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Post-Occupancy Evaluation of an educational building: Case study of the ETS-UESC Building

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Abstract

The physical and environmental conditions of educational institutions are determining factors for occupant comfort. The Post-Occupancy Evaluation (POE) presents itself as a methodology for verifying environmental aspects in full use, considering the technical criteria and the users' perception. This article discusses the particularities of the ETS-UESC building, in Brazil, applying POE with an emphasis on the environmental comfort of the classrooms. For this, an exploratory research was carried out where the users' perception of ambience was verified, through the application of targeted forms and on-site measurements of the thermal and lighting conditions using a thermohygrometer and a lux meter, and natural ventilation conditions by design analysis, in the light of current regulations. The opinions were compared with the environmental measurements to identify the limitations of the building and to find the dissonant points. About 85% of users are bothered by the thermal conditions where they are exposed to high daily temperatures, above 30 ºC. In spring and summer, room temperatures are above those recommended by NR 17 standard. The quality of natural lighting is questioned by approximately 80% of users, even having illuminance above the recommended limit of 300 lux in the daytime cycle. How thermal and lighting conditions restrict the use of spaces was proven, making it necessary to discuss active or passive technical solutions to mitigate these problems. Therefore, some factors and technical solutions were pointed out that will assist in the suitability of the project in question.

Keywords: post-occupancy evaluation; building performance; user perception; educational buildings.

1. Introduction

The standardization of projects in the construction of university buildings, without an evaluation of the adequacy of these for the place to be implanted, generates a series of problems of acclimatization and environmental comfort. Thus, Silva (2016) discusses the need for the adequacy of these environments for educational purposes, and the influence of space on users' behavior and performance.

Therefore, the architectural, spatial, and comfort quality of these buildings need to consider, in addition to architecture and engineering, the perception of users, since they are the main protagonists and agents. For Bortoli and Villa (2020), Post-Occupancy Evaluation (POE) allows obtaining consistent diagnoses related to the characteristic aspects of the building and occupied environment, enabling the identification of the impacts to which it is subject, its flaws, and possibilities for adaptation.

When considering the users and their needs as well as the technical factors in this evaluation, the virtuous cycle of built environment is formed, where the consequences and the relations of project decisions on the built performance can be verified, allowing to reflect about the benefits of a more humanized architecture (Rheingantz *et al*., 2009). POE is part of the cycle of a constructive process, in an integrated way, the process does not end at POE, this is not the final phase of the construction.

Several applications of POE were found in literature. POE is a process of evaluating the performance of a building after it has been occupied for at least several years (Li *et al*., 2018a). Li *et al*.

(2018b) published a review of state-of-the-art and state-of-the practice of POE, analyzing 146 POE projects. Dabaieh *et al.* (2019) used a participatory action research methodology including POE by means of an occupant centered approach for the design and construction of a Trombe wall system, suitable for passive heating and cooling in hot arid climates. Ponterosso *et al.* (2018) describes the office floor of the Land Rover/Ben Ainslie Racing (LR/BAR) Team headquarters building in Portsmouth, UK. The building was constructed and has a Building Research Establishment Environmental Assessment Method (BREEAM) "Excellent" award/certification. As in the present study, the authors quantified the occupant perceptions by a post occupancy evaluation (POE) carried out by survey/questionnaire, and occupants were also questioned on other aspects of their perception of comfort, such as light quality, air quality etc. The results also demonstrate the importance of seemingly small details to the level of comfort experienced by occupants. Gonzalez-Caceres *et al.* (2019) reported that POE can successfully detect causes of poor-quality indoor environment in social housing in Chile. Li *et al.* (2018) intend to help clients and design teams improve their building designs by integrating the views of stakeholders using POE to realize the true spirit of Green Building development.

Preiser *et al.* (2016) affirm that the Post-Occupation Assessment (POE) is the process of assessing environments in a systematic and rigorous way after being built and already inhabited for some time. Mustafa (2017) develops a POE framework that integrates building performance attributes for university buildings and facilities in the Iraqi Kurdistan region based on users' satisfaction. Results showed that 88% of building performance attributes is highly correlated with users' satisfaction. The compelling correlational results confirmed the relevance of POE as a building performance tool.

This process is done by obtaining data from the location and taking measurements with instruments, as well as promoting the active participation of users, as highlighted by Villa *et al.* (2018). The intention is to identify the needs and point out the positive and negative aspects of the spaces, making it easier for the evaluators to better understand the consequences of the design and construction decisions that generated the successes and flaws found.

Bourdeaux *et al.* (2018) studied the energy consumption of three campus buildings covering more than 50,000 m^2 useful ground area and located in the Paris region. The data were collected during more than three years between 2014 and 2017. Statistical analysis tools are used, to identify the main energy drivers and their relative weight in the overall energy consumption for instance. The impact of different thermal regulations is clearly assessed through a post-occupancy study.

