Journal of Umm Al-Qura University for Engineering and Architecture

journal homepage: https://uqu.edu.sa/en/jea

Associating Daylight and Acoustic Design in Internal Educational Spaces with Students Psychological Satisfaction

Abdulhafeez Ahmad M. Alwafi

Department of Islamic Architecture, Faculty of Engineering and Islamic Architecture, Umm Al-Qura University, Makkah, Saudi Arabia.

A R T I C L E I N F O

Article History:
Submission date: 31/01/2021
Accepted date: 31/05/2021

Keywords:
Daylight; Noise; Psychological satisfaction; Indoor spaces; Educational performance.

A B S T R A C T

Introduction*: Certain building design and environmental factors are necessary to characterize critical building environments, especially educational facilities, because they influence students' comfort and cognitive performance. Lighting has crucial importance in educational buildings since a sufficient daylight level is crucial to carry out the necessary educational tasks and ensure optimum student productivity. Moreover, Carefully designed daylighting can transform any room's appearance and make it attractive, welcoming, and even restful. A significant level of acoustics is also required for keeping the students' perception at the peak levels.*
This study aim*s to find the associations between daylighting levels and background noise level on one side, and the students' productivity level and their psychological satisfaction on the other side.*
Subjects and Methods: *Thirty-two students from the College of Engineering and Islamic Architecture at Umm Al-Qura University were screened for their academic performance and psychological satisfaction using questionnaires. Additionally, environmental parameters, including daylight and background noise levels, were measured at the student's location chair and simulated using a computer-based simulation tool named "Design builder" for extra verification to the reads then all the students' records, answers, and environmental reads were coded and correlated using SPSS tool.*
Results: *significant associations were found between students' satisfaction towards the daylight and noise intensity and their actual daylight and noise exposure, side by side, with another significant relationship between the time that students took to solve mathematical problems with the actual daylight and noise reads. Students who were exposed to higher noise level with low daylight intensity were performing lower than their performance when they were exposed to lower levels of noise and higher levels of daylight intensity*
Conclusion *More attention toward light/noise engineering control in educational buildings is required to improve students' psychological satisfaction and educational performance.*

1. Introduction:

Ambient, well-designed environments are supposed to have transitions of light and color design that allow the eye to adapt to changes in the levels of lighting. Sometimes relatively minor modifications in the lighting design of spaces could solve an ongoing, unconquerable problem (as an example, more daylight focused on walls with an accent color to brighten up a dark area) (Gordon, 2015). However, a Perfectly-Designed building is only an architectural issue, as a suitable balance is required between economic, social, and environmental aspects. The triangle in Figure 1 demonstrates the three main aspects of any designed space. It is preferred to avoid spaces with light grey points where a single or a couple of aspects get the project's high values where the other aspects are lost, such as context or human interaction with the building (BRE, 2007).

Compared to the design standards of educational facilities in Saudi Arabia, building performance is not required to be assessed by making pre-design simulations, site measurements, or even post-occupancy studies (Schomaker, 2015). Eventually, architecture usually serves people and responds to the natural environment. So, no matter how sustainable the building is expressed, the post-occupancy evaluation is a necessary approach to assess the reflection of building performance to the users' performance inside the indoor spaces of the building through the users' feedback (Yan, et al., 2015). This situation has been investigated by Imke Wies was Mil, and his research team in 2018, who found that the artificial lighting distribution with measured noise levels led to higher percentages of focused students in elementary schools. Still, they did not investigate the effects of daylighting and noise intensities on students' performance, and a particular relationship between the students' satisfaction and daylighting and noise design was not investigated, which is covered in this research (van Mil, et al., 2018). However, another study by Sapna Cheryan and her research team in 2014 discussed the influences of daylighting, noise, and air quality on students' performance, as the study discussed the effects of the learning environment on the students' performance generally. Still, the study was not focused on the effects of a single environmental factor on the learning quality or students' performance which this study covers with the daylighting and noise intensities (Cheryan, et al., 2014).

Consultants of lighting and interior designers usually demonstrate the reason why an indoor space does not "feel" right. For example, a change in the size of the window or modifying a skylight may affect a whole area dramatically with the appropriate solutions. However, for the higher education industry, the issue of environmental impact is exceptionally substantial. As of yet, many issues related to the design and operation of higher educational facilities challenge this principle tenet (Bellia, et al., 2013). When artificial lighting is compared with daylight in educational spaces, it is usually preferred by most users, as it offers dynamic interiors and views (Bellia, et al., 2013). Daylight is generally used to optimize occupant comfort, besides providing a more pleasant and attractive indoor environment with higher user's performance and productivity (Esfandiari, et al., 2017). Energy usage

* **Corresponding Author**
Department of Islamic Architecture, Faculty of Engineering and Islamic Architecture, Umm Al-Qura University, Makkah, Saudi Arabia.
E-mail address: aawafi@uqu.edu.sa (Abdulhafeez Ahmad M. Alwafi).

association with environmental emissions may also be reduced with the appropriate daylight design, which is considered significant and valuable regarding visual comfort and energy-efficient building design (Seiple, et al., 2018).

