

Post Occupancy Evaluation of the Luminous Environment in Algerian University Classrooms

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Abstract. The luminous environment is one of the most important physical parameters in a teaching space (classroom) due to its impact on the intellectual performance of students, their health and their behavior. The aim of this study is to evaluate the luminous environment in university classrooms located in Constantine, the main university hub of the East of Algeria. A Post Occupancy Evaluation (POE) based on the objective and subjective assessment was carried out at the Department of Psychology of Constantine 2 University in North and West facing classrooms. This study was conducted during the three periods: winter, spring and summer, under clear sky and overcast sky conditions. The objective variables measured by a luxmeter during each course session are: indoor illuminance levels (Ei) on work plan, vertical illuminance levels on boards (Ev), uniformity index (Uo) and outdoor illuminance levels (Ex). At the same time, students perception and satisfaction were reported by a longitudinal questionnaire (N=1221) using subjective scales. The objective assessment shows that the mean interior illuminance is dependent of the sky-type, and it varies with outdoor illuminance. We notice that illuminance levels in north classroom are below the recommended value especially under overcast sky. The illuminance levels in west facing classroom are excessive during the afternoon under clear sunny sky. However, students show a remarkable degree of adaptation to different light levels. They use controls to modify the light level at their work plans.

1 Introduction

The luminous environment is all a physical energy, a visual stimulus and information for perception [1]. The perception of light is affected by large individual differences like sex, age of occupants and the type of visual tasks [2].

For educational buildings, environmental design parameters, including air temperature, air humidity, acoustics, and CO₂ concentration, are crucial. However, according to several research, daylight has the highest impact on overall student progress [3,4,5].

Lighting impacts intellectual performance of students, their physical and psychological health, their mood and behaviour [6]. Nicklas and Bailey [7] stated that students in daylit schools performed 5-14% better than those in non daylit schools.

The Heshong Mahone Group study was the first to assess the impact of daylight on learning. The results showed that students in classrooms with the most daylight had test scores that are 7-18% higher than those in classrooms with less light [8].

Plympton and al. compared the results of four schools with improved daylighting and concluded that it has benefits for student productivity and health [9].

Taylor and Engass reported that students progress 20% and 26% faster in math and reading tests respectively

in classrooms with the most daylighting, compared to those in classrooms with little or no daylight [10].

Kuller and Lindsten examined children's health and behavior in classrooms with and without windows. Authors concluded that study in classrooms without windows affected the basic pattern of the hormone cortisol, which is related to stress, and have a negative effect on children's health and concentration [11].

Fisher [12] and Schneider [13], also confirmed that good daylighting in a classroom has positive effects on user behavior as well.

In addition, lighting design affects the energy consumption of educational buildings. Delvaeye et al. for exemple documented the annual energy savings of three different daylight control systems in a school, ranging from 18% to 46% [14]. Based on an integrated assessment of energy performance and indoor climate in a portuguese school, Bernardo and al. showed that the expected energy consumption reduction is about 11.2% due to a better usage of daylighting [15].

Concerning artificial lighting, retrofitting the lighting system either by installing new luminaires or by simply replacing the lamps in an effort to increase luminaire's luminous efficacy can reduce significantly the energy consumption [16].

Algeria has known since the 2000s a constant evolution of the number of college students. The provision of sufficient university teaching places to meet

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need has led to the reproduction of models of standardized architecture that did not take into account the climatic specificities of each region [17]. This standardization can conduce to an uncomfortable luminous environment negatively affecting occupants.

The aim of this study is to evaluate the luminous environment in university classrooms located in Constantine, North-East of Algeria.

2 Case Study

The case study is the building of the Faculty of Psychology and Educational Sciences (Constantine 2 University) located in Nouvelle Ville, Ali Mendjeli of Constantine. It consists of the two blocks A and B with uncovered patios. It also has 20 classrooms and four lecture halls. The block of classrooms A are oriented north-east and north-west. Those of the block B have a north and west orientation. The investigation was conducted in block B: classroom n°2 and n°4 (Fig.1).