Paying attention to the school environment, Sarmento *et al.* (2020) reaffirm the importance of its adequacy and comfort, stressing that it is essential to consider the importance of the role played by the physical space of the school environment in the performance of users. It is worth noting that these buildings are different from housing, either due to the occupation time or the type of activities carried out, so that, as stated by Bestetti (2014), it is necessary to conduct a study of the perception of space based on the individual who occupies it, since he is even able to interact with the environment through his senses.

In Brazil, the main standard that indicates the appropriate performance parameters for buildings is NBR 15575-1 - Residential buildings - Performance Part 1: General requirements, which came into force in 2013, defining several requirements to obtain the best performance of a building system until reaching an appropriate environmental comfort for the type of space use [NBR 15575-1 (ABNT, 2013a)]. It is important to note that NBR 15575-1 was developed for residential purposes, therefore the minimum requirements to be achieved are not for buildings for educational use. An evaluation of performance in buildings for educational purposes, the measurement procedures of NBR 15575-1 are used, however it is necessary to use other auxiliary standards that will complement the study, such as NR 17/2018, which provides minimum thermal and lighting requirements for environments of intellectual nature, NBR 15220/2005, which deals with thermal performance in buildings and NBR ISO/CIE 8995/2013, which deals with lighting in work environments.

In order to apply and improve this knowledge, this work explores the perception of users of the Pavilion of Exact and Technological Sciences (ETS) of the Universidade Estadual de Santa Cruz (UESC), through a systematic assessment of the environment built through APO, qualifying community sense and quantifying through measurements of environmental conditions.

One of the objectives was to understand the user's perception through the degree of satisfaction of the user with the space he occupies, applying a questionnaire that addresses the environmental conditions of the building. Then, confront this view, with a technical study of the conditions of use through the measurement of thermal and illuminance parameters, using instrumentation and current standards. The results supported the diagnosis of environmental comfort of the building, allowing a reliable description of the problems and possible interventions in the recognized places that improve the quality of the environment.

2. Materials and methods

The Exact and Technological Sciences (ETS) building is located at the Universidade Estadual de Santa Cruz (UESC), municipality of Ilhéus-BA, at a latitude of 14º47'50 "S and longitude of 39º10'28" W.

According to NBR 15220 - Thermal performance of buildings Part 3: Brazilian bioclimatic zoning and construction guidelines for single-family housing of social interest (ABNT, 2005), UESC is located in bioclimatic zone 8, which comprises 53.7% of the Brazilian territory. For this zone, the recommended passive thermal conditioning strategy is permanent cross ventilation, paying attention to the prevailing winds in the region and to the surroundings, as the surroundings can significantly change the direction of the winds. However, passive conditioning is already considered insufficient during the hottest hours for this bioclimatic zone. According to historical reports from Weather Spark (2016), temperatures range from 20 ° C to 30 ° C, rarely below 19 ° C. The predominant average hourly wind direction in Ilhéus is to the east throughout the year, with a large percentage of hours spent in the intermediate directions Northeast and Southeast.

Figure 1 shows the layout of buildings on the UESC campus, highlighting the ETS building, the direction of the prevailing winds and the indication of the directions of the cities of Ilhéus and Itabuna.

Figure 1 – Illustration of the UESC campus with the ETS building highlighted.

The ETS building has 3 floors for administrative and educational use, with 17 classrooms, 26 laboratories and 9 administrative rooms, in addition to other spaces for various use, such as research, study and administrative support groups. Its total built area is 3,773.65 m², and its main front faces the southwest, the left and direct side views to the north and south, respectively.

A survey of the building was carried out through existing plans and projects, obtained from the cataloging bodies of the institution, and then visits were made to the spaces for gauging the detailed measures and construction elements. During this process, photographic records of the environment, observation of the details of interest and checking of details were carried out, as a way to catalog new details for the existing plant. Such action allowed to determine the techniques that would be applied and the points that deserved more attention, being able to exemplify: quantity and type of lamps; presence of blinds, screens and films in the windows; amount of heat generating equipment in the environments; opening dimensions, among others.

For the technical study of the environmental conditions of the building, the points for evaluation were chosen on the 2nd floor of the pavilion, according to the recommendation of standard NBR 15220 (ABNT, 2005), which determines that in the case of buildings, the measured rooms must be on the top floor (Figure 2).

