern small houses plays a significant role in the occurrence and treatment of these disorders. We could prevent and treat these disorders with flexible design , lighting ,and optimal space design. The main objective of this study is to design well-lit spaces to preserve the health and well-being of the occupants of the building and to achieve visual comfort through the application of the elements that lead to this, in addition to the building being compatible with sustainable rating systems and knowing any system concerned with lighting and human comfort.

***Keywords**:* Lighting quality; visual comfort; College field study; and Sustainable Rating Systems.

I. INTRODUCTION

Numerous building evaluation tools available worldwide focus on various aspects of sustainable development and are designed for various types of projects. Only a few systems, however, are widely recognized and truly set a recognizable standard for sustainable development [1]. The five systems reviewed in this thesis were chosen because they are the most popular, influential, and technically advanced rating tools available (LEED, BREEAM, and WELL) For local rating systems (GPRS, and TARSHEED).

- LEED (Leadership in Energy and Environmental Design) was founded in 1993 by the United States Green Building Council (USGBC) to assess and define what green building meant, as well as to give a blueprint for producing sustainable buildings. With LEED, we set a baseline—a complete system for minimizing the environmental impact [2, 3].
- BREEAM, which was first published in the United Kingdom, was the first certification system to analyze building sustainability. BRE (Building Research Establishment) managed and developed the system in the late 1980s, and it was released to the market in 1990 [4, 5].
- The WELL rating system was established (WELL v1) in 2017 and it is developed in 2020(WELL v2). The WELL Building Standard (WELL) is centered on the building's occupants [6].
- In 2009, Egypt's green building Egyptian committee launched the green pyramid rating system. Until the Egyptian Green Building Council and the Housing and Building Research Center developed it in 2012, it lacked execution and implementation. Because the energy sector is more concerned than other rating systems, the GPRS tool was designed using the LEED rating method[7].
- TARSHEED is a new rating system developed by the Egypt Green Building Council (EGGBC), a prospective member of the World Green Building Council. EGGBC was founded as a non-governmental organization in November 2012. Its goal is to promote green building practices in Egypt while also raising public awareness about sustainability and green buildings [8, 9].

The following three charts (Figs. 1, 2, and 3) illustrate the comparison of sustainability rating systems in terms of indoor environment quality, Certificate Points, and lighting in each certificate[2, 6-8, 10].

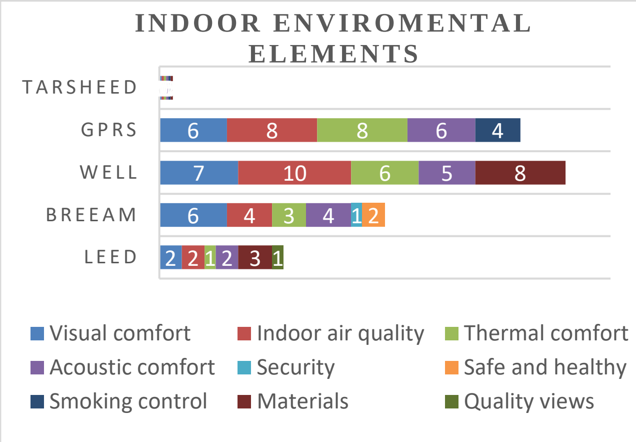

Figure 1. LEED, BREEAM, WELL, GPRS, and TARSHEED indoor environmental quality elements. by researcher.

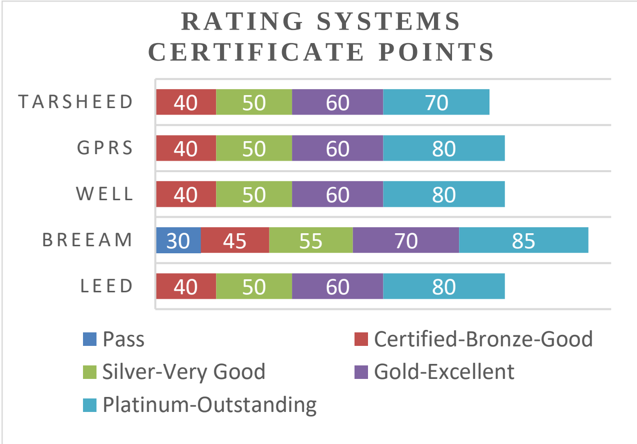

Figure 2. LEED, BREEAM, WELL, GPRS, and TARSHEED rating systems certificate points. by researcher.

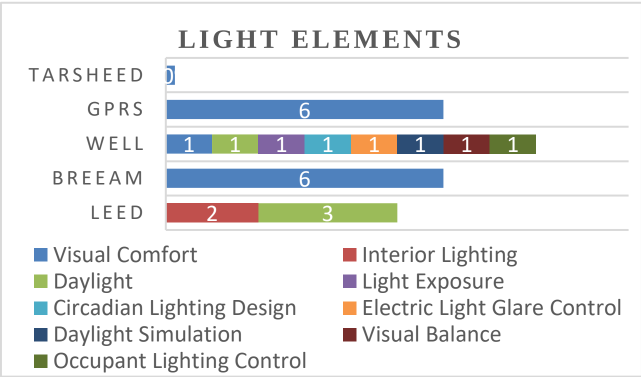

Figure 3. LEED, BREEAM, WELL, GPRS, and TARSHEED light elements. by researcher

Natural and unnatural lighting in buildings:

The sun is the primary source of light for the globe and the sunlight bounces back as it touches the roofs of the buildings and disperses when it hits the atoms of the air, becoming the light we see in the light of the sky[11].

When designing buildings, the architect reflects on how to light them sufficiently for good vision, and the architect must use unnatural lighting when the lighting is reduced deep into the building as a result of opening windows on skylights or indoor patios. The intensity of illumination is measured in lux[11].

Visual comfort in buildings is required so that individuals can perform their tasks properly for an extended period. Light has an impact on productivity and human health. That is why it is critical to consider human comfort[12].

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Main Visual Comfort Indices	
1	Sufficient light
2	(EML)Equivalent Melanopic Lux
3	Electric light glare control
4	Solar glare control
5	Color quality (Color rendering index)
6	color temperature
7	Lighting Control
8	Surface reflectivity
9	Daylighting

Table 1: Main Visual Comfort Indices.

Visual Comfort	International Rating Systems			Local Rating Systems	
	LEED	BREEAM	WELL	GPRS	TARSHEED
Sufficient light		✓	✓	✓	
EML			✓		
Electric light glare control	✓	✓	✓	✓	
Solar glare control		✓	✓		✓
Color rendering index	✓	✓	✓		
color temperature			✓		
Lighting Control	✓		✓	✓	
Surface reflectivity	✓		✓		
Daylighting		✓	✓	✓	✓

Table 2: Comparison of the elements of visual comfort in sustainable rating systems. by researcher.

Amount of healthy lighting required:

Dr. Diijkman's work indicates that healthy lighting ratios in which a person must work are at least 1,000 candle/feet and the value increases to 2,500 candle/feet at peak[13]. The average light in Egypt is higher than these rates and the light intensity at noon is up to 3,500 candle/feet on sunny days while when the sky is overcast the value drops to 1,000 candle/feet[13].

