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Evaluation of Compliance with the Lighting Standards for School Workspace

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ABSTRACT

Adequate lighting bestows visual and non-visual advantages hence promoting improved performance and health. The study undertakes to measure the level of illuminance in classrooms, laboratories, libraries, corridors, and washrooms of Liceo de Cagayan University - Main Campus in order to evaluate compliance with the available lighting standards. Spatial orientation was tested to determine its effect on the light intensity, and uniformity of illuminance among workspace of the same type was also analyzed. It was found out that there was non-compliance of all the laboratories and libraries. Only 3 out of 23 classrooms were compliant with the standard illuminance value of 300 lux, having to mean illuminance values of 396.73 lux, 623.81 lux, and 480.55 lux. There were 9 out of 10 corridors and 6 of the eight washrooms that met the standard of 200 lux; their mean illuminance more than double that of the standard. Illuminance was significantly higher in areas closer to the windows, and there was no uniformity of illuminance among workspace of the same class. It was observed that the amount of daylight greatly influences the light intensity within the workspace and that the lighting solutions installed were not able to supplement daylight to achieve the prescribed level of illuminance.

Keywords: Illuminance level, spatial orientation, lighting standards, school workspace, lux

INTRODUCTION

Light appears to have the most influence on building occupants among all the factors that may be involved. The effects range from physical and physiological to psychological. For a long time, it has already been the concern that lighting design should be appropriate to meet the needs of the building occupants, particularly when it comes to visual task performance. Recently, the link between lighting, performance, and health has made the illuminance of building interiors one of the most prominent considerations in architectural design (Veitch & Newsham, 2013).

Light not only provides visual information but also modulates the circadian rhythm and many non-visual functions, including a state of alertness, mental focus, and cognitive performance. Body tissue functions are affected by light, and atypical lighting conditions may lead to negative consequences on these rhythms (Lee & Kim, 2019). Light is shown to have strong influences on cognition and learning, making it an essential element in educational settings. Apart from transforming or enhancing the appearance of a space, adequate lighting is also essential to productivity (Stefani et al., 2017). Hence, various countries, through the aid of technical organizations, have formulated standardized guidelines for lighting in specific venues of human activity.

Xiao et al. (2020) posit that optimized lighting in constructed environment improves health and well-being, considering the effects that extend beyond visual performance. Moreover, according to the British Health and Safety Executive (HSE), in 2020, lighting is among the components of the work environment that can impact a person's performance. These include effects that may lead to health damage, reduced ability to execute a task, and poor attitude towards work. HSE's earlier studies show that adequate lighting allows the detection of hazards and reduction of eyestrain. The manifestations of eyestrain depend on the lighting conditions and the task at hand, such includes; irritation or inflammation of the eyelids, itchiness; breakdown of vision, and referred symptoms (e.g., headaches, fatigue, and giddiness). Poor lighting can also cause indirect effects. The natural response to insufficient illuminance or veiling reflections is to look at it from a different direction. This can mean adopting unsuitable postures that lead to other forms of discomfort, such as neck and backache. It was shown by Wright Jr. et al.

(2015) and Al Horr et al. (2015) that appropriate lighting in the workplace, like acoustics control and thermal conditions, are very important for improving the morale, well-being, satisfaction, and productivity of occupants.

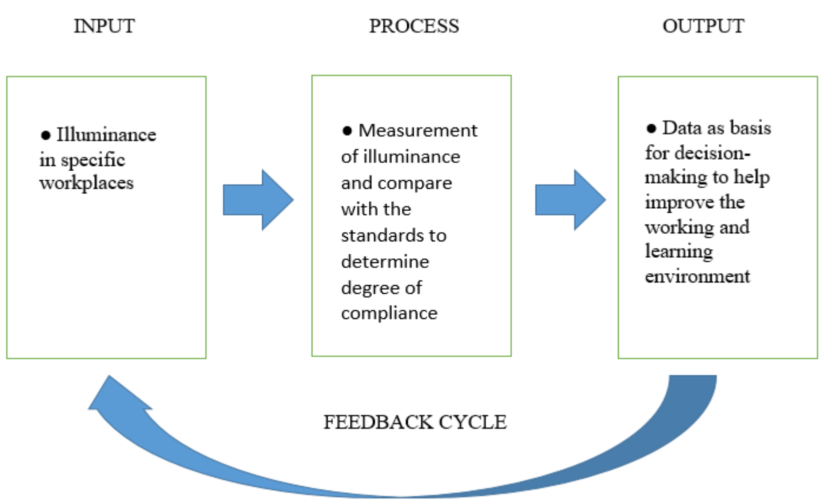
Our labor laws provide for Occupational Safety and Health Standards (OSHS) that are mandatory - the very purpose is to reduce if not eliminate health hazards in the workplace. Such standards dictate the minimum acceptable degree of protection that every worker is entitled to with respect to the working conditions. An integrated survey conducted in 2008 by the Bureau of Labor and Employment Statistics (BLES) in coordination with the DOLE Regional Offices included adequate lighting in work areas, aisles, and passageways as a criterion. Among the highlights of such survey is that about 94.8% of the non-agricultural establishments employing 20 or more workers could implement adequate lighting in work areas. In 2015-2016 an Integrated Survey on Labor and Employment (ISLE) was accomplished by the Philippine Statistics Authority. This time it covered both agricultural and non-agricultural establishments employing 20 or more workers nationwide. It revealed that 72.5% of the private educational institution could adopt the proper maintenance of mechanical and electrical facilities as part of its preventive and control measures/activities.