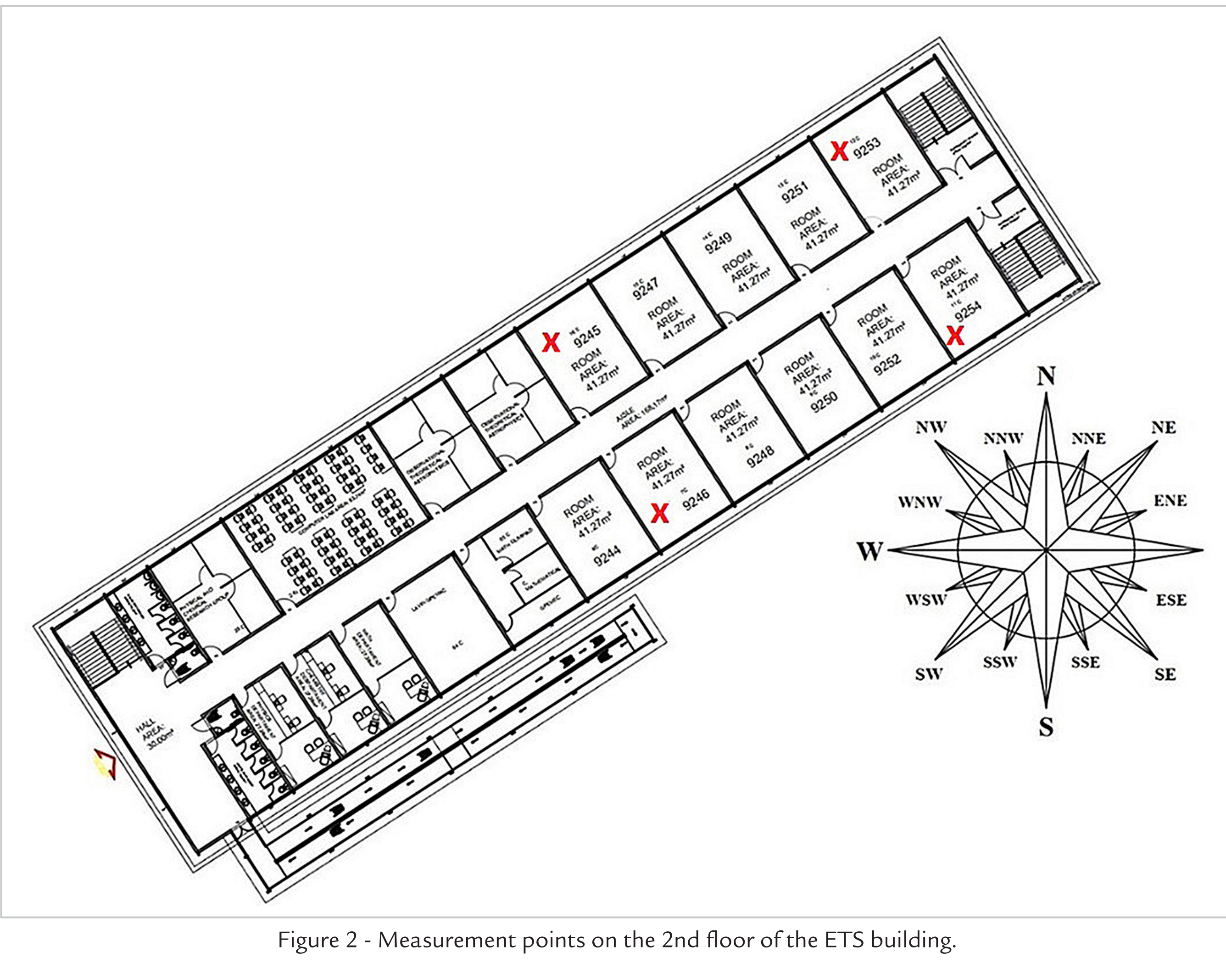

Figure 2 - Measurement points on the 2nd floor of the ETS building.

The points marked in Figure 2 are located in rooms 9245, 9246, 9253 and 9254, with approximate areas of 41.00 m², properly spaced from each other and on opposite sides of the building, contemplating different solar orientations, for a representative assessment.

2.1 Thermal condition measurement

The method used to evaluate the thermal conditions of the indicated places, followed the procedures recommended by NBR 15575-1: Residential buildings — Performance Part 1: General requirements (ABNT, 2013a). For measurements of the dry bulb temperature of the indoor air (± 1ºC) and the relative humidity of the air (± 5%), the Minipa MT 241A Thermohygrometer, installed in the shade, was used in the center of the rooms on a stable wooden support with a height of 1.20 m from the floor. The thermohygrometer was previously calibrated and each measurement was performed after stabilization of at least 5 minutes. As for the external temperature measurements, the thermohygrometer sensors were positioned on the windowsill of the rooms, with a height of 1.50 m.

The requirements of the NBR 15575-1 standard were fulfilled because the air conditioning equipment of the studied rooms was kept off. The condition of natural ventilation is the predominant one since the air conditioning equipment presents recurring technical problems.Therefore, the environment was used with natural ventilation.