Building Type	Place	Daylight coefficient%
schools and colleges	Lecture rooms and meeting rooms	6
	Drawing lounges and work classes	2
	Labs	4
	faculty rooms	3

Table 3: Daylight coefficient in the case of natural lighting from the side windows.

Both Mortenson and Blackwell have found that people aged 30 to 40 years need 1.17 times more lighting than those ages 20 to 30[13].
Older people between 60 and 70 years of age need 2.51 times as much light as young people to see as clearly[13].

Activity	Sights	
Schools	lux	Candle/feet
Workshops, libraries, and reading rooms	300	30
Classrooms, stands, factories, and drawing rooms	500	50

Table 4: Amount of healthy lighting required in schools.

II.METHODOLOGY

The methodology is divided into four basic stages, as illustrated in Figure 2. Each stage has a set of steps, which are detailed in the following subsections.

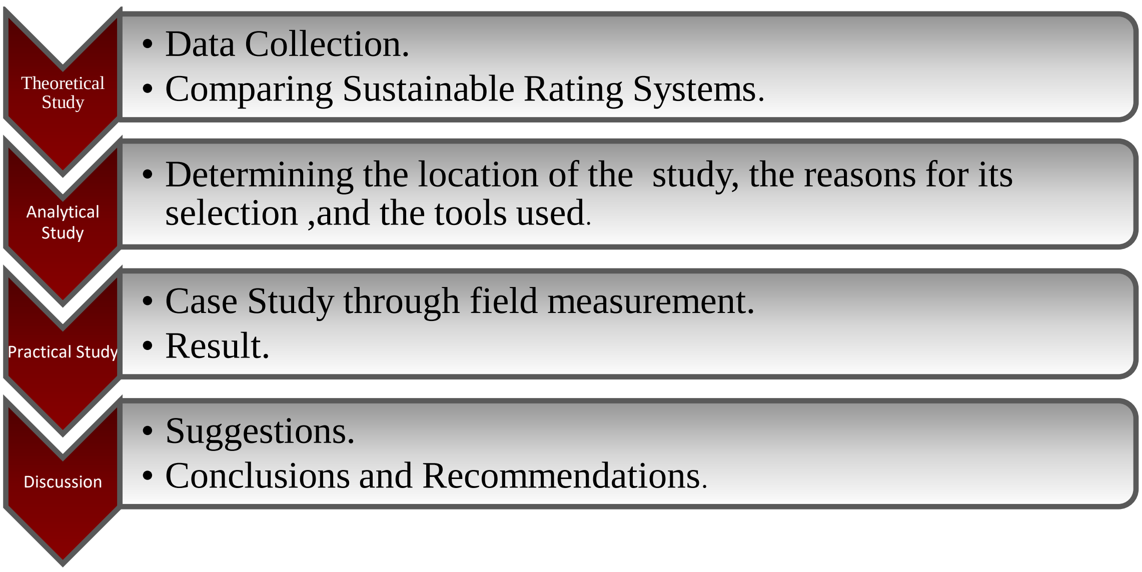


Figure 4. A diagram showing the methodology of the study.

A. Theoretical Study

At this stage, data is collected to define the subject of the study and the comparative analysis was determined by reviewing the literature and comparing a range of international and local sustainable rating systems in the lighting section.

B. Analytical Study

The next stage was to define a measuring ruler to compare the illumination in the selected systems. This stage included a case study through field measurement. The study was limited to educational buildings, as the study of lighting in them is very important and there is an integration between the use of natural and artificial lighting.

Research duration:

1. The study was conducted between February 2021 and October 2021.

2. The period was centered on July 2021 with seven months of practical research.

3. Illumination was measured using a Lux meter during the work period in the study site, at the following times: 9 AM, 12 PM, 3 PM, and 6 PM.

Research Location:

The practical study is based on an analysis of the building of the Mansoura Higher Institute of Engineering and Technology, located on the campus of Mansoura Educational College in Mansoura, Delta. The structure was chosen as a case study for several reasons, the most important of which are:

1. Educational buildings were selected as a case study because the lighting is the most important component of it.

2. Educational buildings integrate the use of daylight and electric lighting.

3. The main reason for choosing this educational building is that I work in it and have complaints from students about the lighting, so I am looking to solve this problem to improve my work environment and my students.

4. The Institute is one of the most modern university educational buildings in the Delta region, with the most advanced lighting systems, and specialized in the process of higher education.

5. The presence of lighting systems in most of the Institute's interior spaces increases electrical energy consumption.

6. The presence of a large number of students in internal spaces, particularly in educational terraces and drawing halls where the number of users in the space exceeds 60 at operating times, causes an increase in lighting loads.

Choosing Mansoura Higher Institute of Engineering and Technology is a case study:

Project Data for Mansoura's Higher Institute of Engineering and Technology

Project Name	Mansoura's Higher Institute of Engineering and Technology (MIET) (Mansoura College Academy)
Location	Talkha, Dakahlia Governorate, Egypt
Project Completion Date	September 2012
Project Category	New Construction
Project Type	Education – College/University
Project site	Previously develop land
Hours of Operation	9 hrs/wk.
Building Surface Area	1647.277

Table 5: Project Data for Mansoura's Higher Institute of Engineering and Technology. by the researcher.

Field measurement:

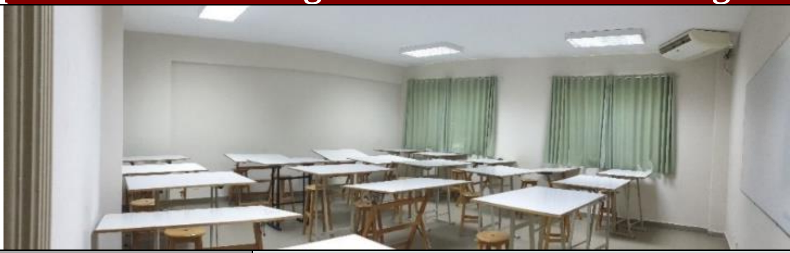
Description of the drawing room in Mansoura college academy	
	
Room Dimensions	W=7.92m *L=6.95m*H=3.3m
Room Surface Area	56.47m2
number of doors	1
Door dimensions	W=90cm, H=2.2m
number of windows	2
windows dimensions	W=2.3m, H=1.5m
windows session	1.2m
number of tables	20 tables
Table height	1.0m
number of bulbs	16 bulbs

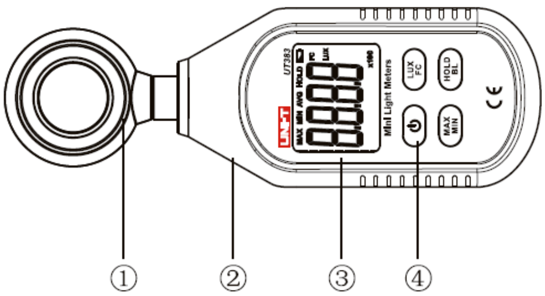
Table 6: Description of the drawing room in Mansoura college academy. by researcher.

C. Practical Study

At this stage, included case study through field measurement and Presentation of the Results.

The Luxmeter is used for field measurement and the background of this device is as follows:

The UT383 is a stable, safe, and dependable mini digital light meter that is widely used in lighting businesses, agriculture and animal husbandry, mining businesses, laboratories, offices, households, streetlight construction, and other applications. The UT383 can accurately measure light intensity and display results in Lux or FC on the screen[14].