The profound effects of lighting on various human physiological processes like vision, mood, cognition, and circadian rhythms connotes an impact on learning and classroom achievement (Mott et al., 2012). Even before the turn of the 21st century, a review by Lyons (2000) on the impact of school facilities on a child's education strongly advocates sufficient and adequate lighting since it was found out that it improves the learning experience significantly. It is widely recognized that students' learning experience and school achievement is affected by the lighting in the learning environment (Barkmann et al., 2012), and Tanner (2008) echoes the notion that student achievement can be affected by the physical design schools. A study by Pulay et al. (2020) presented an association between lighting conditions and on-task behavior or students' engagement in a certain class activity. The results of an experiment by Moolenaar et al. (2013) offered support for the positive influence of classroom lighting conditions on the concentration of elementary students in the Netherlands. A good learning environment that integrates suitable lighting presents an intangible motivation and encouragement for students to learn better by focusing more on the tasks at hand. This suggests that providing the students and teachers the ability to make appropriate adjustments to the lighting conditions depending on the precise area of the workspace and the exact activity to be carried out would increase their attention and consequently their performance (Samani & Samani, 2012).

A report by the Heschong Mahone Group (2003) on the impact of natural light on students revealed that integration of daylight improves students' test score by up to 20%. Taylor and Engass (2009) show that students in classrooms with the highest amount of daylight progress 20% and 26% faster in one year for Mathematics and Reading tests, respectively, compared to their counterparts in classrooms with little or no daylight. A study in Norway indicated that periods with a shorter duration of daylight (e.g., December) could lead to seasonal sleep disruptions, followed by depression and, to lesser extent, anxiety and fatigue (Friborg et al., 2014).

This study attempts to determine the compliance of Liceo de Cagayan University with the recommended Philippine and International lighting standards. Furthermore, it aims to identify any existing conditions that fall short so that appropriate proposals to the administration may be formulated.

FRAMEWORK



The Figure above serves as the model for the project that would guide the researcher and all stakeholders involved in maintaining a safe and productive working environment on the aspect of adequate lighting. The amount of illuminance in areas such as classrooms, offices, laboratories, corridors, etc. will be determined and evaluated against the standards prescribed for each.

The analyzed data will then be presented to the university administrators for appropriate action. Any intervention will be regularly monitored for consistency of compliance.

OBJECTIVES OF THE STUDY

This study aimed to: (a) determine whether there is compliance with the illumination standards set by local {Institute of Integrated Electrical Engineers of the Philippines, Inc. (IEEE), Department of Labor and Employment (DOLE), and Department of Energy (DOE)} and international authorities {Illuminating Engineering Society of North America (IESNA), and European Standards EN 12464-1}, (b) test if spatial orientation affects the illuminance of a particular area in classrooms and laboratories, and (c) analyze whether workspaces of the same type (i.e. classrooms and laboratories) have similar illuminance values.

METHODS

Descriptive Cross-Sectional Research Design was employed in this study to accurately record the lighting conditions in a given workspace at a certain time.
Equipment

1. Lux Meter
2. Laser Distance Measure

Locale of the Study

All buildings of Liceo de Cagayan University (LDCU) main campus where significant amounts of human activity are undertaken were subjected to illuminance measurements. These included classrooms (23), libraries (2), laboratories (12), bathrooms (8), corridors, and walkways leading to rooms within the same building were also assessed (10).

Data Gathering Procedure

Illuminance (lux) was measured using a standard lux meter with the sensor placed precisely on the surface where a task is to be carried out. Maximum and minimum illuminance measurements were taken for each spot. The procedures were conducted between 12:00 noon, and 1:00 P.M with all the artificial light sources turned on. With the exception of the libraries, only the researcher was present inside the workspaces when the readings were taken. The path between the light source and the point of measurement was unobstructed as far as practicable.

Laboratories

Six readings were taken for each worktable, three on the side away from the window and three on the side near the window. Each side was divided into three squares and lux measurement was done at the center of each square. Measurements were also taken on the sink area, display cabinets, teachers' table, counters, and stockrooms.