Both classrooms have the same geometric characteristics. The classrooms surface is 84m^2 ($9.50\text{m} \times 8.80\text{m}$) with a capacity of 50 places. Their depth index was estimated at 2.82 and the window to wall ratio WWR was equal to 50%. The glass material used is a single glazing (4mm thick) type Stopsol Classic Bronze (Sarl AGC) whose visible light transmission VLT is 22%, the solar factor g equal to 55% (Fig.2).

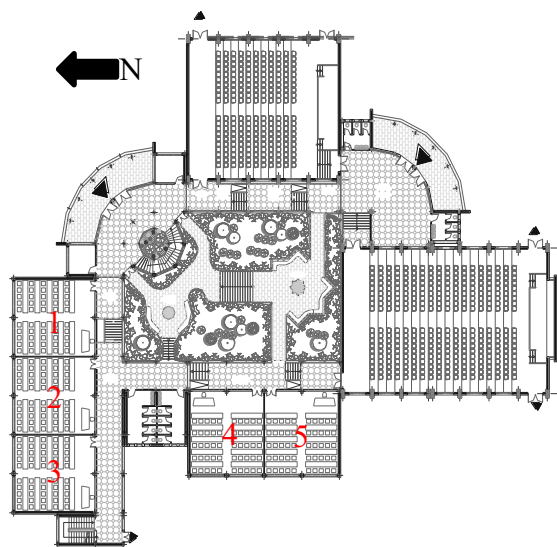


Fig.1. Plan of Ground Floor of Block B – Building of the Faculty of Psychology



Fig.2. Facade of the Faculty of Psychology equipped with simple glazing « Stopsol Classic Bronze »

3 Methodology

A post occupancy survey along with lighting measurements are significant for making a building environment a humancentric one [18].

In this study, a Post Occupancy Evaluation (POE) based on an objective and subjective assessment was carried out at the Faculty of Psychology of Constantine 2 University in North and West facing classrooms. The survey was conducted during the three periods: winter, spring and summer under clear sky and overcast sky conditions.

3.1 Objective Assessment

The objective variables measured by a portable luxmeter Delta OHM HD 2302.0 equipped with photometric probe LP 471 PHOT (Fig. 3) during each course session are: indoor illuminance levels (E_i) on work plan (measuring grid height = 80cm, composed of 20 points), vertical illuminance levels on boards (E_v) (height=160 cm) and outdoor illuminance levels (E_x).

Mean illuminance level (E_m) and uniformity index ($U_o = E_{min}/E_m$) are calculated for each session.



Fig. 3. Luxmeter Delta OHM HD 2302.0

3.2 Subjective Assessment

Students perception and satisfaction were reported by a longitudinal questionnaire (N=1221) using subjective scales.

The questionnaires were distributed to the selected users, 30 minutes after the lesson started simultaneously with the objectives parameters.

The questionnaire was divided into four parts:

Part 1 : General Information about Gender, Age, Individual Student Position in the Classroom ...

Part 2 : Thermal Comfort (published in another paper[19])

Part 3 : Visual Comfort, using:

-Seven point light brightness scale :

1 Very dim, 2 Dim, 3 Slightly dim, 4 neither bright nor dim, 5 slightly bright, 6 bright, 7 very bright,

-Five point Satisfaction scale : from 1-Very satisfied to 5-Very dissatisfied with a central point,

-Acceptability vote.

Part 4 : Individuals' Environmental Parameter Control
 Ninety Eight students and thirteen teachers have participated in the survey: 58 students in west facing classroom and 40 in the northern. The number of questionnaires (observations) collected per classroom and per period are indicated in figure 4. The results were analyzed using Modalisa 5.0 software.

