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HYGROTHERMAL HEALTH AND SUSTAINABILITY INDICATORS IN BUILDING UNIVERSITY OF ARGENTINA

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ABSTRACT

In relation to previous research, there is an increase in interest in the environmental conditions within classrooms, since they are closely linked to the health, well-being, performance and productivity of students with regard to concentration, attention and learning in the educational setting. This work aims to obtain environmental quality indicators, focusing on data related to building thermal behavior and hygrothermal comfort of users in a representative classroom of a university building in Santiago del Estero, Argentina, with the purpose of detecting environmental modifications that may improve student performance in their learning. The methodology combines quantitative and qualitative analysis. In this sense, the national standards IRAM 11900 and series 11600, and the international standards ISO 7730 and ASHRAE 55 on adaptive comfort zones, are used as a regulatory framework. The results indicated that the analyzed area does not present adequate hygrothermal conditions to guarantee the thermal well-being of the students at different times and seasons of the year. The low adoption of passive strategies in the architectural design of the building stands out, which is directly related to the number of hours of discomfort experienced in both summer and winter in the classrooms. The importance of adapting the enclosure envelope to the climatic zone is concluded, considering both the current climate and future climate change scenarios.

KEYWORDS

University Habitat; Energy Simulation; Hygrothermal Comfort; Environmental Well-being

1. INTRODUCTION

From 2005 to the present, although in all the provinces of Argentina and especially in Santiago del Estero, there have been great advances at the level of infrastructure, with a large number of renovations works and new buildings at all levels of the educational system. However, after the 2020 Pandemic, the situation of the quality of the spaces of the educational habitat became visible, where the return to face-to-face classes has been postponed over time, since the classrooms do not have adequate safety conditions for their sanitation, due to lack of adequate ventilation and thermal discomfort. Hygrothermal conditions in educational

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settings, such as temperature and relative humidity, are influenced by ventilation, architectural design, and heating and cooling systems. In many schools, these systems are insufficient, generating extreme temperatures and unfavourable humidity, which increases the risk of respiratory diseases, skin problems, and viral infections (Mendell & Heath 2005); (Kjeldsen et al. 2014). Thermal discomfort can lead to stress, fatigue, and reduced attention span, affecting both health and students' academic performance and behaviour (Brink et al. 2021)

In addition, it is important that, in indoor spaces, users can maintain adequate levels of hygrothermal comfort, according to what is recommended. by the WHO, whose temperature range is stipulated between 18 and 24°C, since outside these values it is possible that there are health impacts due to exposure to excess cold and heat (Almeida, Pinto Paulo Pinho Luís Lemos, and De Giuli 2017). Air should not be recycled, requiring periodic inspection, maintenance, and cleaning of heating, ventilation, and air conditioning systems to ensure that they are effective and safe (ASHRAE 60.2 2017) including procedures for timely, documented, consensus action on requests for change to any part of the standard. The change submittal form, instructions, and deadlines may be obtained in electronic form from the ASHRAE website (www.ashrae.org. The general principle should be the development of educational work in the best conditions of habitability and safety; with the creation of a healthy and optimal environment, which favors participation and good performance in the teaching-learning process

There are international and national precedents that demonstrate the need to deepen research on quantifying levels of well-being and proposing constructive solutions - passive and active - that allow improvement. Internationally, ASHRAE's guidance (2023), conduct comprehensive evaluations of HVAC systems in existing educational centers, and include the installation of high-efficiency filters and demand-controlled ventilation systems. These adjustments seek to improve performance and reduce exposure to pathogens (Zemitis et al. 2023). In Spain, the IAQ4EDU project, funded by the State Research Agency, proposes to combine natural and mechanical ventilation in classrooms to reduce energy consumption and improve comfort (Gaspar et al. 2022). There are passive strategies and nature-based solutions (NBS) that have proven to be effective in improving thermal comfort and air quality in educational buildings. These include the use of natural ventilation, solar shading devices, and thermal masses in walls and ceilings that help regulate internal temperature, reducing the thermal load in hot weather and favoring energy efficiency (Almeida, Pinto Paulo Pinho Luís Lemos, and De Giuli 2017)(Jia et al. 2021). At the national level in Argentina, habitats have been analyzed in university educational programs, in different geographical and climatic areas and the incidence of proposals for improvements for bioenvironmental conditioning. In Buenos Aires, the new building of the Faculty of Exact Sciences of the UBA was recently inaugurated, in the University City <*Zero plus Infinity*>, with a green roof and passive strategies for building energy efficiency. In the south of the country, in La Pampa, an Auditorium and University Residence of La Pampa National Park in the city of Santa Rosa were designed and executed with bioclimatic criteria (Filippín et al., 2002; Flores Larsen et al, 2004). Universidad Nacional de San Juan (UNSJ) is one of the active institutions in evaluating thermal comfort in classrooms in the Cuyo region, characterized by its arid climate and high thermal variability (Ré, Filippín, and Blasco Lucas 2017) ;(Michaux, Blasco Lucas, and Ré 2016)At the National University of the Northeast, UNNE, proposals have been made for thermo-energetic improvement of the envelope in classrooms of the Faculty of Architecture and Urbanism

(Alias, et al 2012). At the National University of Santiago del Estero, the Energy Diagnosis of the Faculty of Exact Sciences and Technologies has been carried out, proposing to implement improvement and monitoring measures (Giuliano, Ortega et al, 2022). For example, the incorporation of a thermal insulator resolved with remnants from the textile industry was proposed to rehabilitate the Student Multipurpose Room (Giuliano, Saez et al., 2022).