The choice of days for measurement followed the recommendations contained in standard NBR 15575-1, which indicated the monitoring in "days with characteristics of a typical summer day, with open skies, preceded by at least one day with similar characteristics", in a way to avoid influence of thermal amplitude and humidity due to an adverse climatic condition.

Because the building spaces have daytime use, measurements were taken in two daily cycles, the daytime cycle being between 12:30 and 2:00 pm, because it is the period of the highest temperature of the day, and the night time between 6:30 pm and 20:00 hours, because it is the period when heat starts to dissipate in the environment. The readings started 5 minutes after turning on the device, so that there was a stabilization of the parameters in the equipment. The measurements were performed in intervals of 10 minutes, and values were checked by an operator and noted until the end of the cycles at the specified time. It is important to mention that the windows of the room were kept open during the reading period to guarantee the natural thermal condition; the air conditioner was kept off; and the door closed. In both periods, the rooms were maintained without occupants and without heat sources, according to the standard.

The values recorded for temperature and humidity, internal and external, were tabulated, and the minimum and maximum values were highlighted. These values were important in verifying the performance of the envelope in the climatic condition during the measurement period; and, in the verification of the compliance with the parameters recommended by the Regulatory Norm NR 17 - Ergonomics (Brasil, 2018), which guides the ideal condition of ambient temperature for the performance of labor and intellectual activities. Table 1 summarizes the parameters referenced in this article.

Table 1 – Criteria for thermal evaluation.

Standard	Criteria
NBR 15575-1	$T_{i,max} \leq T_{e,max}$ (minimum performance)
NR 17	$20° C \leq T_i < 23° C$

T_i is the room temperature inside the building, $T_{i,max}$ is the diary maximum value of temperature inside the building; $T_{e,max}$ is the diary maximum value of temperature outside the building.

2.2 Measurements of visual comfort

The evaluation of the luminous comfort was performed from measurements of the level of illuminance (Ee, i) in lux units, which indicates the amount of light within an environment, obtained with the Minipa MLM1011 digital lux meter (± 4%).

NBR 15575-1 (ABNT, 2013a) recommends that the period of measurement of natural illuminance should be between 09:00 and 15:00, of a typical summer day. This recommendation allowed the first reading cycle to be carried out in the same interval as the temperature and humidity reading, between 12:30 and 14:00. Thus, the device was installed on the same stable wooden support positioned in the center of the room, on a platform 0.75 m from the floor, where readings were taken every 10 minutes until the end of the cycles at the specified time. Immediately after reading the internal illuminance, the device was taken to the window sill to read the external luminous flux. Other recommendations contained in the standard were observed, such as keeping the artificial lighting turned off and opening the windows fully, even those with film or opaque surfaces. As for artificial lighting, the procedure adopted was similar, but with readings between 18:30 and 20:00 on the same day, with 10-minute intervals.

After the illuminance readings, the values were compared with the parameters of the NBR ISO / CIE 8995 standard (ABNT, 2013b), which provide an illuminance reference for working environments, shown in Table 2.

Table 2 - Illumination maintained for educational building facilities.

Environment	Illumination maintained ($\overline{E}_m$) (lux)
Classrooms	300
Night classrooms	500

Source: Adapted from NBR ISO/CIE 8995 standard (ABNT, 2013b).

2.3 User perception questionnaire

As a method of assessing the perception of users, questionnaires were applied to users of the building, with the main group being teachers and students. The questions were objective with multiple-choice answers, where the user can point out their impressions in an orderly, intuitive, anonymous and independent way.

The questionnaires had 7 questions about the specified rooms of the ETS building. The objective responses ranged from "I totally agree" to "I totally disagree". In the discussion of the results, the percentages of "I totally agree" and "I agree" will be grouped, as well as "I totally disagree" and "I disagree". The questions were:

1. The noise that comes from outside the rooms bothers you;
2. The room receives good natural lighting;
3. The artificial lighting in the rooms is adequate;
4. The sunlight interferes with the activities developed in the room;
5. In summer, the rooms provide thermal comfort;
6. The wind disturbs the activities developed in the room.

The answers to the questionnaires were collected by using a Google form. As it is a building with varying lengths of stay, it was decided to leave the consultation free, without reaching a minimum quotient. This is because most of the public that uses the building has a reduced length of stay, such as students who remain in the building when they are in work activities (internship or research), and teachers during their teaching activity.

Subsequently, the data were tabulated, evaluated, and discussed, presenting the users understanding of the aspects addressed in relation to the space of the ETS building.

3. Results

3.1 Space survey

In summary, rooms 9245, 9246, 9253 and 9254 have active temperature control through air conditioning devices with 60,000 BTUs. The other parameters observed and updated in the plants were systematized in Table 3 for the rooms in question.