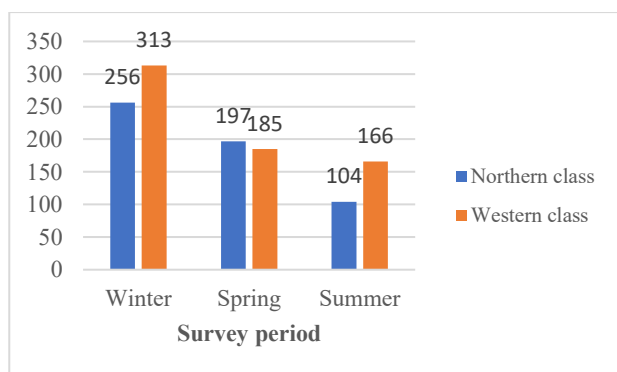


Fig. 4. Distribution of Questionnaires (observations) per Classroom and per Period

4 Results

4.1 Objective Assessment results

According to standard EN 12464-1 [20], illuminance levels recommended for adults classroom are : 500 lx on work plane (Height=0.8m), 600 lx for vertical illuminance level on board and uniformity index = 0.6.

Tables 1 and 2 summarise mean illuminance levels calculated for each session during the three periods.

4.1.1 The West Facing Classroom

Under overcast sky conditions

Indoor illuminance levels on work plan and board ranged lower than the adequate amount of daylight which shows that daylight cannot be the sole source of

illumination and additional artificial lighting is needed for accomplishing the task without visual discomfort :

Mean horizontal illuminance levels (E_m) ranged between 352 lx at 9 :30 am and 565 lx at 2pm.

-Vertical illuminance levels on board (E_v) varied between 234-300 lx.

The glazing material with low visible light transmittance (22%) affected negatively the daylight of the classroom :

Maximal illuminance level ($E_{max}=1203$ lx) was registered near opened windows, whereas half of this value was recorded near closed windows ($E=508$ lx).

Under clear sky conditions

In general, during the morning, mean indoor illuminance levels were below the recommended value ($E_m=366$ lx at 9 :30 am in winter).

From noon, the values increased due to the penetration of direct sun beams in the classroom.

During the afternoon, indoor illuminance levels ranged higher than the adequate amount of daylight (over 2000 lx) in which the over-supply of daylight is likely to cause visual discomfort (Glare), and the daylight conditions were non uniform.

Table 1. Mean Illuminance Levels in the West Facing Classroom (in lx)

	9:30a m	11 am	12:30 pm	2pm	3:30pm
Overcast Sky	352	420	463	565	435
Winter clear sky	366	409	522	973	1043
Spring Clear sky	460	581	877	997	1125
Summer Clear sky	255	607	878	1321	1462

4.1.2 The North Facing Classroom

Under overcast sky conditions

The lighting conditions in the north facing classroom varied according to the behavior of the occupants who manipulated the windows and the use of electric lighting. With combined lighting (natural and electric) and all the windows closed at 9:30 a.m., the illuminance values ranged between 186 lx and 694 lx with an average of 375 Lx. The lighting condition was uniform.

With combined lighting and some windows opened at 11 a.m, illuminance levels varied between 294 lx and 1532 lx with $E_{mean}=626$ lx. In fact, the opening of windows multiplied by two the light levels.

Without electric lighting and after closing the windows at 3.30 p.m. (outdoor illuminance level $E_x=4620$ lx), very low indoor illuminance was registered varying between 21 lx near the back wall and 254 lx near the windows, with an average value of 88 Lx.

Vertical illuminance levels on board E_v was insufficient all the day and varied between 49 lx at 3 :30 pm (without electric lighting) and 282 lx at 11 a.m (with electric lighting).

Under clear sky conditions

In wintertime, the occupants have opted for combined lighting throughout the day but in the early morning, the lighting was insufficient. The increase of the outdoor illuminance levels at 11 a.m. and 12:30 p.m. improved the lighting on the work plan: we noted that 50% and 80% of the illuminance levels were above the recommended value at 11 a.m. and 12:30 p.m. respectively. During the afternoon, the decrease of outdoor illuminances conducted to a decrease of indoor illuminance levels, which became insufficient. However, the general lighting was uniform throughout the day and the vertical illuminance on board varied between 154 lx at 9:30 a.m. and 521 lx at 12:30 p.m.