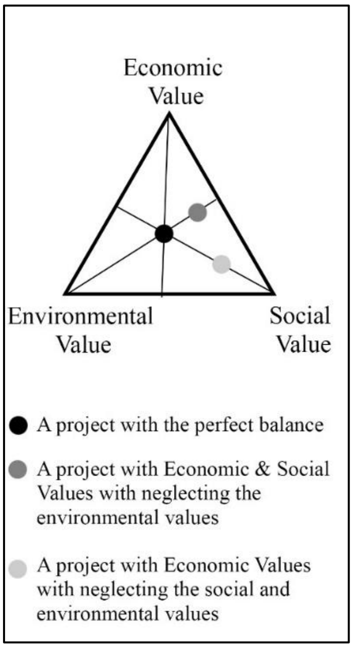

Figure 1 (The main three aspects for any project) (BRE, 2007)

Consequently, the acoustics design in lecture halls has been internationally researched in recent years. It was found that the poor acoustics design has a negative effect on the students and lecturers, as seen in a study by McKenzie in 1999 (McKenzie-Garner, et al., 1999). For sure, good acoustics design is also essential in lecture halls, as the background noise should be minimized, and the room materials and form must be designed to support the acoustics for the sake of providing high speech intelligibility (Dunn, et al., 2015). As the seat numbers in a lecture hall are usually high compared to a small classroom, the excellent speech acoustics achievement is more complex (ang & Lu, 2018). In Germany, DIN 18041 was revised then presented in 2004. DIN 18041 specifies three noise limits categories. These are a function of the distance between the talker and listeners and the type of instruction (for hearing impaired, challenging, and foreign language texts for lecture hall's noise limits of 35 dB(A) or 30 dB(A) are recommended (Eggenschwiler, 2005).

Table 1 (Maximum allowed background noise according to DIN 18041) (Eggenschwiler, 2005)

Requirements	Maximum allowed background noise (dB.)
Low	40
Medium	35
High	30

1.1. Research aims

The main aim of this research is to investigate the association between daylight intensity and background noise on one side, and the students' psychological satisfaction on the other side, check Figure 7. Daylight and noise were measured simultaneously, together with the assessment of the students' psychological satisfaction to establish guidelines for the better architectural design of educative buildings.

2. Subjects and Methods:

2.1. study location

The selected case study was conducted in the College of Engineering and Islamic Architecture at Umm Al-Qura University. The selection of this educational facility was based on the following criteria; the existence of the Faculty within the boundaries of Umm Al-Qura University check Figure 2, which includes many other faculties and schools that generate much noise near Main Academic Axe. Simultaneously, the west northern areas are quiet, with little background noise generated from the parking area near the northern areas. Check Figure 3.

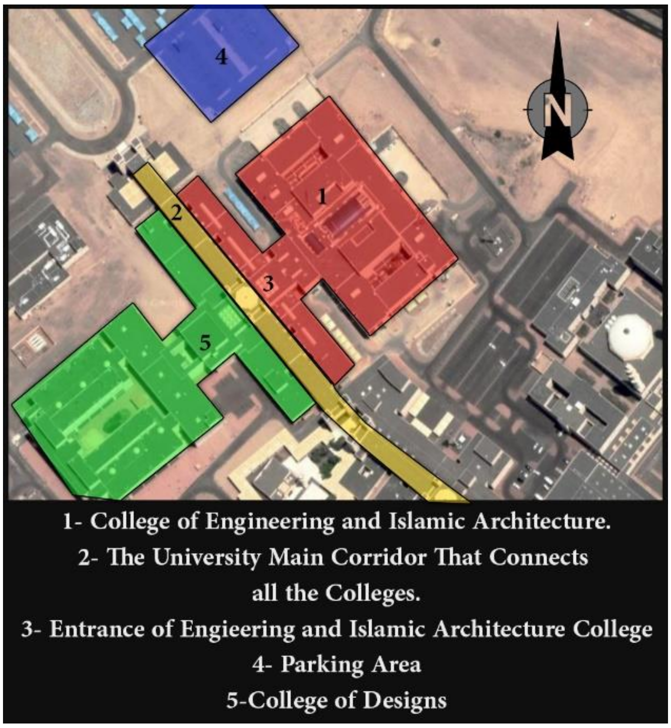

Figure 2 (Masterplan of Umm Al-Qura University – College of Engineering and Islamic Architecture) (Umm Al-Qura University projects adminstration, 2020)

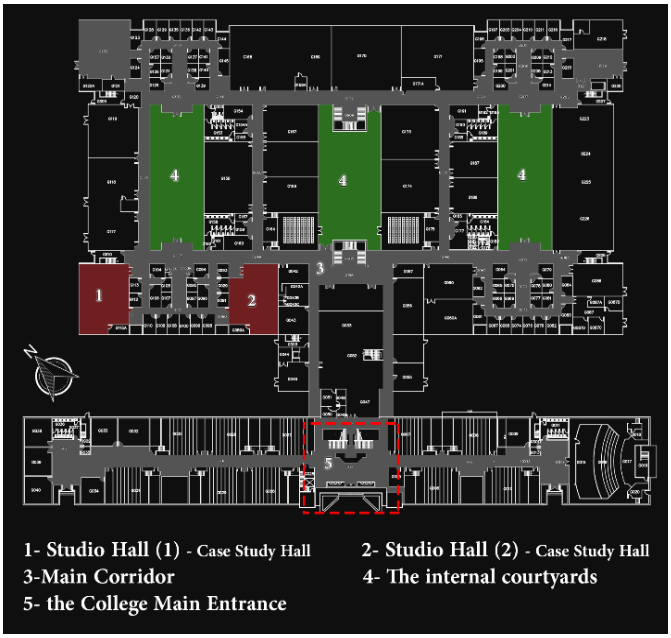

Figure 3 (the faculty ground floor plan demonstrating the case study: studio halls 1,2) (Umm Al-Qura University projects adminstration, 2020)

2.2. studied spaces and durations

The daylight also varies in each studio hall due to the floor plan ratio of each space. However, the existence of northern windows on the studio hall (1) results in the daylight without direct sunlight but poorly distributed due to the low window high ratio to the space depth, as shown in Figure 4.