Classrooms

Each classroom was partitioned into three sections. Every section was further divided into three squares, and measured for illuminance at the center of each. Individual measurements for the teacher's table and writing board were also done.

Library

Six readings were recorded for every study table, shelf row, and bookcase, with measurements taken at equal distances.

Washrooms/Lavatories

Three readings were recorded for every cubicle, wash area, sink, and urinal bay.

Corridors and Hallways

The illuminance of the main passageway for each workspace assessed was measured at equal intervals of two meters. The readings were taken approximately one meter above the floor.

In determining whether lighting is evenly distributed and obtain the average illuminance for the whole work area, it was divided into a minimum of 9 squares of approximately equal areas. A lux reading was taken from the center of each square. The mean value was then compared with the available standards.

Statistical Treatment

The treatment of data was carried out using IBM SPSS Statistics 25 software. Descriptive Statistics (Mean) was deemed appropriate in an attempt to establish if LDCU complies with the lighting standards on illuminance (lux). Paired Sample T-Test was used to determine whether there is a difference in the lux values with respect to certain positions or orientations on the surface being measured. ANOVA tells whether illumination among the workspaces of the same type varies or not.

RESULTS AND DISCUSSION

Objective 1. To determine whether there is compliance with the illumination standards set by local {Institute of Integrated Electrical Engineers of the Philippines, Inc. (IEEE), Department of Labor and Employment (DOLE), and Department of Energy (DOE)} and international authorities {Illuminating Engineering Society of North America (IESNA), and European Standards EN 12464-1}

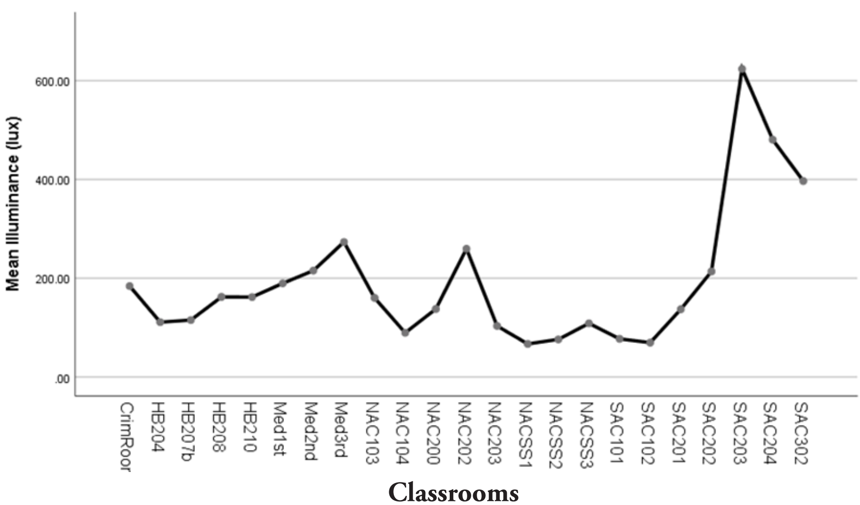


Figure 1. Means Plot of Illuminance Values Taken from Classrooms.

Table 1

Descriptive Statistics of Illuminance Values Taken from Classrooms

Descriptives

	N	Mean	Std. Deviation	Minimum	Maximum
Crimson	18	184.02	80.61	103.40	386.00
HB204	18	110.93	35.89	55.00	169.20
HB207b	18	115.19	46.72	54.00	192.10
HB208	18	162.03	63.49	74.20	296.00
HB210	18	161.76	66.07	82.50	308.00
Med1st	18	189.58	93.55	34.30	321.00
Med2nd	18	215.29	87.39	67.30	387.00
Med3rd	18	273.27	146.65	58.60	536.00
NAC103	18	160.01	126.61	62.20	477.00
NAC104	18	89.43	36.72	56.50	173.60
NAC200	18	137.58	72.70	47.10	270.00
NAC202	18	259.51	162.00	101.20	616.00
NAC203	18	103.19	33.30	54.50	160.40
NACSS1	18	66.87	29.25	27.40	134.40
NACSS2	18	75.98	25.42	42.50	100.90
NACSS3	18	108.46	30.90	58.50	157.00
SAC101	18	77.09	45.47	32.70	153.70
SAC102	18	69.44	33.80	27.40	125.10
SAC201	18	137.05	73.42	50.80	271.00
SAC202	18	213.63	220.24	53.10	702.00
SAC203	18	623.81	742.17	67.50	1956.00
SAC204	18	480.55	443.01	89.40	1258.00
SAC302	18	396.73	486.73	95.90	1764.00
Total	414	191.80	256.86	27.40	1956.00