In spring time, the lighting conditions are improved : between 40% and 100% of the values were above the recommended one. The zone near opened windows registered values around 2000 lx. The general lighting is non-uniform and the vertical illuminance on board Ev varied between 327 lx and 475 lx.

In summer time, without electric lighting, the average illuminance level varied between 555 lx at 9.30 a.m. and 705 lx at 11 a.m. Maximum values exceeding 2000 lx are recorded near windows that have remained open all day. The lighting at the back of the classroom was insufficient (200 lx), thus giving non-uniform lighting and vertical illuminance of the board Ev oscillated between 389 lx and 504 lx.

Table 2. Mean Illuminance Levels in the North Facing Classroom (in lx)

	9:30a m	11 am	12:30	2pm	3:30pm
Overcast Sky	375	626	352	481	88
Winter clear sky	327	518	564	450	419
Spring Clear sky	600	618	813	836	712
Summer clear sky	555	705	645	440	403

4.2 Subjective Assessment results

4.2.1 The West Facing Classroom

Figures 5 and 6 indicate light brightness vote and satisfaction vote of western classroom's users:

In winter (N=313), 64.1% of respondents described their classroom's lighting environment as "neither bright nor dim", 13% as "slightly bright", 12.8% as "bright" and only 0.6% as "very bright", while 9.3% of occupants considered the room to be "Slightly dim" or "dim". 94.6% of users were satisfied with their lighting environment, mainly qualifying it as "Neutral" at 72.4%. While 5.4% were dissatisfied.

In mid-season (N=185): 63.8% of respondents found the classroom "neither bright nor dim", 20% described their lighting environment as "slightly bright", 10.3% as "bright" and only 1% as "very bright". The vote "slightly dim" was used by only 5% of occupants: a high satisfaction rate.

In summer (N=166), 69.3% of respondents described the lighting environment as "neither bright nor dim". 24.7% considered it "slightly bright", "bright" or "very bright". The majority of the sample (92%) were "satisfied" with their lighting environment, mainly describing it as "neutral" (65.7%), while 8% were "dissatisfied".

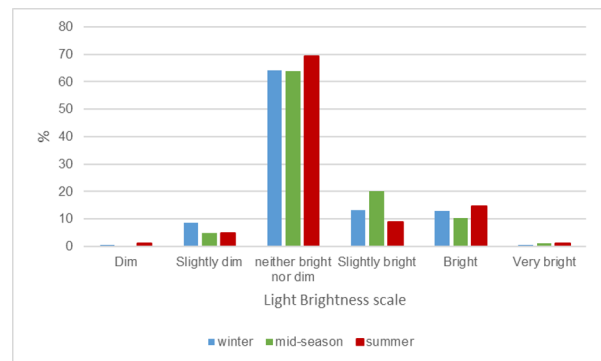


Fig. 5. Light Brightness Vote in West Facing Classroom

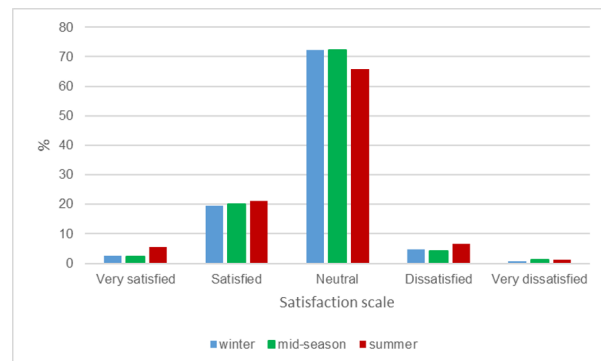


Fig. 6. Satisfaction Vote in West Facing Classroom

For acceptability vote, 97% of occupants found the room's lighting environment "acceptable" in winter and mid-season. This percentage was lower in summer: 90.3%.