1. Illumination transducer.
2. Meter case.
3. LCD display.
4. Function Keys.

Figure 5. Describe the Lux meter device.

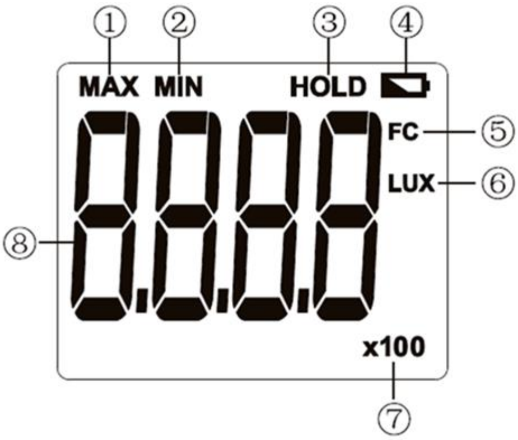


Figure 6. Screen of lux meter.

Figure 7. Lux meter device.

1	Maximum measurement	**5**	Foot candle
2	Minimum measurement	**6**	Lux
3	Data hold	**7**	Value*10 or value*100
4	Low battery	**8**	Illumination value

Table 7: Explanation of the screen of the lux meter

D. Discussion

The final stage of the study includes suggestions, conclusions, and recommendations.

III. RESULTS AND DISCUSSION

The lighting was measured by the lux meter at four different times during working hours in the building. Three cases were monitored, they are daylighting only, electric lighting, and daylighting and electric lighting together to monitor the lighting inside the space and monitor problems.

A. Measuring lighting at 9 am:

The first experiment to measure the intensity of illumination in the chosen case study was measured at 9 am in three different cases: daylighting only, electric lighting, and daylighting and electric lighting together, and results show:

1. In the case of daylight:

• We find that the intensity of illumination is very high near the windows and reaches 3733 lux, and this leads to intense glare, as shown in figures 8-9 and table 8.

•We find that the lighting is irregular in the drawing room, which leads to an imbalance among the students, as shown in figures 8- 9 and table 8.

•The lighting near the door is less than the required intensity and reaches 463 lux, as shown in figures 8- 9 and table 8.

•We find the change in the intensity of illumination on the blackboard when measured at three different points and the lighting is much higher than required, as shown in figure 10 and table 9.

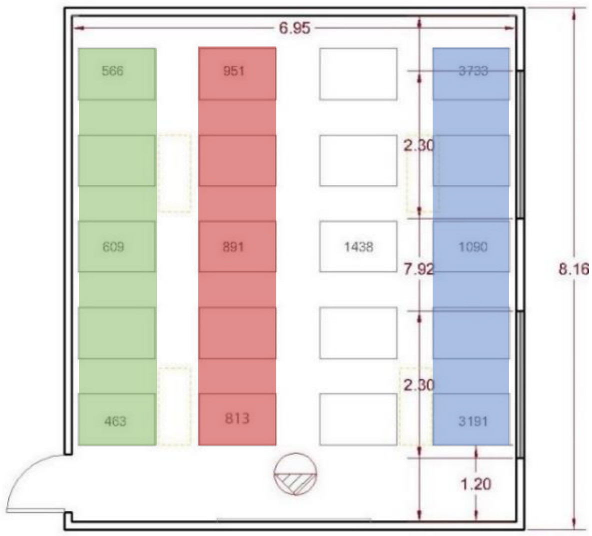


Figure 8. Plan of the drawing room when using daylight only at 9 Am.

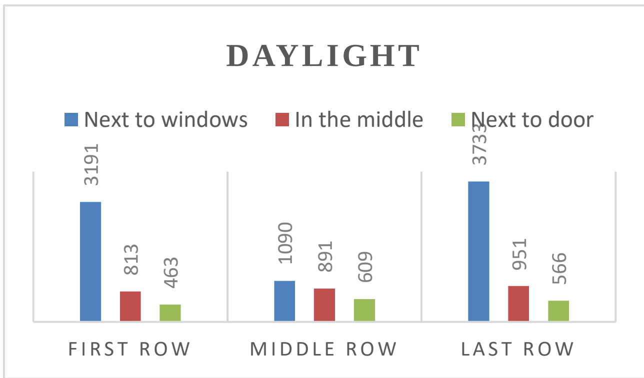


Figure 9. Daylight measurements at 9 AM.

	Next to windows	In the middle	Next to door
First row	3191	813	463
Middle row	1090	891	609
Last row	3733	951	566

Table 8: Daylight measurements at 9 AM.

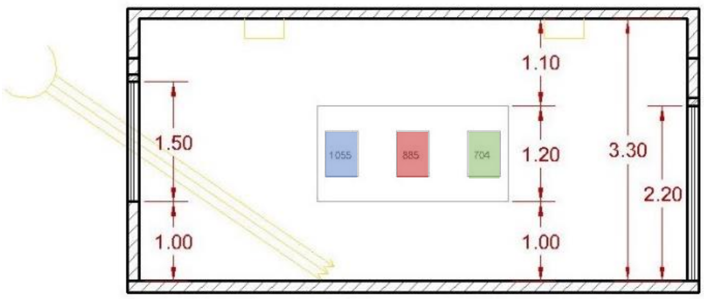


Figure 10. A section to show the measurements on the blackboard.

	Next to windows	In the middle	Next to door
Blackboard	1055	885	704

Table 9: Daylight measurements at 9 AM on the blackboard.

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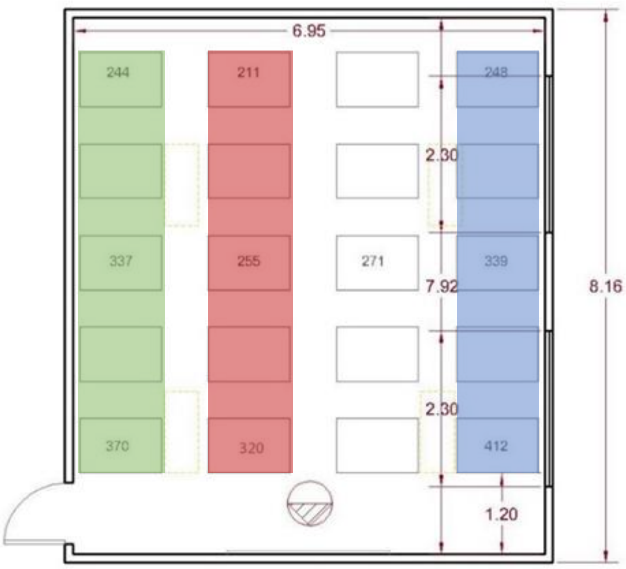
2. In the case of electric lighting:

- We find that the highest intensity of illumination is in the first row, as shown in figures 11-12 and table 10.
- The lowest light intensity is in the last row, and the lowest point is 211 lux, as shown in figures 11-12 and table 10.
- Electric lighting alone is not sufficient for the lighting requirements of the place, as the highest point is 412 lux, as shown in figures 11-12 and table 10.
- We find the change in the intensity of illumination on the board when it is measured at three different points and the illumination is much less than what is required up to 82 lux, as shown in Figure 13 and Table 11.