The means plot of lux readings was derived to determine whether the overall illuminance of each classroom is up to the standard value of 300 lux - the local and international standard established by IEEE, DOLE, DOE, IESNA, and EN 12464-1 (Figure 1). As shown in Table 1, SAC302 ($M = 396.73$, $SD = 486.73$), SAC203 ($M = 623.81$, $SD = 742.17$), SAC204 ($M = 480.55$, $SD = 443.01$) complied with and even exceeded the standard level of illumination. There were illuminance readings that registered relatively high for the three classrooms, the maximum values of 1764 lux, 1956 lux, and 1258 lux for SAC302, SAC203, and SAC204, respectively. The amount of natural light that pours into them is primarily responsible for the higher lux values compared to the other classrooms, this is attributed largely to their location and/or design that affords ample stream of natural light to flow through windows on two sides of the room. Table 1 also reveals that classrooms with larger illuminance values tend to have greater standard deviations, which underscores the disparity of light intensity between artificial light installations and daylight. It would then mean that the occupants would be subject to variable visual perceptions or experience depending on which specific point they are inside such classrooms.

de Bruin-Hordijk and de Groot (2009), in their study entitled "Lighting in Schools" sought to test various classroom designs to determine which among them could provide the desired level of illuminance. They found out that classrooms which allow two-sided daylighting have the best operation. Such performance could even be enhanced when there is a 'roof window' incorporated in the design of the classroom.

The size of the windows and their vertical position allows light coming from outside to diffuse more effectively across the room. The existence of a barrier or obstruction in the form of adjacent buildings or trees that stand near the ingress of natural light such as windows and doors considerably reduce illuminance. Such will also result in a significant discrepancy in the illuminance values of workspaces even if they are situated within the same building regardless of similarity in their dimensions and design as well as the lighting solution installed.

The lighting solution used in the classrooms is alike, consisting of fluorescent tubes and standard surface mount or recessed luminaires, which in combination with any amount of natural light that managed to get inside was not able to provide for the standard level of illuminance in the majority of them analyzed. This suggests that the lamps and lighting fixtures installed in the classrooms thus far evaluated are not effective in bringing about the desired amount of illuminance necessary for the optimum visual and learning environment for teachers and students.

It is beyond dispute that light influences both physiological and psychological conditions of an individual and hence affect one's general well-being and ability to concentrate ("Light for Education and Science," 2010). Lighting solutions that meet the standard of quality should be among the priority issues in the agenda of every school administrator concerned.

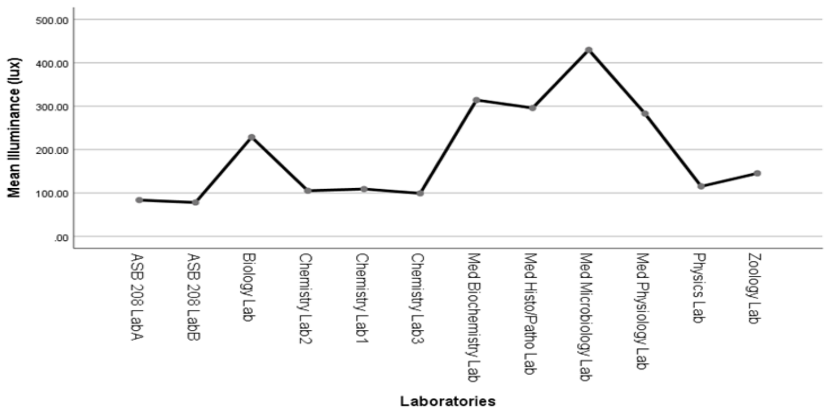


Figure 2. Means Plot of Illuminance Values Taken from Laboratories.

Figure 2 shows that none of the laboratories meet the recommended level of illuminance that is 500 lux set by the Illuminating Engineering Society of North America (IESNA) in their 8th edition of Lighting Handbook. This is adapted in the updated Manual of Practice on Efficient Lighting authored by the Institute of Integrated Electrical Engineers of the Philippines, Inc (IIEE) in cooperation with the Energy Management Association of the Philippines (ENMAP) and the Philippines Lighting Industry Association (PLIA) through the technical assistance provided by the Philippine Efficient Lighting Market Transformation Project (PELMATP). This illuminance is suitable for the performance of visual tasks of high contrast and small size, or low contrast and large size, typical of such exercises involving chemicals and biological specimens. Inadequate lighting will impair visual functions resulting in inaccuracies of the data gathered but also causes fatigue, stress, and diminished alertness, which are among the non-visual effects of poor lighting (Gornicka, 2008).

A combination of these visual and non-visual effects may adversely influence how persons do physical and mental work in the laboratory. It is well documented that inadequate lighting diminishes concentration. Thus students and even instructors could experience absentmindedness and lethargy. These situations reduce performance and productivity – specifically what academic institutions are actively avoiding. According to the guidebook issued by the Health and Safety Executive entitled Lighting at Work, poor lighting is linked to Sick Building Syndrome. Symptoms include headaches, lethargy, irritability, and poor concentration. Studies by the Innova Design Group posted in 2014 show that low illuminance has been associated with slower reading, reduced concentration, poor posture, and long term weakened vision.