4.2.2 The North facing classroom

Figures 7 and 8 indicate light brightness vote and satisfaction vote of northern classroom's occupants: During the winter period (N=256), 68% of respondents described their room's lighting environment as "neither bright nor dim", 18.8% as "slightly bright", 7% as "bright" or "very bright". On the other hand, 6.3% of occupants rated it as "slightly dim". The majority of users (92.6%) expressed satisfaction with the classroom's lighting environment, describing it as "Neutral" in 72.3% of cases. The rate of dissatisfaction was 7.4%.

In mid-season (N=197), 73% of voters described the lighting environment as "neither bright nor dim", while 11.7% described it as "slightly bright" and 5.1% as "bright". 10% of occupants rated their classroom as "slightly dim" to "dim". The satisfaction rate showed a slight decrease, with 88.8% of users expressing satisfaction with the lighting environment, describing it mainly as "Neutral" in 69% of cases, while the rate of dissatisfaction increased to 11.2%.

In summer (N=104), 73.1% of respondents voted "neither bright nor dim", 17.4% as "slightly bright", "bright" or "very bright", and 9.7% as "slightly dim to dim". 89.2% of users were "satisfied" with their lighting environment, mainly describing it as "neutral" (74%). 10.8% were "dissatisfied".

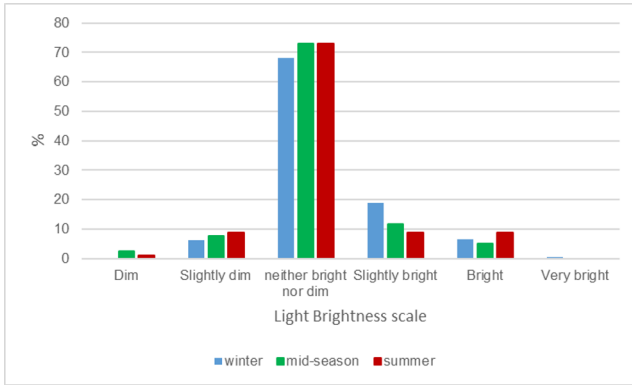


Fig. 7. Light Brightness Vote in North Facing Classroom

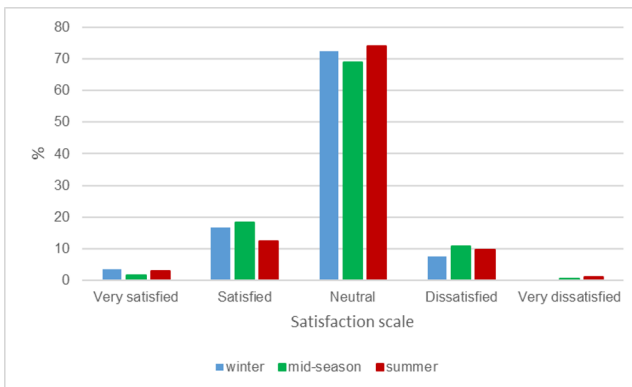


Fig. 8. Satisfaction Vote in North Facing Classroom

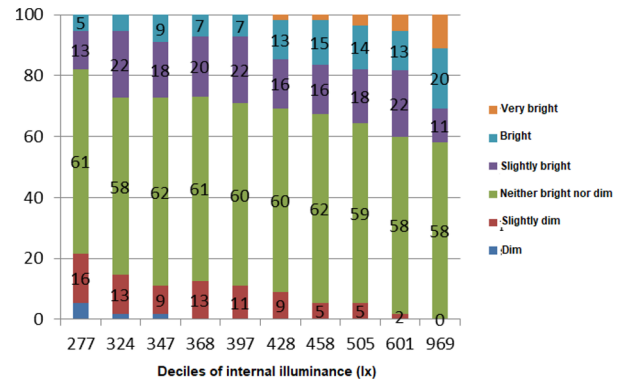
For the acceptability vote, the majority of users voted for an "acceptable" environment, both in winter (90.2%), mid-season (89.8%) and summer (90.4%).