Figure 4 (demonstrating studio hall (1) plan details, furniture design, and window view)

meanwhile, a single-window on studio hall (2) is oriented to the western south side. Still, the skylighted court is on the northern side, which results in better daylight distribution over the daytime mixed with direct sunlight after 12 PM, which affects the students' sight inside the studio hall. Moreover, the existence of the southern block beside the northern wall of studio hall (2) maximizes the daylight distribution as the daylight on the north side is less than the south side of the interior space, as shown in Figure 5.

Figure 5 (demonstrating studio hall (2) plan details, furniture design, and window view)

2.3. ethical approvals

All approvals were obtained from all the participants in the research. Moreover, all the students voluntarily participated in the research study, the aims and procedures of the research were fully explained to them, and oral informed consent was obtained. Students were free to refuse participation without any penalty. The total number of participating students was thirty-two.

2.4. Methodology

The research methods are based on exposing the target students to different daylight and noise intensities and then measure their performance in each case, so the 32 students were set in specific places in each studio hall, then were asked first to answer a survey questionnaire about their satisfaction towards the daylight and noise surrounding them. They were asked to do a small mathematical test. Finally, they were given a 15 min lecture about an architectural topic, after which they were offered an evaluative mini-exam about the lecture. Upon completing the exam, they were asked to move to the other studio hall, where they were totally free to select their seating places. Their seating places were recorded, and repetition of the previous procedures as the first studio hall was done in the new seating location. All the survey questionnaires and tests results were gathered. Which eventually led to four different situations (student cases):

- **Students with improved daylight and decreased noise**
- **Students with improved daylight and increased noise**
- **Students with decreased daylight and increased noise**
- **Students with decreased daylight and decreased noise**

The results of the four situations were recorded and set into a statistical analysis to help to figure out the relationship between the daylight and noise intensity and the students' performance. Check Figure 6, which provides a stepwise flowchart for the adopted methodological procedures.

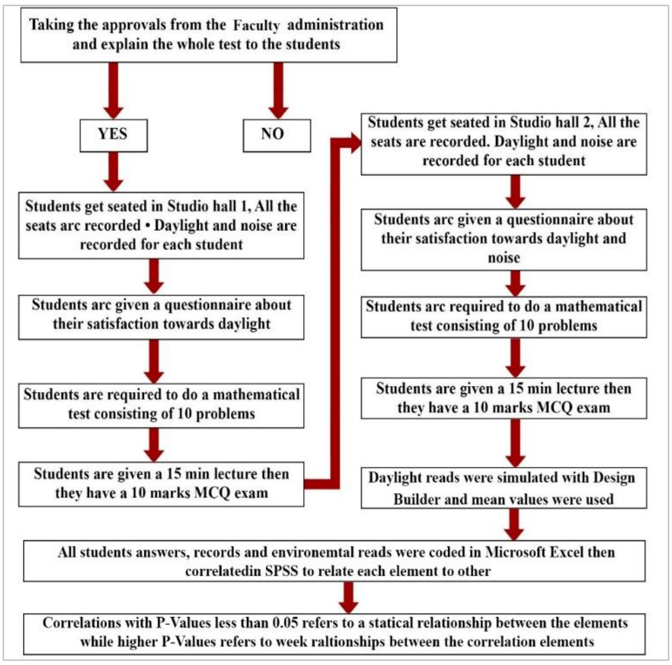

Figure 6 (flowchart demonstrating the methodology used in the research)

2.5. Measurements and results

1.1.1. Daylight measuring

Daylight was measured by a light measuring tool "Pros kit lux meter", as shown in Figure 7. Furthermore, for extra verifications, the Studio halls were modeled in a computer-based building performance simulation tool named " Design-Builder Software", check Figure 8, in which the same measured points by the light measuring tool were spotted to have the simulated measures from "Design-Builder".

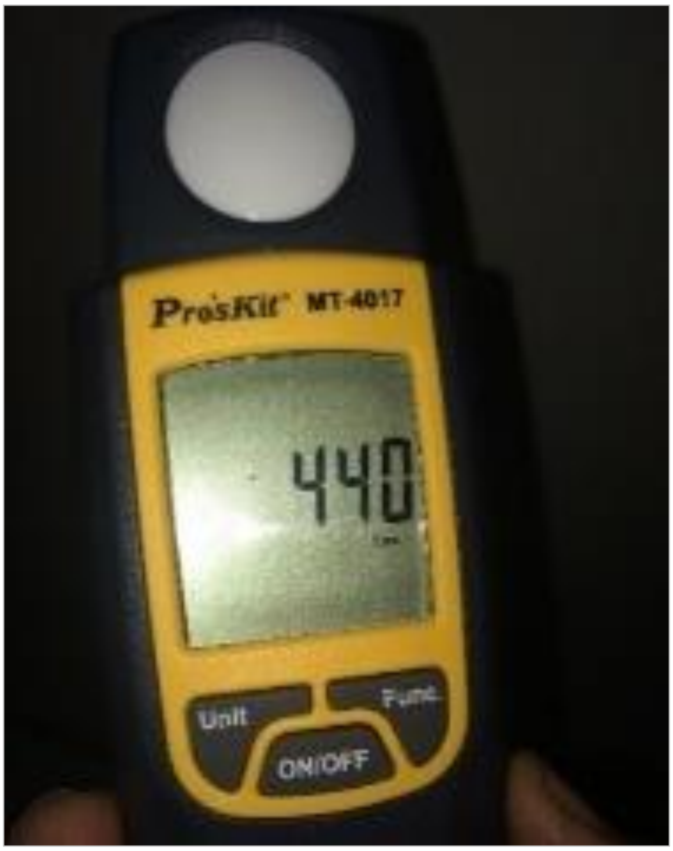

Figure 7 ("Pros kit" Lux meter tool)