Damage to laboratory materials and equipment is usually caused by mishandling and mishaps. Such incidents can directly be attributed to poor visual cues and mental focus. Laboratory accidents in schools contribute at least to capital losses which have to be ultimately shouldered by the students. Hence, it would be a sound management policy to invest in lighting equipment and fixtures as it impacts both health and economic components.

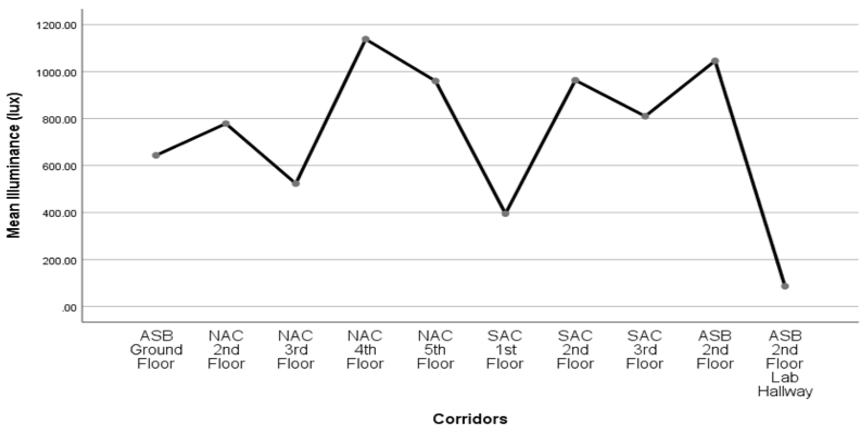


Figure 3. Means Plot of Illuminance Values Taken from Corridors of Various Floors in North Academic Cluster (NAC), South Academic Cluster (SAC), and Arts and Sciences Building (ASB).

All the corridors analyzed except ASB 2nd Floor Lab Hallway were found to greatly exceed the standard for overall illuminance of 200 lux (Figure 3). Again, the location of these corridors with respect to direct exposure to daylight prominently dictates light intensity and quality of lighting. In the situation of ASB 2nd Floor Lab Hallway, daylight barely seeps through the area. Classrooms and other laboratories line both sides along the length of the corridor, effectively blocking the daylight. The lighting solution installed in this corridor failed to adequately provide appropriate illumination to offset the poor daylighting adequately.

Dutch schools make use of "Corridorwindow" design which has a roof window above the corridor and another model which employs shed roofs above the corridor (de Bruin-Hordijk & de Groot, 2009). These two models were found out to be good daylight design and improve to a great extent the quality of lighting. Daylight was not a problem for the other corridors, which registered above-standard lux values since one entire side allows a greater extent of exposure to the sun's radiation. Particular attention needs to be paid to lighting in corridors since they are used for general circulation and, in most respect, become part of the escape routes in emergency events; thus effective, spatial orientation is imperative. Properly illuminated corridors and other circulation routes ensure safety while traversing to and fro from one workspace to another and allows appropriate visibility of the surroundings like the presence of signs or markers.

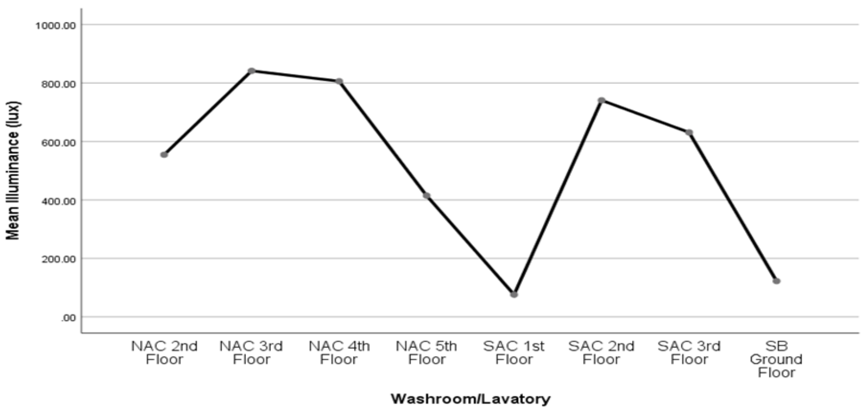


Figure 4. Means Plot of Illuminance Values Taken from Washrooms/ Lavatories Located on Respective Floors of the North Academic Cluster (NAC), South Academic Cluster (SAC), and Arts and Sciences Building (ASB).