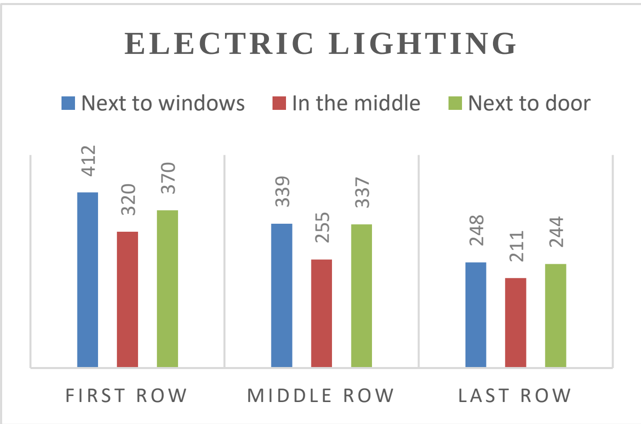


Figure 12. Electric lighting measurements at 9 AM.

Figure 11. Plan of the drawing room when using electric lighting only at 9 Am.

	Next to windows	In the middle	Next to door
First row	412	320	370
Middle row	339	255	337
Last row	248	211	244

Table 10: Electric lighting measurements at 9 AM.

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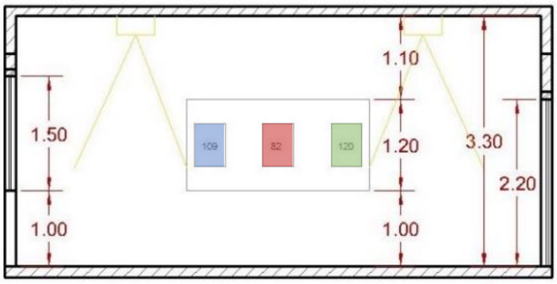


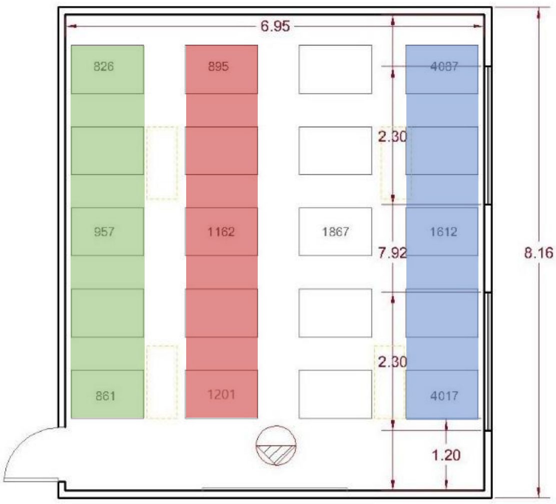
Figure 13. A section to show the measurements on the blackboard.

	Next to windows	In the middle	Next to door
Blackboard	109	82	120

Table 11: Electric lighting measurements at 9 AM on the blackboard.

3. In the case of daylight and electric lighting:

- We find that the intensity of illumination is very high near the windows and reaches 4017 lux, and this leads to intense glare, as shown in figures14-15 and table 12.
- We find that the lighting is irregular in the drawing room, as shown in figures 15-14and table 12.
- The lighting near the door is less than the lighting near the window and reaches 463 lux, as shown in figures 14-15 and table 12.
- We find the change in the intensity of illumination on the blackboard when measured at three different points and the lighting is much higher than required and reaches 1270 lux, as shown in figure 16 and table 13.



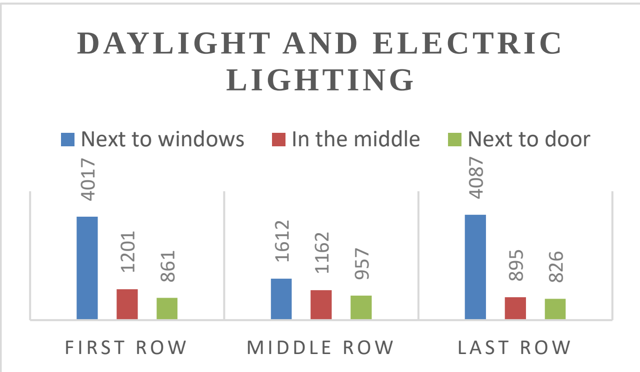


Figure 15. Daylight and electric lighting measurements at 9 AM.

Figure 14. Plan of the drawing room when using Daylight electric lighting only at 9 Am.

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	Next to windows	In the middle	Next to door
First row	4017	1201	861
Middle row	1612	1162	957
Last row	4087	895	826

Table 12: Daylight and electric lighting measurements at 9 AM.

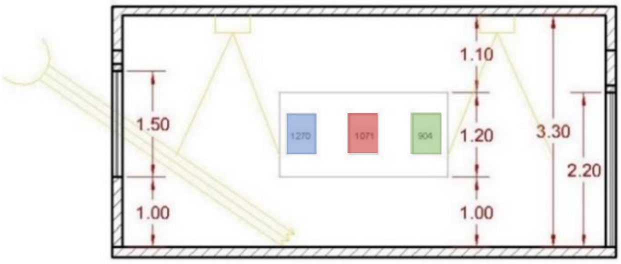


Figure 16. A section to show the measurements on the blackboard.

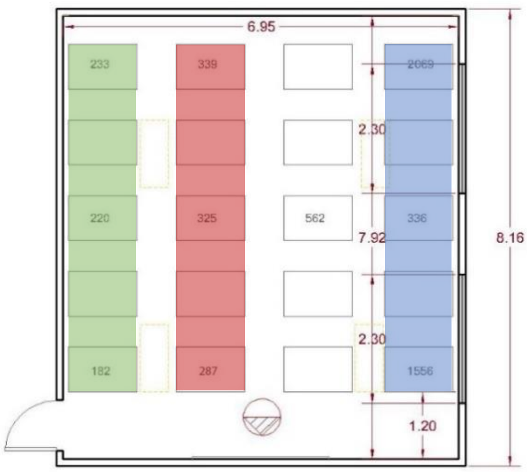
	Next to windows	In the middle	Next to door
Blackboard	1270	1071	904

Table 13: Daylight and electric lighting measurements at 9 AM on the blackboard.

B. *Measuring lighting at 12 pm:*

1. In the case of daylight:

- We find that the intensity of illumination is very high near the windows and reaches 2069 lux, as shown in figures 17-18 and table 14.
- We find that the intensity of the lighting is very low in the drawing room and reaches 182 lux, as shown in figures 17-18 and table 14.
- We find the change in the intensity of illumination on the board the illumination is low 247 lux, as shown in Figure 19 and Table 15.



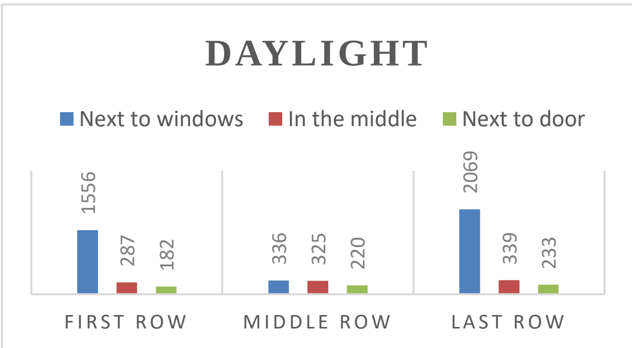


Figure 18. Daylight measurements at 12 PM.