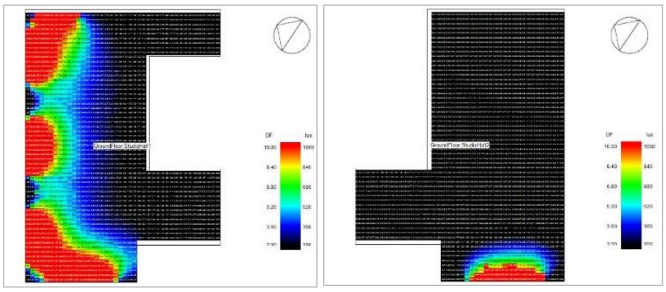

Figure 8 (daylight simulation results for Studio Hall 1,2)

The final step in daylight measuring was comparing the mean values between the "pros kit" Lux meter tool and the simulated daylight intensity values obtained by "design-builder" to reach the optimum daylight measures as shown samples of the measures in Table 3.

Finally, the test sample was divided into two groups; Group 1: students with seats exposed to daylight intensity over 400 lux. Group 2: students with seats exposed to daylight intensity of less than 400 lux.

Table 3 (the recorded data from the Lux meter and simulation)

	Studio hall 1				Studio hall 2			
Daylight by design builder (lux)	135	214	230	896	196	630	361	108
Daylight by lux meter (lux)	133	210	230	896	200	630	367	104
Mean daylight (lux) ± standard deviations	134±1	212±2	230±0	896±0	198±2	630±0	364±3	106±2

1.1.2. Background Noise Measuring

Background noise was measured with a mobile-based application named "Decibel 10" which measures the current noise intensity at the test time. Based on the hypothesis that the outside environment is the primary noise source for each Studio hall, the noise was measured at three different points in each hall at the nearest point to the window named point 1. The farthest point of the window was named point 2, and the middle point was named point 3. The measuring time was at 11:00 AM. Students are usually spending in-between classes time outdoor the studio halls areas that affect students at Studio hall 1,2 at the same time the nearby parking to studio hall 1 that generates much noise to the students. The recorded data could be checked in Table 4. Furthermore, finally, they were grouped into students with seats exposed to noise over 50 dB and students with seats exposed to noise less than 50 dB.

Table 4 (Background noise intensity recorded data)

Location	Studio hall 1			Studio hall 2		
location	The nearest point to the window	The middle point of the hall	The furthest point from the window	The nearest point to the window	The middle point of the hall	The furthest point from the window
Background noise intensity (dB.)	48.4	42.4	39.1	68.5	62.6	55.1

1.1.3. Assessment of Psychological satisfaction and cognitive performance:

- The survey questionnaire assessing psychological satisfaction was adopted from a previously designed and published questionnaire by (Eldaly, et al., 2016). The questionnaire consisted of four primary subscales: 1. Personal information, 2. Rating of Institute interior spaces, 3. Rating of the Institute exterior spaces, 4. Rating of the current studio hall where the test was done, 5. Rating of the student's Mood over the last week, the students' Mood was measured by a scale of 15 questions forming 75 marks, then the marks of each student were categorized into three main categories; Mild Mood, Moderate Mood, and optimum Mood. The questions were rephrased to become suited to the educational facilities, not the healthcare facilities, as the initially designed questionnaire. The questionnaire was in English. Moreover, all the questions had numbered answers that helped to correlate the students' answers with their actual daylight and noise levels.

Test of cognitive performance; the test was adopted from a previously designed mathematical test by (Herber, et al., 2017). Students were exposed to a 20 mathematical problem. Each student should measure the time taken to solve the problems and write them down. The cognitive performance was obtained through the improvement in the taken time to solve the same problems, as each student was exposed to particular daylight exposure and background noise, then the time taken was measured, then each student was moved to another seat on the other studio hall to take the same measures. The mathematical test is designed to assess the student's concentration and problem-solving skills when exposed to certain daylight and noise levels.

- Measuring a student's comprehension and memorizing. : Students were asked to attend a 15 min lecture. Students in studio hall 1 had a lecture about "the power usages in building". While in studio hall 2, they had a lecture about water usage in residential buildings" with a total duration of 15 min. At the end of both lectures, students' comprehension and understanding of the lecture were assessed by a post-lecture test consisting of 10 questions. They were asked to start solving the questions for a total duration of 5 min. The questions were MCQ with two or four answers to choose from them. Check the supplementary File 2 for more details about the questions. After that, each paper was collected and assessed by the researcher, and two scores were recorded for each student in the studio hall 1 case and studio hall 2 case.