Table 3 – Evaluation of building.

Room	Lighting					Ventilation			
	Lamps		Window		Presence of shutter	Window film		Opening	
	Units	Type	Power (W)	(m)		Presence	Condition	Window (m)	Door (m)
9245	16	Tubular	28	5.62x1.90	Yes	yes	bad	2.73x1.23	0.90x2.10
9246	12	Tubular	28	5.62x1.90	No	yes	bad	2.73x1.23	0.90x2.10
9253	8	Tubular	18	5.62x1.90	Yes	yes	bad	2.73x1.23	0.90x2.10
9254	10	Tubular	18	5.62x1.90	No	yes	bad	2.73x1.23	0.90x2.10

3.2 Evaluation of user perception

The questionnaires were distributed between the months of October and December 2019, and their main objective was to understand how users feel the environmental comfort conditions of the ETS building. In total, 138 people answered the forms, being 88 students (representing 15% of the students of Exact and Technological Sciences) and 50 teachers (representing 24% of teachers of Exact and Technological Sciences), whose answers were organized by the respective functions in the institution: (01) teachers and (02) students.

Approximately 60% of teachers and 68% of students are disturbed by the external noise of the rooms, indicating a problem in the sound insulation between the rooms and the corridors of the building. This situation is amplified when the door is kept open, which, in turn, is necessary to have natural cross ventilation. The alternative to reduce the impact of external noise is to close the door and use air conditioning.

Regarding natural lighting, approximately 60% of teachers and students consider the rooms to be well lit, in both measurement cycles. However, despite this user approval regarding the luminous flux, about 74% of the professors and 80% of the students question its quality, since this same flux is excessive and generates glare and visual discomfort. One of the problem causes is the reflective glass surface of the slate that generates this diffuse light distribution, associated with the materials of the other illuminated surfaces in the room. The main concept here is that of ideal lighting for the environment, which not only encompasses the normative parameters of the luminous intensity on the surfaces, but how significant and comfortable this luminance is for the user.

Another identifiable cause for this dissatisfaction with the excess of natural light is the inadequate orientation of the building. In other words, during the planning phase of the building location, only the standard campus layout was considered, without a study of the influence of solar direction throughout the day and the seasons on the building. As a result, the rooms have their openings receiving excess light and heat for a long period of time, especially in the west.

Regarding artificial lighting, 66% and 59% of teachers and students, respectively, considered the illuminance at adequate levels.

Regarding thermal comfort, 82% of teachers and 85% of students answered that the rooms are not suitable for prolonged stays without air conditioning, showing a failure of the rooms. It is inferred that this problem is due to the inadequate implementation of the building facing direct solar radiation; the application of low performance materials with high thermal transmittance; and, of the openings without an external passive barrier, which allows the direct incidence of light in the rooms and retention of heat in the environment, with the critical periods being the morning for the right side and the afternoon for the left. This scenario remains throughout the year as there is no significant climate variation in the bioclimatic region 8.

Natural ventilation was an issue with little controversy, as the rooms rarely operate closed and with conditioned temperature. The condition of natural ventilation of the rooms is predominant and it was in this condition that the measurements were made. Of the respondents, 54% of the professors claimed to be indifferent to the question of natural ventilation, while 38 % said that there were no problems caused by ventilation condition for the development of the activities performed in the classroom. For students, 69% considered themselves uncomfortable with the lack of natural ventilation in the rooms when the doors are closed. Such situation can be verified on the spot, since in the normal conditions of use of the rooms, the windows and doors are open, and the natural ventilation prevails but it is insufficient and does not reduce the room temperature. This is due to the inadequate positioning of the building in the face of the prevailing winds in the region, as according to INMET (2010), the predominant wind direction occurs in the northeast of the building, however the walls serve as a barrier and prevent air from entering the rooms.

3.3 POE

The post-occupation technical evaluation was carried out under three criteria: thermal, light and ventilation. The on-site measurements of the temperature and the luminous flux incident in the rooms were carried out in the months of November 2019, December 2019 and March 2020, covering the spring until the end of summer, being the hottest period of the year.

3.3.1 Thermal condition

The internal and external measurements of the building were compiled and are shown in the graphs of Figures 3 to 6, with the indicated spring and summer cycles. The reference temperature given by NR 17 - Ergonomics (Brasil, 2018) has been added, which recommends that ideal temperatures for work environments of an intellectual nature vary between 20º C and 23º C.