Figure 4 reveals that two washrooms did not comply and even well below the lighting standard of 200 lux. This is in substantial contrast with the rest of the washrooms evaluated, which far surpassed the same standard value. The washrooms on the 1st floor of the South Academic Cluster (SAC 1st Floor) and the ground floor of the Arts and Science Building (SB Ground Floor) are deprived of daylight. The lighting fixtures were not adequate to provide the appropriate illuminance despite turning them all on. Two setbacks were seen as far as the contribution of natural light to the overall illuminance is concerned. One is the total absence of regular windows for the SAC 1st floor washroom (only gratings for ventilation were incorporated in the structure) and the orientation of the windows for SB Ground Floor washroom, which faces directly a foyer that effectively limits the amount of daylight that seeps through the windows. The rest of the washrooms, on the other hand, which are strategically situated at the far ends of the building floor, can receive ample supply of daylight coming through the windows opening from two sides.

Table 2

Descriptive Statistics of Illuminance Values Taken from Libraries

Descriptives

	N	Mean	Std. Deviation	Minimum	Maximum
MainLibGroundFlrTables	27	121.47	35.27	80.60	207.00
MainLibGroundFlrShelves	43	95.11	69.03	13.60	352.00
MainLib2ndFlrTables	32	145.87	74.58	42.70	267.00
MainLib2ndFlrShelves	34	81.90	57.75	27.60	237.00
GradMedLibTables	16	182.25	55.08	105.30	270.00
GradMedLibShelves	8	170.73	44.11	102.40	222.00
Total	160	797.34	335.83	372.2	1555

An analysis of the illuminance in the libraries indicates that the average value for the illuminance of the reading tables and shelves failed to comply with the standard, which is 500 lux and 200 lux, respectively (Table 2). None of the reading tables were able to register the prescribed level of light intensity. However, 12.5% of the shelves in the Graduate and Medical Library, 4.7% in the Main Library Ground Floor, and 2.9% in the Main Library Second Floor were able to meet the 200 lux standard. The lighting solutions in these libraries cannot supplement whatever amount of natural light can contribute to the overall illuminance of the reading tables. This prevents achieving the appropriate level necessary for reading and writing in order to avoid eye strain and enhance focus. A substantial area of the libraries, especially the main library, both on the ground floor and the second floor, cannot be reached by direct daylight. This could be due to the arrangement and position of the tables or the windows themselves because of their dimensions or design.

Since a certain percentage of the shelves have enough lighting, it may be inferred that these shelves may either be situated closer to the windows without any obstruction from the rest of shelves and other furniture, or these shelves have been provided with adequate artificial lighting. It has been observed that there were shelves cramped or confined in such a small space that shadows are being cast. These render an overhead light source mounted at an improper angle ineffective and cause variable light intensities. It should be noted that uniform lighting allows optimal visual conditions and could provide suitable quality of illumination regardless of room modification and furniture rearrangement.

Objective 2. To test if spatial orientation affects the illuminance of a particular area in classrooms and laboratories.

Null Hypothesis 1. H0: Spatial orientation does not affect the illuminance of a specific spot within a classroom or laboratory.

Table 3

Paired Samples Test Comparing Illuminance Values within Classrooms of Locations Far from Windows (FW) and Near the Windows (NW)

Paired Samples Test

	t	df	*p*	Decision
HB210FW - HB210NW	-10.63	8	0.00	reject null hypothesis
HB208FW - HB208NW	-15.50	8	0.00	reject null hypothesis
HB207bFW - HB207bNW	-8.38	8	0.00	reject null hypothesis
NAC200FW - NAC200NW	-16.18	8	0.00	reject null hypothesis
HB204FW - HB204NW	-20.48	8	0.00	reject null hypothesis
SAC102FW - SAC102NW	-10.39	8	0.00	reject null hypothesis
SAC101FW - SAC101NW	-6.15	8	0.00	reject null hypothesis
SAC302FW - SAC302NW	-2.76	8	0.03	reject null hypothesis
NAC103FW - NAC103NW	-3.92	8	0.00	reject null hypothesis
NAC202FW - NAC202NW	-6.81	8	0.00	reject null hypothesis
NAC104FW - NAC104NW	-4.60	8	0.00	reject null hypothesis
NAC203FW - NAC203NW	-12.24	8	0.00	reject null hypothesis
NACSS1FW - NACSS1NW	-5.49	8	0.00	reject null hypothesis
NACSS2FW - NACSS2NW	-9.60	8	0.00	reject null hypothesis
NACSS3FW - NACSS3NW	-14.32	8	0.00	reject null hypothesis
Med1stFW - Med1stNW	-13.75	8	0.00	reject null hypothesis
Med2ndFW - Med2ndNW	-11.61	8	0.00	reject null hypothesis
Med3rdFW - Med3rdNW	-2.33	8	0.05	reject null hypothesis
CrimRoomFW - CrimRoomNW	-5.05	8	0.00	reject null hypothesis
SAC201FW - SAC201NW	-10.18	8	0.00	reject null hypothesis
SAC202FW - SAC202NW	-3.97	8	0.00	reject null hypothesis
SAC203FW - SAC203NW	-4.40	8	0.00	reject null hypothesis
SAC204FW - SAC204NW	-5.71	8	0.00	reject null hypothesis