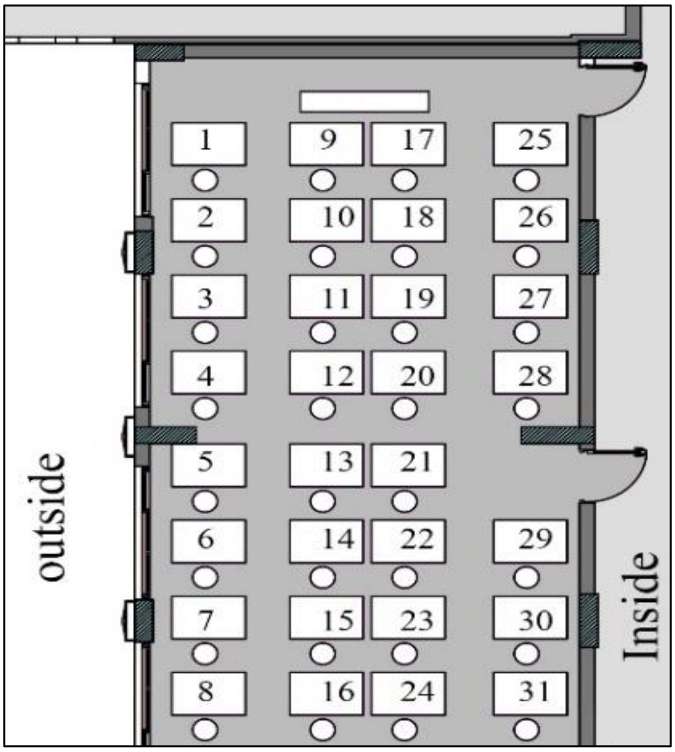

Figure 9 (students' seats coding)

1.1.4. Statistical methods

All students' data were entered into an Excel sheet (version 365 pro), which was copied into the SPSS program version 20 (IBM Corp, 2011). The data were adequately coded, and variables were grouped accordingly. Numerical data were presented as means and standard deviations, and then proper associative and correlative statistics were done between the psychometric questionnaires and the environmental variables.

We coded the students' seats 1:32, where 1:8 is the nearest row to the window and 25:32 in the farthest seats from the window, as shown in Figure 9.

Then each student's answers were coded and recorded with the daylight intensity and noise intensity. Then an SPSS file was created, and correlations were done between the following items:

- Students' satisfaction towards daylight and noise with the actual daylight and noise intensity measures.
- Students' actual daylight and noise intensity and their own Mood
- Students' answer time of the 2nd part of the questionnaire with the actual daylight and noise intensity measures
- Students' marks in the 3rd part of the questionnaire associated with the measures of daylight and noise intensity.

3. results

- **students' satisfaction associated with daylight and noise levels.**

The relationship between the daylight that the students are exposed, and their satisfaction with the daylight, distribution, type, and what they think about the windows in the studio hall are shown in Table 5. The calculated P refers to the significance of the relationship between the actually measured daylight intensity and the questionnaire questions, as in the first question, the P-value was .03, which refers to a significant relationship between the actual daylight intensity and the students' satisfaction towards the daylight. Moreover, the relationship between the daylight intensity and the students' satisfaction towards the daylight distribution was significant, with a P-value of 0.02. However, the relationship between the daylight intensity and the artificial lighting intensity was not significant with a P-value of 0.2, but another relationship was significant between the students' opinion about the window's size and their actual daylight intensity. Moreover, the relationship between background noise intensity and students' psychological satisfaction towards noise in the studio halls is shown in (Table 6), where students were asked two questions about their satisfaction, which led to a significant relationship between the actual level of background noise and the students' satisfaction towards the quietness of the studio hall with a P-value of 0.02. However, the relationship between the students' ability to hear background noises and their actual background noise reads was not significant as the P-value was 0.2.

Table 5 (associations between students' opinions about satisfactory daylight and actual daylight intensity)

Selected questionnaire items	Daylight > 400 lux	Daylight < 400 lux	P-value
The intensity of lighting is satisfactory? Disagree Agree	 14 - (22%) 32 - (50%)	 6 - (9%) 12 - (19%)	0.03
Is the daylight poorly distributed on drawing boards? Disagree Agree	 6 - (9%) 40 - (63%)	 2 - (3%) 16 - (25%)	0.02
The intensity of artificial lighting is satisfactory in the daytime? Disagree Agree	 22 - (34%) 24 - (38%)	 8 - (13%) 10 - (15%)	0.2
Has the studio hall large windows? Disagree Agree	 4 – (6%) 42 – (66%)	 0 – (0%) 18 – (28%)	.07

Table 6 (associations between students' opinions about satisfactory noise and actual measured noise) intensity)

Selected questionnaire items	Noise > 50 dB	Noise < 50 dB	P-value
Is there enough quietness? Disagree Agree	 40 - (63%) 12 - (19%)	 10 - (15%) 2 - (3%)	0.02
Can you hear a lot of background noises? Disagree Agree	 21 - (33%) 31 - (48%)	 8 - (13%) 4 – (6%)	. 2

- **association of students' Mood with daylight and noise levels**

Table 7 demonstrates the association between students' mood and light intensity was referring to the existence of a significant relationship, as the P-value was .015, which indicates the effect of daylight intensity on students' Mood. On the other hand, the relationship between noise intensity and student mood was not significant at all, as the P-value was .3, which indicates the absence of noise intensity effect on students' Mood, and this could be explained due to the low range of difference between the noise intensity in the nearest and furthest point from the windows in the studio halls.

Table 7 (associations between students' Mood and actual daylight and noise reads)

Patient's Mood / Daylight questions	mild mood satisfaction	moderate mood satisfaction	optimum mood satisfaction	P-value
Light sufficiency (≥ 400 lux)?				
Higher than 400 lux	1	7	1	0.015
Lower than 400 lux	11	12	0	
Noise intensity (≤ 50 dB)				
Higher than 50 dB	8	14	2	0.3
Lower than 50 dB	4	4	0	

- **association of students' problem-solving time with daylight and noise levels**

Table 8 summarizes the relationship between the time needed by students to solve 20 simple mathematical problems and the environmental variables (noise & light). The reads taken from studio hall 1 and studio hall 2 for each student were recorded in the columns of daylight and noise intensity and time column, then the last column was for the difference, it was calculated by subtracting the values from studio hall 2 from the values from studio hall 1 resulting + or – values based on the student's records in each studio hall. From that column, it can be observed that the students took less time to solve the problem when they were moved from lower daylight intensity to higher daylight intensity or when moved from higher background noise to a lower daylight noise. And statically relationship could be obtained.