4.3 The Correlation between Objective and Subjective variables

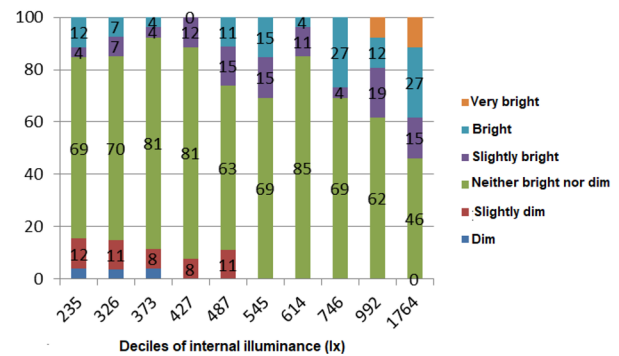
4.3.1 Subjective Responses to Light Level

The subjective responses were divided into deciles of internal illuminance measured on the work plan.

Figure 9 shows the occupants' perception of the lighting environments as a function of the illuminance deciles. According to both graphs, there is a progressive increase in the impression of brightness with increasing illuminance level, but the "neither bright nor dim" evaluation predominates at all illuminance levels. These results are consistent with those of Rebelo and Menezes [21] and Nicol and al. [22].



a- In winter



b- In summer

Fig. 9. Subjective Responses to the Brightness Question for Deciles of Indoor Illuminance Level

Moreover, the correlation between the average horizontal illuminance measured in the classroom and the average brightness vote to the task plane indicates a non-significant relationship between the two variables, with $R^2=0.175$ (Fig.10).

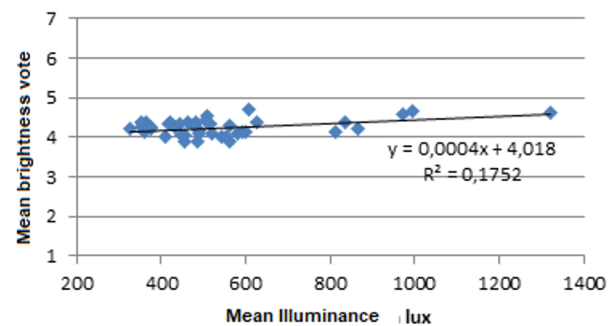


Fig. 10. Scatterplot of the mean brightness vote against the mean horizontal indoor illuminance

4.3.2 The Relationship between the Light Brightness Vote and the Acceptability Vote

Nicol and al [22] suggest that in hot climates, people prefer dark environments, which favours the use of small openings, synonymous with coolness. To verify this hypothesis, we compared the acceptability vote for the lighting environment with the perception of brightness expressed by the occupants (Figure 11).

Our survey showed that the lighting environments described as "neither bright nor dim" (4), "slightly bright" (5) and "bright" (6) were the most acceptable and therefore the most appreciated by users, with over 80% of votes. On the other hand, light environments described as slightly dim (3), dim (2) and very bright (7) were less popular. We conclude that the population surveyed prefers bright rather than dim environments.

On the other hand, we noticed that this acceptability of the light environment does not change with the seasons.

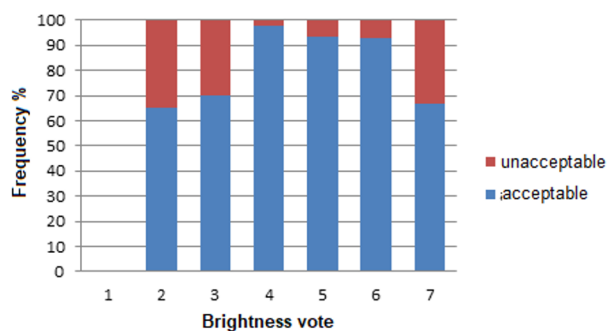


Fig. 11. Relationship between Acceptability vote and Light Brightness vote

4.3.3 Acceptability of the Lighting Environment in classrooms

The acceptability of the lighting environment in classrooms is judged on the basis of three qualitative evaluation criteria and one quantitative criterion. The quantitative criterion refers to the value of the horizontal illuminance measured on the work plane, which must be greater than 500 lx according to the recommendations. The proposed qualitative criteria relate to the direct acceptability vote, the sum of the votes (4, 5 and 6) on the brightness perception scale and satisfaction with the lighting environment based on the five-point scale (Σ very satisfied, satisfied and neutral). The lighting environment is qualified as acceptable when the value of the evaluation criterion is greater than 80%.