Paired samples test indicates the comparison between specific locations within the classroom near windows and far from windows. These locations describe positions with respect to distance from windows which allow penetration of daylight. Thus, measurements far from windows were taken from the middle portion in rooms with two-sided daylighting and on the far opposite end in rooms with single-sided daylighting.

It appears from the p values in Table 3 that the illuminance values in locations near the windows are significantly higher than those taken away from the windows. This result was obtained despite the overhead lighting fixture being installed evenly spaced inside the classrooms. This again underscores the stark difference in the illumination that daylight provides compared to artificial light. In the data made available by the National Optical Astronomy Observatory (NOAO), a U.S. national observatory operated by the Association of Universities for Research in Astronomy, outdoor light level on a clear day is approximately 10,000 lux. Inside the building, the light level may be reduced to approximately 1,000 lux in areas closest to the windows. In the middle area, it could go as low as 25-50 lux. This is where additional lighting equipment is to be supplied to compensate for low illumination. The quality of light, like the amount of glare, flicker, contrast, and shadows, also factor considerably in the effectiveness of indoor illumination. The type and color of paint used for the walls and ceilings, as well as the surface type and color of furniture or equipment inside the room, can affect the quality of indoor lighting.

The dynamic and full-spectrum properties of daylight result in a much higher light intensity and hence likewise registers higher illuminance values. It is sound practice to utilize optimal exposure and utilization of daylight to enjoy its full benefits. Natural light not only provides visual information but also modulates the circadian rhythm and many non-visual functions, including a state of alertness, mental focus, and cognitive performance. Light is shown to have strong influences on cognition and learning, making it an essential element in educational settings.

Studies on daylight likely show that natural light promotes the students' physical and psychological health as well as influences their mood, behavior, and learning. Various researches have demonstrated several benefits that daylight has, such, as the generation of Vitamin D through the skin. The nature of the light spectrum in sunlight enables it to promote improvement in human health that could not be replicated by electric lighting. Light affects endocrinal and hormonal systems and hence metabolic processes through the vision system (Court, 2010).

Table 4

Paired Samples Test Comparing Illuminance Values within Laboratories of Locations Far from Windows (FW) and Near the Windows (NW)

Paired Samples Test

	t	df	p	Decision
ChemLab1FW - ChemLab1NW	-79.08	35	0.00	reject H_0
BioLabFW – BioLabNW	-52.17	35	0.00	reject H_0
PhysicsLabFW – PhysicsLabNW	-105.5	41	0.00	reject H_0
ChemistryLab2FW - ChemistryLab2NW	-67.05	35	0.00	reject H_0
ZoologyLabFW – ZoologyLabNW	-69.53	35	0.00	reject H_0
ChemLab3FW - ChemLab3NW	-131.8	23	0.00	reject H_0
ASB208LabAFW - ASB208LabANW	-70.41	29	0.00	reject H_0
ASB208LabBFW - ASB208LabBNW	-91.41	35	0.00	reject H_0
MedBiochemLabFW – MedBiochemLabNW	-11.04	17	0.00	reject H_0
MedPhysiologyLabFW - MedPhysiologyLabNW	-14.04	27	0.00	reject H_0
MedHistoPathologyLabFW - MedHistoPathologyLabNW	-14.56	29	0.00	reject H_0
MedMicrobiologyLabFW - MedMicrobiologyLabNW	-2.25	27	0.03	reject H_0

Table 5

Descriptive Statistics of Illuminance Values Taken from Laboratories

Descriptives

	N	Mean	Std. Deviation	Minimum	Maximum
ASB 208 Lab A	30	83.62	32.39	20.60	128.10
ASB 208 Lab B	36	78.02	27.70	31.30	128.10
Biology Lab	36	228.62	31.21	174.30	289.00
Chemistry Lab 2	36	105.11	35.34	27.00	165.50
Chemistry Lab 1	36	109.08	29.66	55.90	158.90
Chemistry Lab 3	24	99.15	14.90	75.60	129.60
Med Biochemistry Lab	18	314.17	71.40	226.00	431.00
Med Histo/Patho Lab	30	295.80	76.82	186.30	482.00
Med Microbiology Lab	28	429.76	165.57	193.60	726.00
Med Physiology Lab	28	282.88	81.83	182.30	477.00
Physics Lab	43	115.18	23.36	75.70	166.80
Zoology Lab	36	145.34	30.60	73.40	191.90
Total	381	179.28	122.22	20.60	726.00