- **association of the students' memory impairment with daylight and noise levels**

Table 6 also summarizes the increase or decrease in the students' marks through the column named "marks", the marks for each student was recorded after each exam in studio hall 1 and studio hall 2, then in the "difference" column, the marks from studio hall 2 were subtracted from marks in studio hall 1 for each student, resulting + or – values based on the answers and marks of each student. However, the differences in most of the cases were ±1 or ±2 out of the total 10 marks available.

Table 8 (associating students' mathematical problems solving time, lectures questions marks, daylight exposure, and noise intensity)

Seat No.	Studio hall 1				Studio hall 2				difference			
	Daylight (lux)	Noise (dB)	Time (S)	Marks (…/10)	Daylight (lux)	Noise (dB)	Time (S)	Marks (…/10)	Daylight (lux)	Noise (dB)	Time (S)	Marks (…/10)
1	156	38.2	123	6	636	68.3	94	6	-480	-30.1	29	0
2	172	38.6	94	7	640	68.1	73	6	-468	-29.5	21	1
3	163	39.1	85	10	647	66.2	82	8	-484	-27.1	3	2
4	148	39.0	63	10	648	67.3	67	9	-500	-28.3	-4	1
5	174	39.6	95	9	646	65.7	90	9	-472	-26.1	5	0
6	185	40.3	83	8	641	66.1	74	7	-456	-25.8	9	1
7	148	39.5	79	5	637	66.7	71	4	-489	-27.2	8	1
8	167	38.1	74	7	630	65.7	78	7	-463	-27.6	-4	0
9	192	42	137	3	291	61.3	135	4	-99	-19.3	2	-1
10	196	41.2	106	6	298	61.5	103	6	-102	-20.3	3	0
11	193	40.3	127	2	304	62.0	126	3	-111	-21.7	1	-1
12	201	41.5	74	9	305	63.1	76	8	-104	-21.6	-2	1
13	206	41.9	97	7	306	61.9	105	6	-100	-20	-8	1
14	203	42.1	149	4	309	61.3	142	3	-106	-19.2	7	1
15	198	41.2	116	0	300	61.1	110	2	-102	-19.9	6	-2
16	196	40.9	112	6	304	60.7	117	4	-108	-19.8	-5	2
17	335	43.1	89	8	163	58.3	103	7	172	-15.2	-14	1
18	340	43.4	93	9	163	58.0	97	9	177	-14.6	-4	0
19	346	43.6	136	3	164	57.7	135	4	182	-14.1	1	-1
20	345	44.3	114	6	170	57.4	119	5	175	-13.1	-5	1
21	341	44.1	119	5	175	57.8	127	3	166	-13.7	-8	2
22	339	43.7	93	8	172	57.3	107	6	167	-13.6	-14	2
23	344	43.9	74	9	169	56.3	85	8	175	-12.4	-11	1
24	349	44.0	95	9	167	56.9	98	7	182	-12.9	-3	2
25	637	47.1	62	10	99	56.1	94	9	538	-9	-32	1
26	780	48.8	94	10	101	55.9	124	10	679	-7.1	-30	0
27	792	48.4	119	8	105	55.6	128	8	687	-7.2	-9	0
28	803	49.6	127	6	104	55.2	142	5	699	-5.6	-15	1
29	795	50.1	103	9	103	55.7	106	8	692	-5.6	-3	1
30	799	49.3	93	6	107	55.9	103	7	692	-6.6	-10	-1
31	804	48.2	125	4	104	55.3	123	5	703	-7.1	2	-1
32	807	47.9	114	8	103	55.2	126	٧	-103	-7.3	-12	1

4. Discussion

This study focused on finding the relationships between environmental factors like daylight and noise on the one hand and students' productivity in higher educational internal spaces on the other hand. Each student was exposed to certain daylight and noise intensity and was asked to do a psychometric questionnaire and solve ten mathematical problems in a test, and then they had a 15 min lecture, after which an evaluative test of 10 marks was done. Finally, they were asked to move to another space the same previous procedures were repeated, in order to measure the difference in daylight and noise between the old and new seating places, and also measuring the difference in their satisfaction about daylight and noise, their taken time to solve the exam, and their own marks in the final exam after the lecture. At first, most of the students who were exposed to daylight intensity over 400 lux expressed satisfaction from the daylight intensity and distribution. The same students' felt that the studio hall seems to have large windows. However, students on the other side of the windows, where the daylight intensity was lower than 200 lux, felt unsatisfied by the daylight intensity and distribution. Additionally, they thought that the studio hall should have a larger window. The P values for these comparisons demonstrated vital statistical significance between the actual daylight levels and the students' satisfaction towards the daylight design in the internal spaces. These results are in line with other studies that referred to a design guideline of 400 lux to the reading drawing activities in the higher educational spaces (Nordquist & Laing, 2015) (Manahasa & ozsoy, 2016).