Figure 17. Plan of the drawing room when using daylight only at 12 pm.

	Next to windows	In the middle	Next to door
First row	1556	287	182
Middle row	336	325	220
Last row	2069	339	233

Table 14: Daylight measurements at 12 PM.

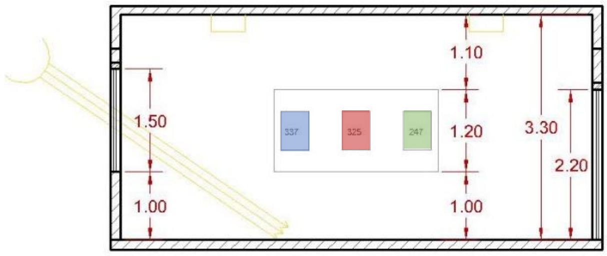


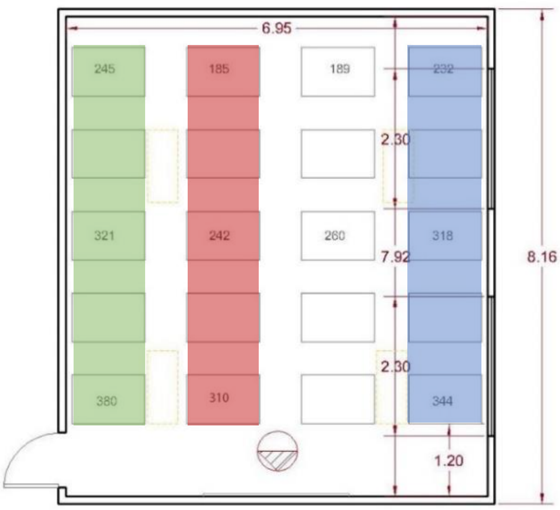
Figure 19. A section to show the measurements on the blackboard.

	Next to windows	In the middle	Next to door
Blackboard	337	325	247

Table 15: Daylight measurements at 12 PM on the blackboard.

2. In the case of electric lighting:

- Electric lighting is not sufficient for the lighting requirements of the place, as the highest point is 380 lux, as shown in figures 20-21 and table 16.
- We find that the least illumination intensity is in the last row and the highest in the first, as shown in Figures 20-21 and Table 16.
- We find that the intensity of illumination on the blackboard is much less than what is required up to 75 lux, as shown in Figure 22 and Table 17.



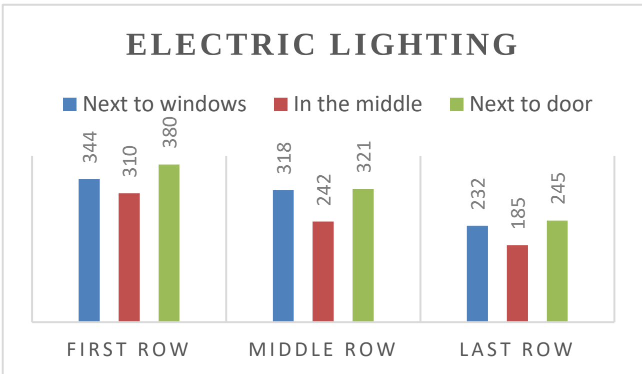


Figure 21. Electric lighting measurements at 12 PM.

Figure 20. Plan of the drawing room when using electric lighting only at 12 PM.

	Next to windows	In the middle	Next to door
First row	344	310	380
Middle row	318	242	321
Last row	232	185	245

Table 16: Electric lighting measurements at 12 PM.

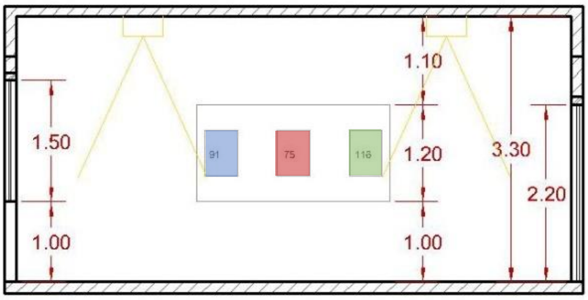


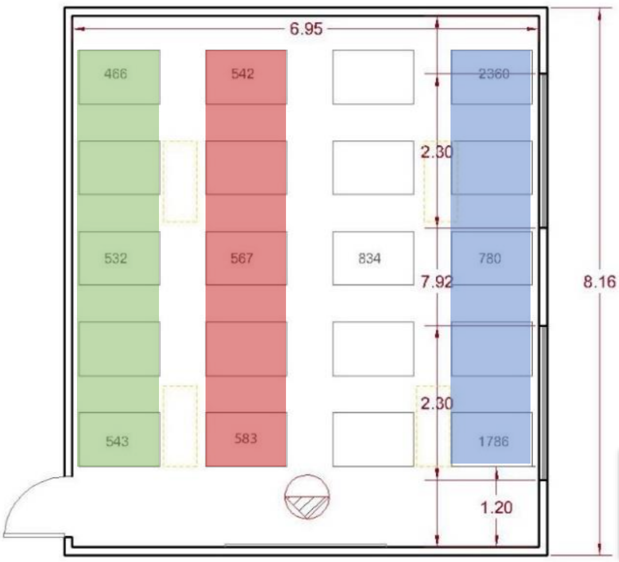
Figure 22. A section to show the measurements on the blackboard.

	Next to windows	In the middle	Next to door
Blackboard	91	75	116

Table 17: Electric lighting measurements at 12 PM on the blackboard.

3. In the case of daylight and electric lighting:

- We find that the intensity of illumination is very high near the windows and reaches 2360 lux, in contrast to the illumination near the door, which is as low as 466 lux, as shown in Figures 23-24 and Table 18.
- We find that the intensity of illumination on the blackboard is much less than what is required up to 75 lux, as shown in Figure 25 and Table 19.



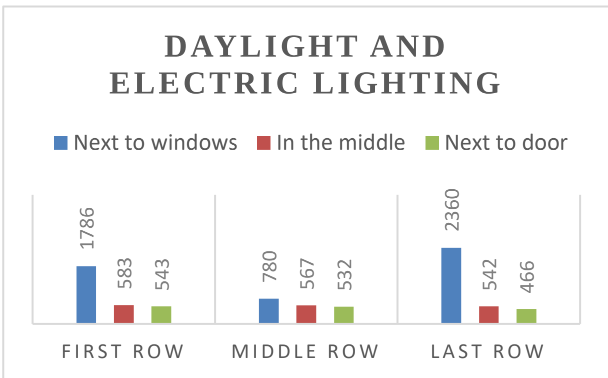


Figure 24. Daylight and electric lighting measurements at 12 PM.

Figure 23. Plan of the drawing room when using Daylight electric lighting only at 12 Pm.

	Next to windows	In the middle	Next to door
First row	1786	583	543
Middle row	780	567	532
Last row	2360	542	466

Table 18: **Daylight and electric lighting measurements at 12 PM.**

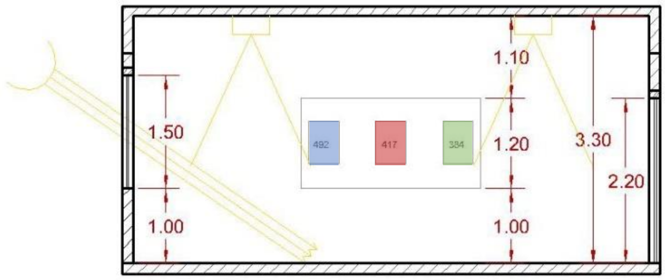


Figure 25. A section to show the measurements on the blackboard.