Paired samples test on laboratories yields the same result as that performed on classrooms. There is a statistically significant difference in illuminance between readings taken from locations far from the windows and near the windows (Table 4). This gives the inference that the variation in the values is due to the difference in the quantity of daylight that can penetrate through the windows. The one-sided daylighting design - only one side of the room has windows - of ASB208 Lab A, ASB208 Lab B Chemistry Lab 1, Chemistry Lab 2, Chemistry Lab 3, Zoology Lab, and Physics Lab accounts for their low overall illuminance compared to the two-sided daylighting design of the Medical Laboratories. The lesser the amount of natural light getting inside leads to lower variation in illuminance across the different areas measured within the workspace (Table 5).

Objective 3. To analyze whether workspaces of the same type have similar illuminance values.

Null Hypothesis 2. H0: Workspaces of the same type have uniform illuminance.

Table 6

Analysis of Variance of Illuminance Values among Classrooms

	ANOVA			
	df	F	*p*	Decision
Between Groups	22	7.003	.000	Reject Null Hypothesis
Within Groups	391			
Total	413			

There was a statistically significant difference between groups was determined by one-way ANOVA, $F(22, 391) = 7.003$, $p = 0.000$ (Table 6). Several factors (i.e. design, location, type of lighting solutions, etc.) are at play in producing the amount of illuminance inside the workspace. More importantly, the circumstances of similarity in design and type of lighting solutions utilized for the classrooms indicate that the extent of daylight diffusion inside is the primary element determining whether the overall illuminance is compliant with the standards.

Table 7

Analysis of Variance of Illuminance Values among Laboratories

	ANOVA			
	df	F	*p*	Decision
Between Groups	11	101.95	.000	reject null hypothesis
Within Groups	369			
Total	380			

The laboratories are found to vary significantly in the amount of illumination as analyzed using one-way ANOVA, $F(11, 369) = 101.946$, $p = 0.000$ (Table 7). The Med Microbiology Lab being recorded with the highest overall illuminance. The medical laboratories (Med Physiology, Med Biochemistry, Med Histo/Patho, and Med Microbiology) are all similarly designed with the same fixtures installed. However, due to the arrangements or spatial orientation of the furniture and display specimens (some laboratories have their specimens placed on the tables rather than on display cabinets), there is a variation on how much light is able to cause illumination on the surfaces inside.

CONCLUSIONS

The study determined that Liceo de Cagayan University-Main Campus was largely non-compliant with the lighting standards set for classrooms and non-compliant with that of laboratories and libraries. It was observed that basically, four factors were responsible for the outcome of the evaluation. First is the design - the number, dimensions, and placement of the windows hugely contributed to the amount of daylight that enters the workspace. Second is the location – the position of the workspace relative to any structure that obstructs daylight. The third is spatial orientation – the illuminance of a specific spot in the workspace depends on its orientation with respect to the windows. Fourth is the lighting solution – the artificial lighting installed is not capable of augmenting the daylight to achieve the prescribed light intensity. Nevertheless, the evaluation of corridors and washrooms yield results predominantly in favor of compliance with the standards. The extent of daylighting was seen as the single most important element influencing illuminance in the latter two workspaces.

It was also established in this study that spatial orientation affects illuminance. Specifically, the area being measured with reference to the window has a significant influence on the lux value measured. As stated otherwise, the illuminance readings taken near the windows are significantly higher than those taken farther away.

Finally, it was analyzed that because of the factors mentioned above, either solely or in combination, the amount of illumination for the same class of workspace varies significantly even if they have similar designs or are located within the same building.

RECOMMENDATIONS

1. Incorporate a suitable daylighting plan into the architecture of the University buildings in general and workspaces in particular so that occupants can take advantage of its physical and emotional health benefits. Orient students and teachers about the plan so that they can gain from integrating and managing daylight effectively. Energy conservation, high-class attendance, good health, strong academic performance, and reduced stress are only among the benefits of adequate daylight in educational environments.
2. Install lighting solutions that will significantly contribute to achieving the appropriate level of illuminance. There are already available lighting systems that would not only meet the minimum standard but the recommended performance as well. As educational institutions aspire to embrace modern teaching and learning forms, there must be careful attention given to dynamic lighting. Group activities are more emphasized, and there is an increased frequency using computers and other digital devices. These trends demand variable lighting solutions to generate a pleasant and suitable ambiance for any type of activity.
3. Learn smart spatial utilization so that the interior designing and arrangement will not impair adequate diffusion of light. Furniture and fixtures should be put in strategic spots, and only those necessary for the optimal use of the workspace must be placed therein. Specific colors and surface types must also be taken into account when designing and fitting the workspace. This could enhance the quality of illumination.

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