Moreover, most of the students who were exposed to higher intensities of background noise (over 50 dB) expressed their dissatisfaction with the quietness of the learning environment. Most of them mentioned that they hear a lot of background noises that affect their concentration and performance during the learning process. Meanwhile, other students who were exposed to the lower level of background noises expressed to be more satisfied with the background noises, which assures many other researches about the perfect acoustic level for the higher education that was set to be (35 dB) as a design guideline by the German DIN and other researchers (Eggenschwiler, 2005) (Ellis, 2018).

Moreover, the students' cognitive performance was found to be statistically related to daylight and noise intensities. More daylight leads to decreased time in solving the same problems by the same student, mixed with another decrease in the solving time when the background noise was decreased too. While other students were found to take more time to solve the same problems when exposed to lower daylight intensities or higher background noise levels. Many other studies were assuring the point of offering higher daylight or lower noise level and related this to offer better indoor environmental quality in many researches (Rodriguez, et al., 2016) (Ko, et al., 2017) but with no static relationship, which could be observed through Figure 10 and figure 11, as the total took time to solve the problems was found to be statically related to the amount of daylight or noise levels.

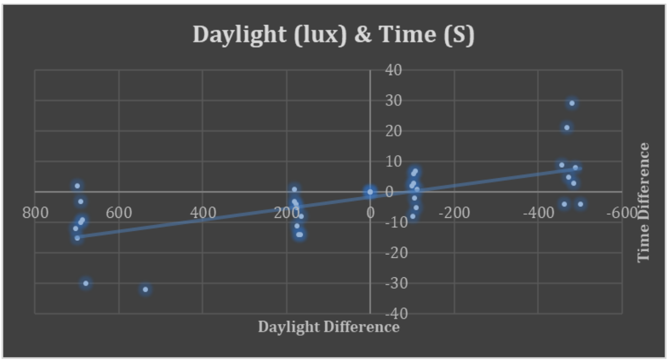

Figure 10 (normal distribution of daylight intensity differences and solving time differences)

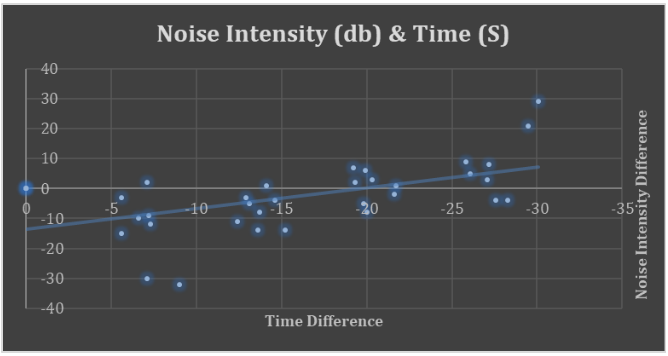

Figure 11 (normal distribution of noise intensity differences and solving time differences)

The normal distribution of the daylight difference with solving time difference seems to have a significant trendline referring to a significant relationship. However, the many students' cases seemed to be located away from the trendline, which could be explained by that most of the students were feeling anxious in the first trial, but with the second trial in the problem-solving process, the anxiety feelings that was affecting them lowered and this affected their solving time. Moreover, the same distribution of noise difference and solving time difference was also referring to the same relationship that existed with the daylight. However, the normal distribution seemed to have more students away from the trendline, which refers to a weaker relationship than the relationship between the difference of solving time and daylight intensity difference. The normal distribution of noise difference and solving time is demonstrated in Figure 11.

The 3rd correlation's results were not referring to any significant relationship, as the difference in each student's result was 0 or ±1 in most of the cases and ±2 in slight cases, so the normal distribution of the marks differences and daylight or noise intensity were not referring to any relationship with very week trendline. This could be explained because of the tiny number of questions, which led to only ten marks in each questionnaire.

5. conclusion

At this point, it would be easy to conclude many associations between students' psychological satisfaction and productivity with daylight intensity and background noise intensity. Shedding light on the 1st correlation will lead to a strong relationship between students' satisfaction of daylight intensity and distribution with a certain amount of daylight, which is specified in many lighting design guides (Lechner, 2014) (Steffy, 2002) (Flynn, et al., 1979)

Finally, we can conclude the existence of a strong relationship between students 'subjective sense of satisfaction towards daylight intensity and the actual objective daylight intensity that they are exposed to and another relationship between background noises and their satisfaction with the learning room's quietness. On the other hand, a relatively strong relationship between the daylight intensity and students' concentration, and also between background noises and students' concentration.

2. EcommEndations

The researcher would like to recommend to all the educational spaces designers, owners, and constructions to put into their consideration during building designs to provide sufficient daylight intensity and to reduce the noise that can affect the students' learning process. A limit of 400 lux is usually recommended to make sure of the students' satisfaction towards the daylight design inside the educational interior spaces. Furthermore, a 40 dB background noise level should not be exceeded to make sure of the students' satisfaction towards the acoustic design inside the educational interior spaces. These design and constructional precautions will ensure maximum student performance and will not affect the learning process negatively.

References

[1] ang, Z. & Lu, F., 2018. ACOUSTICAL ENVIRONMENT DESIGN OF THE LECTURE HALL BASED ON THE IMPROVED ACOUSTIC INDEX ANALYSIS. *FEB-FRESENIUS ENVIRONMENTAL BULLETIN,* p. 2922.

[2] Bellia, L., Pedace, A. & Barbato, G., 2013. Lighting in educational environments: An example of a complete analysis of the effects of daylight and electric light on occupants. *Building and environment,* pp. 50--65.

[3] BRE, 2007. *A BRE guide: Designing Quality Buildings.* London: Building Research Establishment .