Figure 12 shows the acceptability of the lighting environment in the classrooms investigated in winter and summer period. We note that the level of acceptability is almost identical for the three qualitative criteria, since it exceeds 90% during the two periods of investigation: this confirms that the users of the classrooms are very satisfied with their lighting environment throughout the academic year. This high level of satisfaction can be explained in part by the presence of daylight and the view to the outside. On the other hand, the quantitative criterion is far from reflecting the real acceptability of the lighting environment by users, since only 26% of the values recorded on the useful plan exceed 500 lx in winter and 54% in summer.

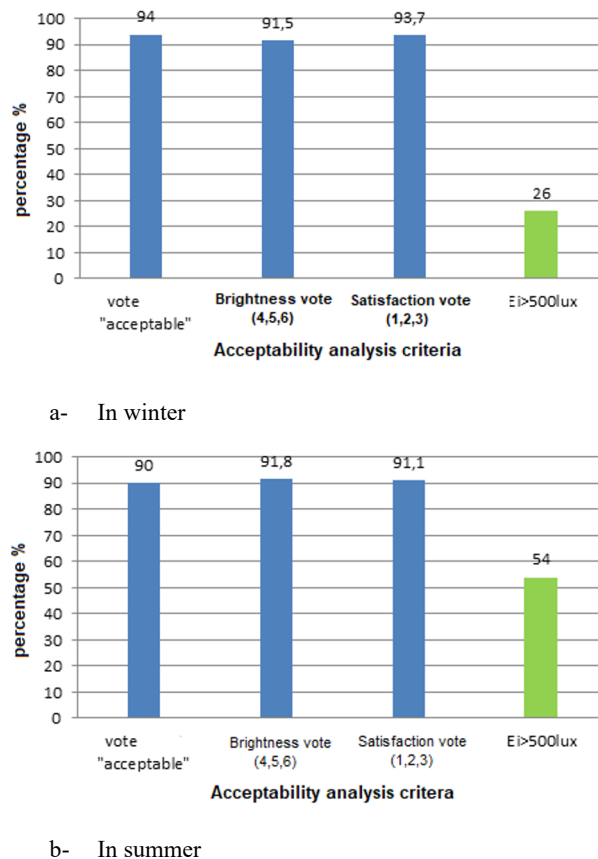


Fig. 12. Acceptability of the lighting environment in the classrooms

5 Conclusion

The aim of this study is to evaluate the luminous environment in Algerian university classrooms. A Post Occupancy Evaluation (POE) based on the objective and subjective assessment was carried out at the Faculty of Psychology of Constantine 2 University in north and west facing classrooms.

Measurements of indoor illuminance on the useful plane showed that the lighting in the north facing classroom was insufficient but uniform, especially under overcast conditions, while the west facing classroom recorded excessive illuminance values in the afternoon, under clear sky conditions, due to direct sunlight and the absence of effective solar protection, making its lighting particularly non-uniform and contrasting, and the risk of glare very high. It should be noted that the choice of glazing material used had a negative impact on the lighting conditions in the classrooms, reducing by half the amount of light that penetrated into these spaces. As a result, the state of the windows (open/closed) had a significant impact on the lighting conditions in the classrooms.

However, the questionnaire revealed a high level of satisfaction among users with their lighting environment in both classrooms, despite their resorting to adaptive actions to correct visual discomfort. We also noted a gradual increase in the impression of brightness as the illuminance level increased, but the relationship between

the average illuminance measured and the average brightness vote was not significant.

Finally, the survey revealed that the population surveyed prefers bright environment to dim lighting, and this preference does not change with the seasons.

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