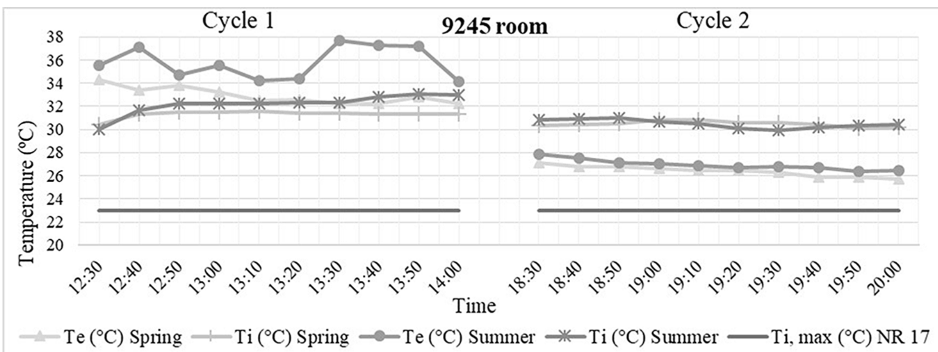

Figure 3 – Temperature measurements of room 9245.

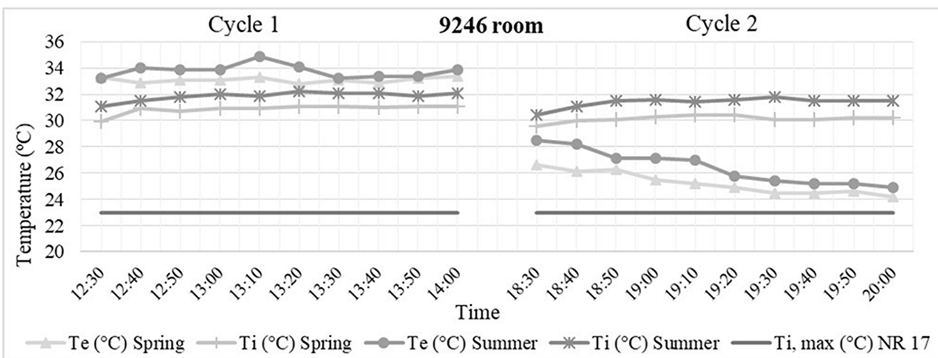

Figure 4 – Temperature measurements of room 9246 .

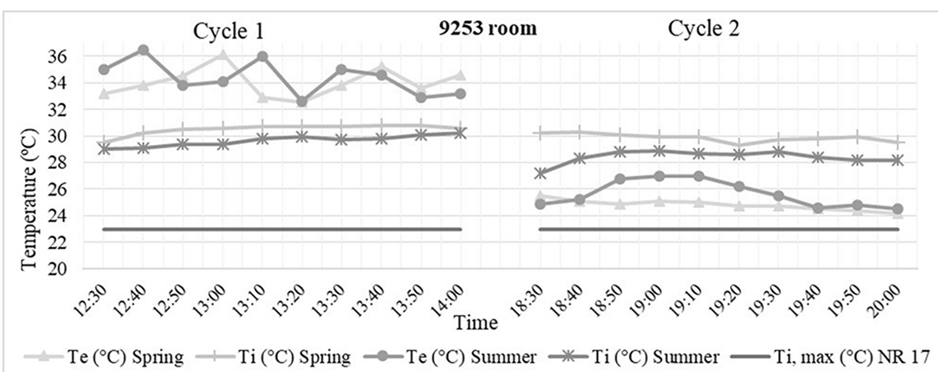

Figure 5 – Temperature measurements of the room 9253.

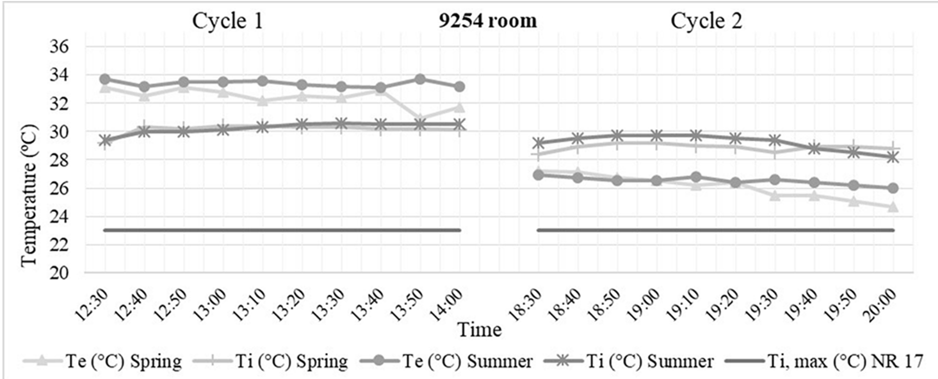

Figure 6 – Temperature measurements of the room 9254.