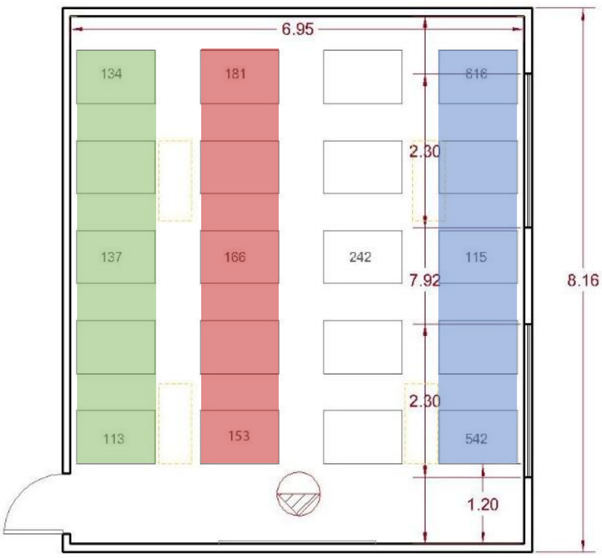
	Next to windows	In the middle	Next to door
Blackboard	492	417	384

Table 19: Daylight and electric lighting measurements at 12 PM on the blackboard.

C. *Measuring lighting at 3 pm:*

1. In the case of daylight:

- We found that the intensity of illumination is high near the windows in the first and last rows, and it reaches 616 lux, and it is low in many points of the room, as shown in Figures 26-27 and Table 20.
- We find that the intensity of illumination on the blackboard is much less than what is required up to 188 lux, as shown in Figure 28 and Table 21.



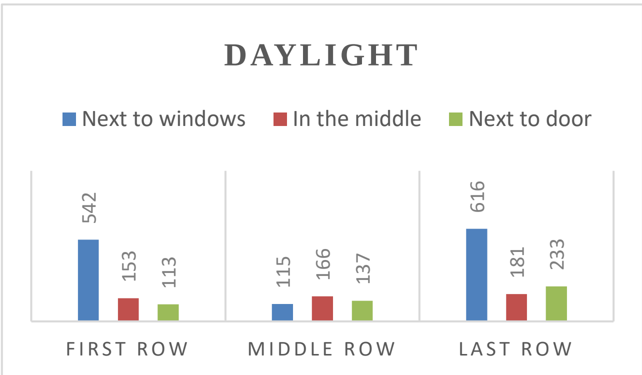


Figure 27. Daylight measurements at 3 PM.

Figure 26. Plan of the drawing room when using daylight only at 3 pm.

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	Next to windows	In the middle	Next to door
First row	542	153	113
Middle row	115	166	137
Last row	616	181	134

Table 20: Daylight measurements at 3 PM.

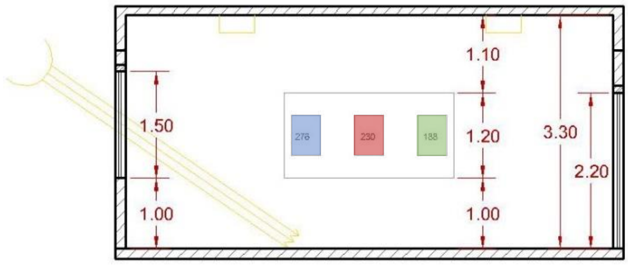


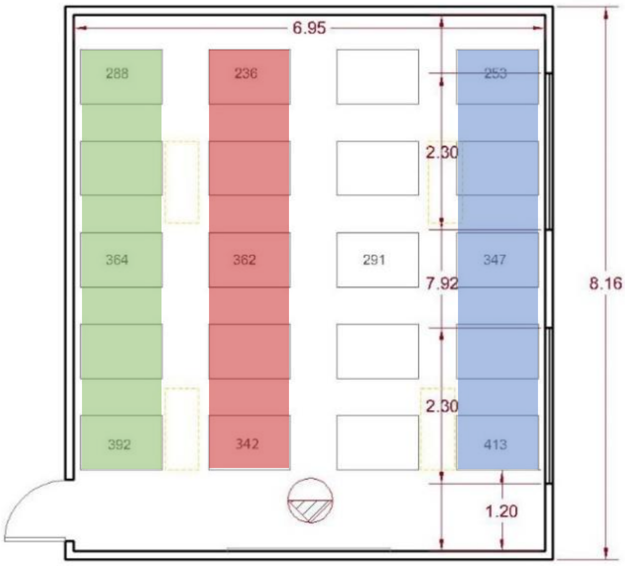
Figure 28. A section to show the measurements on the blackboard.

	Next to windows	In the middle	Next to door
Blackboard	276	230	188

Table 21: Daylight measurements at 3 PM on the blackboard.

2. In the case of electric lighting:

- We find that the least illumination intensity is in the last row and electric lighting alone is not sufficient for the lighting requirements of the place, as the highest point is 413 lux, as shown in figures 29-30 and table 22.
- We find that the intensity of illumination on the blackboard is much less than what is required up to 85 lux, as shown in Figure 31 and Table 23.



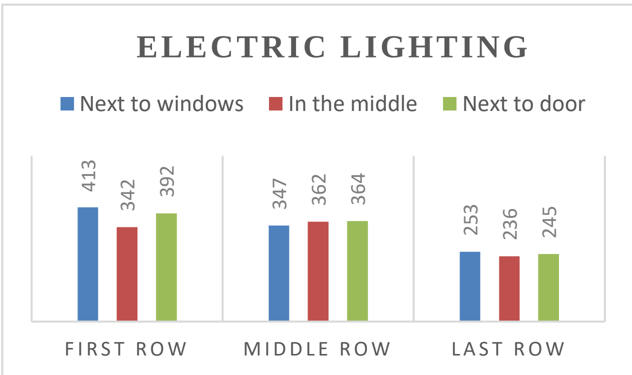


Figure 30. Electric lighting measurements at 3 PM.

Figure 29. Plan of the drawing room when using electric lighting only at 3 PM.

	Next to windows	In the middle	Next to door
First row	413	342	392
Middle row	347	362	364
Last row	253	236	288

Table 22: Electric lighting measurements at 3 PM.

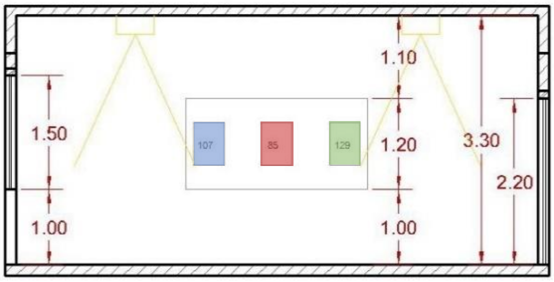


Figure 31. A section to show the measurements on the blackboard.