[4] Cheryan, S., Ziegler, S. A., Plaut, V. C. & Meltzoff, A. N., 2014. Designing classrooms to maximize student achievement. *Policy Insights from the Behavioral and Brain Sciences,* pp. 4--12.

[5] Dunn, F., Hartmann, W., Campbell, D. & Fletcher, N. H., 2015. *Springer handbook of acoustics.* s.l.:Springer.

[6] Eggenschwiler, K., 2005. *Lecture Halls-Room Acoustics and Sound Reinforcement.* Budapest, Hungary, s.n., pp. 2059--2064.

[7] Eldaly, K., Zaki, N. & El-Gizawi, L., 2016. The associations between daylight sufficiency in hospital wards and patient satisfaction with mental healthcare services: An egyptian sample. *Acta Medica International,* 3(2), p. 101.

[8] Ellis, C., 2018. *Community Space Design in Higher Education.* s.l.:California State University Channel Islands.

[9] Esfandiari, M., Zaid, S. M. & Ismail, M. A., 2017. Investigating the Indoor Environment Quality Parameters and Their Relationship with Occupants' Satisfaction in Office Buildings: A Review. *Journal of Design and Built Environment,* pp. 181--194.

[10] Flynn, J. E., Hendrick, C., Spencer, T. & Martyniuk, O., 1979. A guide to methodology procedures for measuring subjective impressions in lighting. *Journal of the Illuminating Engineering Society,* pp. 95--110.

[11] Gordon, G., 2015. *Interior lighting for designers.* s.l.:John Wiley \& Sons.

[12] Herber, S. P., Quis, J. S. & Heineck, G., 2017. Does the transition into daylight saving time affect students' performance?. *Economics of Education Review,* Volume 61, pp. 130--139.

[13] Ko, W. H., Brager, G., Schiavon, S. & Selkowitz, S., 2017. Building envelope impact on human performance and well-being: experimental study on view clarity. *CBE Internal Report.*

[14] Lechner, N., 2014. *Heating, cooling, lighting: Sustainable design methods for architects.* s.l.:John wiley \& sons.

[15] Manahasa, O. & ozsoy, A., 2016. Do architects' and users' reality coincide? A post occupancy evaluation in a university lecture hall. *A| Z ITU Journal of the Faculty of Architecture,* 13(3), pp. 119--133.

[16] McKenzie-Garner, P. et al., 1999. The effects of excessive vocalization on acoustic and videostroboscopic measures of vocal fold condition. *Journal of Voice,* pp. 294--302.

[17] Nordquist, J. & Laing, A., 2015. Designing spaces for the networked learning landscape. *Medical teacher,* 37(4), pp. 337--343.

[18] Rodriguez, R., Yamin Garreton, J. & Pattini, A., 2016. Glare and cognitive performance in screen work in the presence of sunlight. *Lighting Research & Technology,* 48(2), pp. 221--238.

[19] Schomaker, R., 2015. Accreditation and quality assurance in the Egyptian higher education system. *Quality Assurance in Education,* 23(2), pp. 149--165.

[20] Seiple, W. et al., 2018. effects of Lighting on Reading Speed as a Function of Letter Size. *American Journal of Occupational Therapy,* 72(2), pp. 7202345020p1--7202345020p7.

[21] Steffy, G., 2002. *Architectural lighting design.* s.l.:John Wiley \& Sons.

[22] van Mil, I. W. et al., 2018. Noise measurements during focus-based classroom activities as an indication of student's learning with ambient and focused artificial light distribution. *Euronoise2019 Crete.*

[23] Yan, D. et al., 2015. Occupant behavior modeling for building performance simulation: Current state and future challenges. *Energy and Buildings,* Volume 107, pp. 264--278.

6. Acknowledgements

We are grateful to the head administration of students participating in this study for their time and efforts.

7. Funding

No funding has been reported for this study.

8. REVIEWERS COMMENTS

Reviewer #1

Reviewer comment	Author edits
1. Mention the simulation software and SPSS sections in the abstract and in Figure 6.	the simulation software and SPSS were mentioned in abstract and figure 6 as required.
2. More references are required to strength the study. Checking styles & references are required.	More references were added to the study, and the reference style was changed to "Harvard Angelia 2008" as used in the journal.
3. All figures and tables should include relevant captions and references. Please paraphrase the captions and insert the references.	Most of figures are illustrated by the author for the research application steps and results, However, all the other figures and tables that references to another studies, the references were add to their captions.
4. The practical sections writing needs improvement. The writing style in other sections is appropriate. However, proof reading is encouraged.	The whole paper English writing was just reviewed and rephrased for better English writing and proofing.

Reviewer #2

Reviewer comment	Author edits
1- Demographic data for the participating students is incorrect. The participating students are male, and the building is for male students.	The demographic data were edited then deleted as require by Reviewer #2, edit #3.
2- Noise has been studied very briefly, and the results of the study cannot be relied upon as it was not profound. It is recommended to limit the study to the effect of daylight and its effect on the productivity of students of architecture in the studio.	Noise wasn't illustrated and studied like the daylight since the noise difference between the drawing halls is only 25:30 dB, However the designed questionnaire and tests were designed to measure the students' perception in four different situations with increased or decreased daylight or noise, and canceling the noise part of the research means that the whole research should be repeated starting from the designed questionnaires to the results.
3- Paragraphs 8, 9 and 10 are unnecessary and can be deleted.	The paragraphs are surly not related to the research core, however, they were proving that the research was done voluntary and with variety of students.
4- The Figure 9 (students' seats coding) at the end of the search is duplicate and unnecessary.	The figure was deleted