It is immediately apparent that in all cases, both in spring and summer, temperatures were above those recommended by NR 17, considering the natural conditions, where the air conditioning was off and the windows were open . These high temperature conditions to which users are exposed can reduce the physical performance of the human body when subjected to prolonged exposure, leading to fatigue, exhaustion and irritability, according to Bormio (2007), Lopes (2007) and Lamberts et al. (2014) emphasize.

NBR 15220-3 (ABNT, 2005) foresees situations in which the passive thermal conditioning installed in the buildings present in the bioclimatic zone 8 is insufficient, indicating the use of forced air flow equipment, exhaust fans and fans, or air conditioning environments in order to achieve adequate thermal comfort. However, a dependence on active thermal conditioning is generated in order to reach the recommended thermal level, creating a burden for the building administrator with the preventive and predictive maintenance of the equipment, in order to maintain their proper functioning, in addition to the energy cost during their construction lifespan.

As a criterion given by NBR 15575-1 (ABNT, 2013a), it is recommended that the internal temperature of the building be less than or equal to the external temperature, respecting the minimum performance indicated in Table 1. Thus, taking this criterion, the maximum temperatures were evaluated of the rooms in each measurement cycle, with the verification of compliance with the normative reference. The outside and inside temperatures in each room in spring and in summer meets the standard requirements in the daytime but not in the night classrooms.

Thus, in general, it appears that in the daytime period (Cycle 1), the maximum internal temperatures were lower than the outside temperatures, proving that at that time, the building met the minimum thermal performance requirement given in NBR 15575-1. However, in the night period (Cycle 2) the outside temperatures were milder in relation to the interior of the rooms, showing that there is a thermal problem in the building envelope that needs to be solved. That is, the envelope receives all daytime thermal load and continues to dissipate into the room at night, maintaining the environment with the highest internal temperature.

3.3.2 Lighting

The assessment of visual comfort was carried out under the precepts provided by a NBR ISO/CIE 8995-1 (ABNT, 2013b), which defines the recommended levels of illuminance for each type of environmental use, providing light comfort to users. For the case in question, it was found that the recommended level is 300 lux for Cycle 1 and 500 lux for Cycle 2. The luminous flux enters the rooms through the side openings of the building, through sliding glass windows and covered with dark film, which have 9.88 m² of total area, with only 3.33 m² of usable opening area.

Artificial light is generated by fluorescent tubes with 28 W (rooms 9245 and 9246) and 18 W (rooms 9253 and 9254), installed in luminaires with reflectors and distributed evenly within the room. Tables 4 and 5 show the lux values measured in the environments under study in the two cycles.

Table 4 – Internal illumination of classrooms (spring).

Rooms	Cycle 1 (12:30 –14:00) E_i (lux)	Comply with NBR ISO/CIE 8995-1?	Cycle 2 (18:30 – 20:00) E_i (lux)	Comply with NBR ISO/CIE 8995-1?
9245	456.8	Yes	341.5	No
9246	511.0	Yes	395.0	No
9253	622.7	Yes	122.3	No
9254	500.2	Yes	207.6	No

Table 5 – Internal illumination of classrooms (summer).

Rooms	Cycle 1 (12:30 –14:00) E_i (lux)	Comply with NBR ISO/CIE 8995-1	Cycle 2 (18:30 – 20:00) E_i (lux)	Comply with NBR ISO/CIE 8995-1
9245	800.1	Yes	365.5	No
9246	622.7	Yes	122.3	No
9253	730.9	Yes	150.4	No
9254	962.9	Yes	231.5	No

Lamberts *et al*. (2014) mentions that visual comfort is achieved by the sufficient amount of light, well distributed and that does not generate glare. Knowing this and checking Tables 4 and 5, it is confirmed that in Cycle 1, the amount of light is more than sufficient although it does not have quality, according to users. This particularity creates visual discomfort for users, since the distribution of natural light is diffuse and the surfaces in the room are reflective.

In Cycle 2, artificial lighting did not reach the minimum value of 500 lux recommended by NBR ISO / CIE 8995-1, which despite not having been reported as a nuisance factor by users in assessing satisfaction, their values have significant differences that can harm performance in activities by causing discomfort and excessive effort. This situation is due to the lack of a luminotechnical study for the use of the rooms, which culminated in an under-dimensioning of the luminaires, lamp choices based only on cost and non-uniform layout in the rooms.

3.3.3 Recommendations for the actual project

The user perception applied questionnaires show that the biggest problems are high internal temperatures and the discomfort caused by direct sunlight. A possible technical solution, with adequate cost and impact, is the installation of a passive protection external to the building, on the faces with greater solar incidence (southeast and northwest), as articulating windshields that can be associated with the existing films (Lamberts *et al*., 2014). This kind of solution was also reported by Brito *et al*. (2019) in a scholar building thermal simulation located in 7 and 8 bioclimatic zones, using climate data from the Salvador city, in order to increase the number of comfort hours. Rackes *et al*. (2015) and Spagnuolo (2019) discuss about the use of night ventilation, and the increase of internal air velocity in schools situated in similar zones. Using computer simulations of thermoenergetic performance, these strategies provided the best scenarios of comfortable occupation.