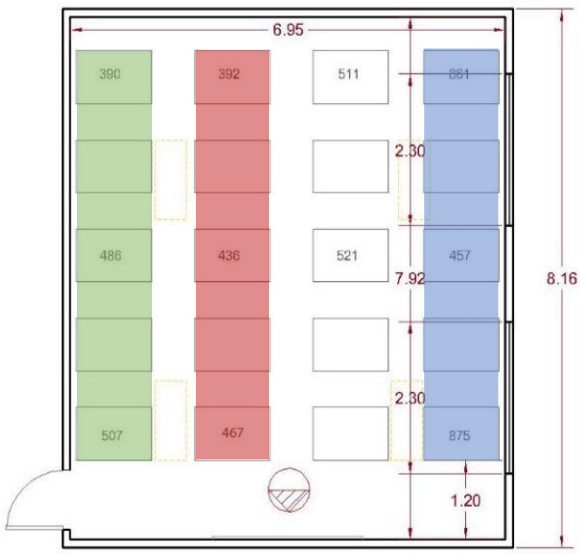
	Next to windows	In the middle	Next to door
Blackboard	107	85	129

Table 23: Electric lighting measurements at 3 PM on the blackboard.

3. In the case of daylight and electric lighting:

• We find that the intensity of lighting in many points is less than what is required to complete the tasks and the intensity of illumination is very high near the windows, as shown in Figures 32-33 and Table 24.

• We find that the intensity of illumination on the blackboard is much less than what is required up to 85 lux, as shown in Figure 34 and Table 25.



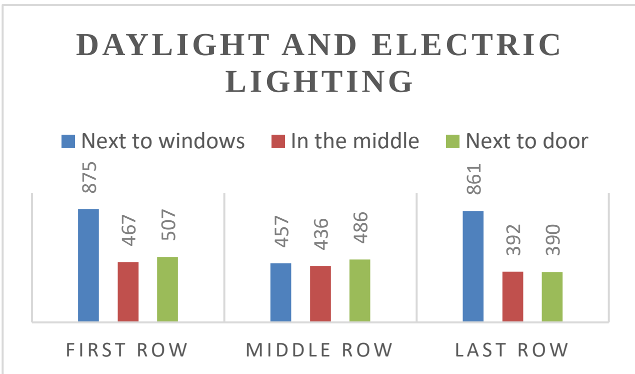


Figure 33. Daylight and electric lighting measurements at 3 PM.

Figure 32. Plan of the drawing room when using Daylight electric lighting only at 3 Pm.

	Next to windows	In the middle	Next to door
First row	875	467	507
Middle row	457	436	486
Last row	861	392	390

Table 24: Daylight and electric lighting measurements at 3 PM.

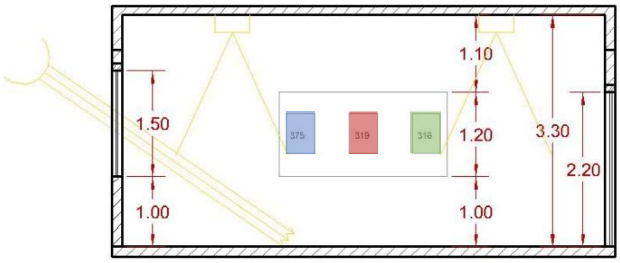


Figure 34. A section to show the measurements on the blackboard.

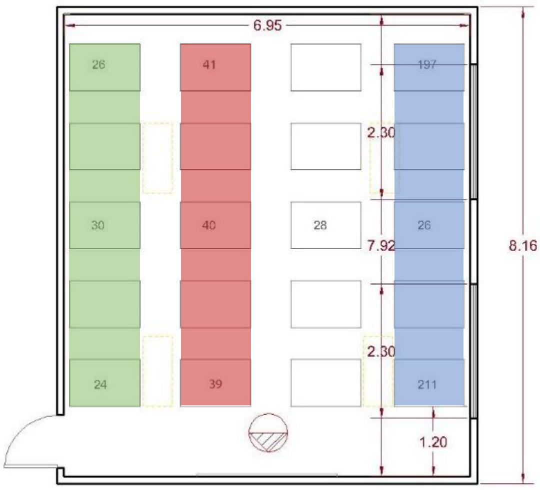
	Next to windows	In the middle	Next to door
Blackboard	375	319	316

Table 25: Daylight and electric lighting measurements at 3 PM on the blackboard.

D. Measuring lighting at 6 pm:

1. In the case of daylight:

- The intensity of illumination is less than required at each point in the space and the lighting near the door is less than the lighting near the window, s as shown in Figures 35-36 and Table 26 ,so in this case, the place is almost opaque.
- We find that the intensity of illumination on the blackboard is much less than what is required up to 85 lux, as shown in Figure 37 and Table 27.



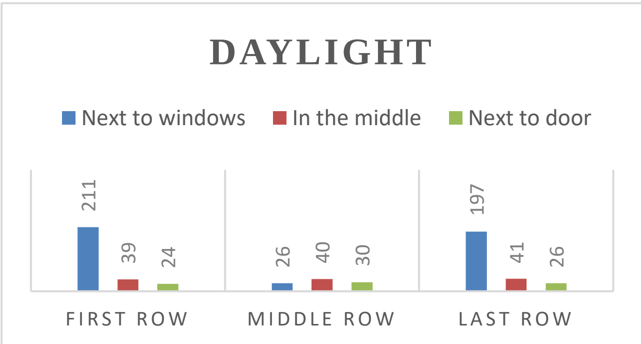


Figure 36. Daylight measurements at 6 PM.

Figure 35. Plan of the drawing room when using daylight only at 6 pm.

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	Next to windows	In the middle	Next to door
First row	211	39	24
Middle row	26	40	30
Last row	197	41	26

Table 26: Daylight measurements at 6 PM.

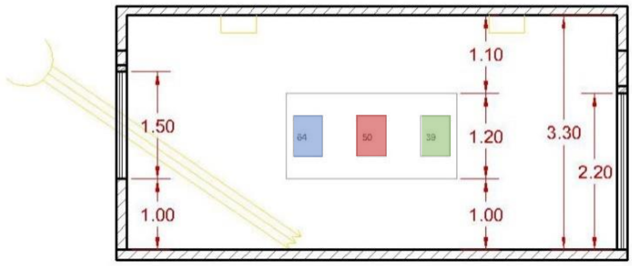


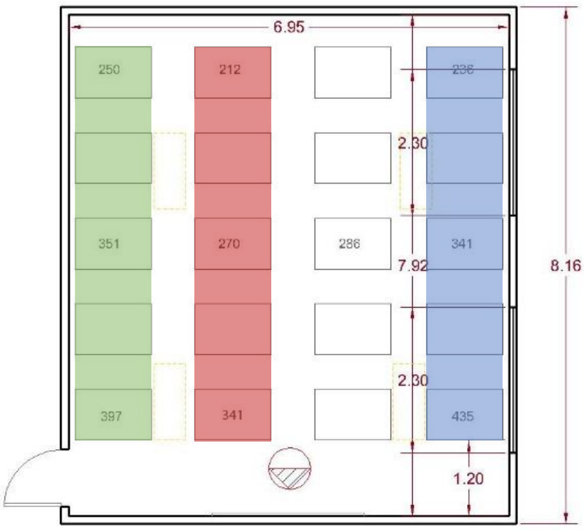
Figure 37. A section to show the measurements on the blackboard.