Lamberts *et al*. (2014) presents another solution, using elements of bioclimatic architecture, such as a vegetable curtain on the walls using plants, such as climbing plants. This would serve both as a vegetal covering to reduce the levels of insolation on the facades, improving the conditions of thermal comfort and reducing the use of active air conditioning in the environment. However, the need for permanent maintenance of the facades and revegetation at each cycle also increases, requiring trained teams and implying costs not considered in the design phase.

A second long-term bioclimatic solution is to recover the vegetation on the southeast and northwest façades by installing a tree barrier. The vegetation could be used to reinforce the wind or to soften it, being able to change its direction and speed (Mascaró, L.R.; Mascaró, R., 2002). This, in turn, would provide an improvement in the external microclimate of the building and promote overlapping of the facades. The species should be chosen with care, being those with accelerated growth and having good leaf area. However, Spagnuolo (2019) simulated the application of this bioclimatic strategy in school projects and observed that the use of vegetations just provided comfort hours during 20% of the time. It means that this kind of solution must be used in conjunction with other solutions to achieve a better performance.

The application of ventilated facades is also an applicable technique, through the installation of recyclable panels, forming a second skin on the illuminated face of the building. These facades are structured on an external and lightweight aluminum structure, and can be installed in phases. According to Borodulin and Nizovtsev (2021), it includes an insulation layer, and a ventilated opening. These openings allow, in addition to the direct incidence of sunlight on the facade, the creation of air blades, which by thermal convection allows the exchange of hot air constantly through the “chimney effect”, allowing the building to breathe with the renewal of air, in addition to having low maintenance requirements. Brito *et al*. (2019) recommended the use of ventilated roofs, with the same objective of ventilated facades.

Regarding the problems related to artificial lighting, a luminotechnical study must be carried out, verification of the load capacity of the lighting system, installation of lamps of adequate power for the type of activity and a better distribution of the luminaires, meeting the recommendations set out in the NBR ISO / CIE 8995-1.

It is expected that with the application of these measures, the conditions of environmental comfort will be improved. A new APO must be carried out after the problems are mitigated, considering in this case, whether there is a need to maintain active air conditioning. This is already a strategy used in the building, but with high energy consumption and costs with overhaul of the appliances. If it is decided to keep the HVAC active, it is believed that a resizing of these may be applicable, with the choice of devices with suitable power and greater energy efficiency.

3.3.4 Recommendations for future campus projects

One of the objectives of conducting a POE is to generate knowledge about the construction problems of the building. This experience will allow the improvement of the projects and observation of criteria that improve the functionality of this building.

It starts with the choice of the implantation site, with the observance of adequate climatic conditions; followed by a project that has solutions that improve the environmental comfort conditions of users; thus, a location should be chosen that allows maximum natural lighting and ventilation, without excess light and heat. The choice of materials that are suitable for structure and fencing should be rethought, choice of frames that favor full opening, the application of passive solutions from the construction phase applied to the facades, integration of the building with a plant barrier, meeting the requirements for construction systems set out in the current performance standard, NBR 15575.

4. Conclusions

The general objective of this study was to carry out a Post-Occupancy Assessment in the ETS building with an emphasis on observing environmental comfort conditions for users. The tool proved to be effective as an investigative reference and was validated with a technical study. In addition to assisting in the identification of problems and the degree of significance this generates for end users, it is important to choose the best strategy to solve the problems encountered and avoid future ones.

In this way, dealing with a subject with a great subjective burden, requires that engineering and architecture bring with it a social aspect, since human senses need to be attended to, being a challenging and complex task. The sstudy shows that mere application of norms and standards can lead to structural problems, an increase in the operational cost of the building during its life cycle.

Reaching normative parameters is desirable within a scenario where the building is suitable for that bioclimatic environment, otherwise, problems with false positives will be encountered. As a result, a situation may arise where a standard criterion for good thermal comfort is met, but due to specific local conditions not being felt by the user public, as in NBR 15575, in which the thermal and lighting comfort requirements proved to be insufficient for the building and it became necessary to seek complementary standards with more demanding criteria, such as NR 17 and NBR ISO / CIE 8995. With this, even in an ideal scenario proposed by the standard, one can question or improve some environmental aspect for serving the user audience. This is due to the need for Engineering and Architecture to integrate good practice with the individual and inherent aspects of the human being, and how it relates to the environment with its personal environmental and climatic preferences.

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