	Next to windows	In the middle	Next to door
Blackboard	64	50	39

Table 27: Daylight measurements at 6 PM on the blackboard.

2. In the case of electric lighting:

- We find that the least illumination intensity is in the last row and electric lighting alone is not sufficient for the lighting requirements of the place, as the highest point is 435 lux, as shown in figures 38-39 and Table 28.
- We find that the intensity of illumination on the blackboard is much less than what is required up to 91 lux, as shown in Figure 40 and Table 29.



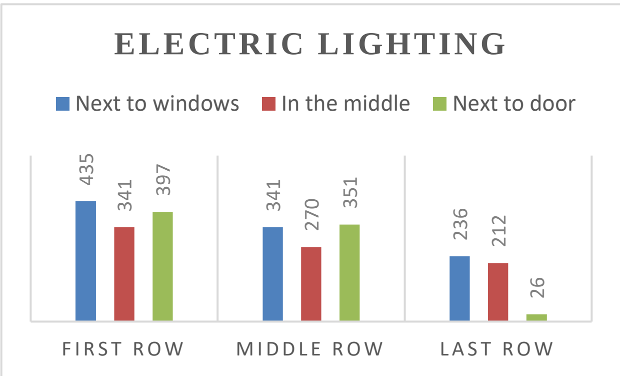


Figure 39. Electric lighting measurements at 6 PM.

Figure 38. Plan of the drawing room when using electric lighting only at 3 PM.

	Next to windows	In the middle	Next to door
First row	435	341	397
Middle row	341	270	351
Last row	236	212	250

Table 28: Electric lighting measurements at 6 PM.

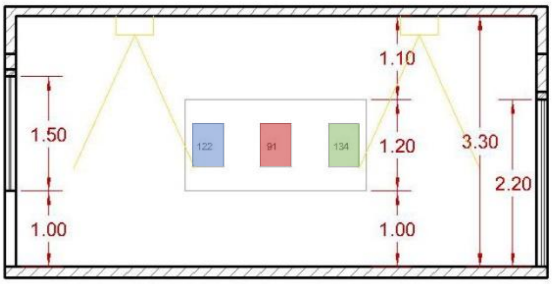


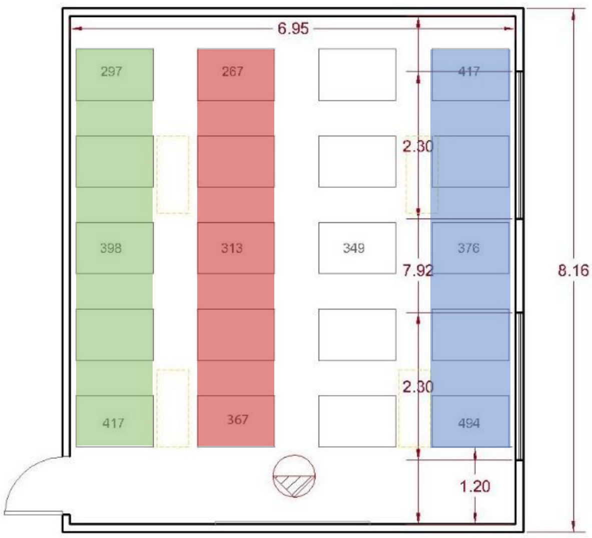
Figure 40. A section to show the measurements on the blackboard.

	Next to windows	In the middle	Next to door
Blackboard	122	91	134

Table 29: Electric lighting measurements at 6 PM.

3. In the case of daylight and electric lighting:

- We find that the intensity of lighting at many points is less than what is required to complete the tasks, as shown in figures 41-42 and Table 30.
- We find that the lighting is irregular in the drawing room, which leads to an imbalance among the students, as shown in figures 41-42 and Table 30.
- We find that the intensity of illumination on the blackboard is much less than what is required up to 129 lux, as shown in Figure 43 and Table 31.



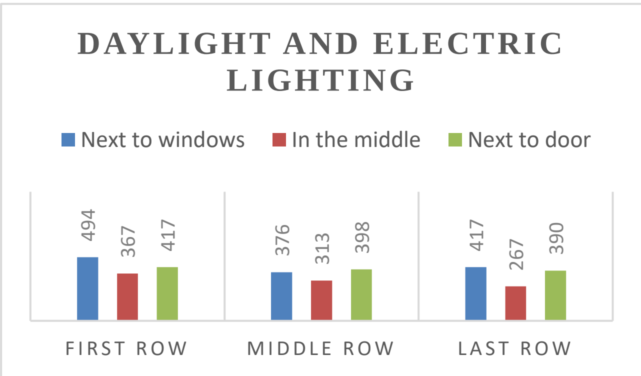


Figure 42. Daylight and electric lighting measurements at 3 PM.

Figure 41. Plan of the drawing room when using Daylight electric lighting only at 6 Pm.

	Next to windows	In the middle	Next to door
First row	494	367	417
Middle row	376	313	398
Last row	417	267	297

Table 30: Daylight and electric lighting measurements at 6 PM.

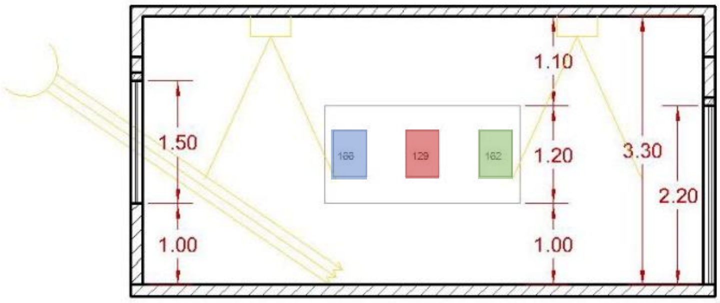


Figure 43. A section to show the measurements on the blackboard.

	Next to windows	In the middle	Next to door
Blackboard	166	129	162

Table 31: Daylight and electric lighting measurements at 6 PM on the blackboard.

IV.CONCLUSIONS

This paper discussed the importance of lighting and its impact on human comfort, including the identification of visual comfort points, and some of the sustainable rating systems and lighting elements were discussed, to find that the system most concerned with visual comfort points is the American Wall rating System, as shown in Table 2 as it was specially created For the occupants of the building and their comfort, and then a case study of a drawing room was conducted at four different times to apply the first point of comparison, which is surfactant light, to find out whether the lighting is sufficient or not in the space.

Through the previous practical study, a lot of problems were found, and they were mentioned in the results for each case, and they must be solved to reach a healthy space that will achieve visual comfort for the users of the space.

Recommendations

- Irregular lighting distribution leads to visual disturbances among students, so it is necessary to re-design and distribute lighting in the ceilings, as there are many spots with glare and others without lighting.
- It is possible to use moving lighting on each drawing table to allow the student to control it.
- Designing and distributing lighting for the blackboard, and it is possible to put lighting directly on it from the sides to open it in the case of poor lighting, as we saw in the previous cases.
- It is necessary to use mechanical curtains that close and open according to the amount of lighting needed by the place if the electric lighting is open, as we found in many cases that the intensity of the lighting is high, which causes glare near the windows.
- It is suggested to pay attention to the application of the points of the well rating system, as it is concerned with the comfort and requirements of the occupants of the building, and we conclude from this that when applying the points for lighting, the place reaches the required visual comfort.

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