Together, the aforementioned tools constitute a parameter to measure and evaluate indicators of the environmental quality of the habitat, for the monitoring of habitability conditions and continuous improvement. However, its use in Argentina is not mandatory, therefore, it is essential to raise awareness among professionals responsible for decision-making in the built habitat, and especially in buildings of educational institutions that prioritize health and sustainability guidelines in projects prior to construction.

In this sense, the objective of this work is to evaluate the level of hygrothermal comfort as an indicator of the quality of health and habitability of users in a university building in Santiago del Estero. In order to analyze the current situation of the faculty and propose constructive improvements through passive strategies to improve the performance in the learning processes of students and teachers. A typical classroom of the Faculty of Medical Sciences (FCM) of the National University of Santiago del Estero (UNSE) located in northern Argentina is taken as a case study.

2. METHOD

The methodology combines quantitative and qualitative analysis: 1) geographical and climatic characterization of the site (IRAM 11.603, 2012); 2) systematization of constructive and geometric data from the case study through in situ survey; 3) proposal for energy rehabilitation according to the results of the steady-state energy balance analysis; 4) comparative assessment of the base and an improved case of the hygrothermal behaviour of the envelope (IRAM 11.605, 1996) according to EPDA: Passive Strategies for Passive Architectural Design (IRAM 11.900, 2019); 5) energy simulation of the base and rehabilitated cases, through the SIMEDIF 2.0 calculator program (Flores Larsen, 2019) and 6) verification of hygrothermal comfort according to PMV (Predicted Mean Vote) of the thermal zones of the building. This version of the software used for Windows is designed and updated by members of the Non-Conventional Energy Research Institute (UNSA -CONICET). The thermal model with which it operates allows the simulation of the dynamic behaviour of buildings in many premises based on their geometric and constructive characteristics, air renewals, location, orientation and external climatic conditions (Flores Larsen & Lesino, 2001). The software uses weather files in EPW format, which provide detailed weather data and allow for an accurate representation of the weather conditions of the building environment. Previous study on energy simulation carried out with SIMEDIF for the city of Santiago del Estero carried out by the research team is taken as a sensitivity analysis to corroborate that the data are coherent (Ortega et al., 2021). It serves as a tool to simulate the thermal behaviour of buildings and the level of thermal comfort according to the ANSI/ASHRAE 55 standard, which allows estimating the feeling of comfort through the PMV. The analytical method calculates both variables based on the wrapping index, metabolic rate, air velocity, operating temperature and humidity. Therefore, it is predicted that the PMV reflects the average value of the votes cast by a large group of people regarding a seven-level psychophysical scale when subjected to different thermal environments. This scale ranges from: cool (PMV<-2.5), cool (-2.5<PMV<-1.5), slightly cool (-1.5<PMV<-0.5), neutral (-0.5 <PMV< 0.5), slightly warm (0.5<PMV< 1.5), warm (1.5<PMV< 2.5), hot (PMV< 2.5). The comfort

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zone establishes the conditions in which 80% of people, in sedentary or light activity, find the environment thermally accepts.

3. RESULTS

3.1. Geographic and climatic characterization of the site

Figure 1 shows the building of the Faculty of Medical Sciences, located on a separate property from the UNSE headquarters and later. Its location corresponds to the coordinates of: south latitude 27°48'03", west longitude 64°14'57" and altitude 149 meters above sea level. Located in the Capital department, with address Pasaje Sargento Cabral N° 1234, Belgrano neighborhood, 2 km from the city center. This town belongs to the Very Warm Bioenvironmental Zone I and subzone a, with thermal amplitude greater than 14º C, according to the bioenvironmental classification for the Argentine Republic (IRAM 11,603, 1996).

The climate is of the BSh type "Dry semi-arid steppe" according to the Köppen-Geiger climate classification (1936). The winter period is not very significant, as it presents average temperatures higher than 12 °C. On the other hand, the spring, summer, and even autumn seasons present maximum temperature values greater than 34°C and average values greater than 26°C, with thermal amplitudes of up to 15°C. Therefore, this period of time is the longest and is considered the most unfavourable. In turn, the daily global solar irradiation recorded on an average of the last 25 years by NASA (2021) is within the average values identified in the country, oscillating between 2.5 kWh/m2 in the months of June and July, and reaching 7.0 and 6.5 kWh/m2 in the warm months (figure 2). Regarding annual precipitation, it is an annual average of approximately 600 mm (SMN, 2024), where the maximum levels of rain are recorded and distributed between the months of October and March. In figure 2 below, the correlation between these data can be seen by month, since in the months where the highest values of global radiation and precipitation occur, the



Figure 1. Location of the Facultad de Ciencias Médicas- Universidad Nacional de Santiago del Estero, in the Capital of the Santiago del Estero Province- Argentina. Source: self made.

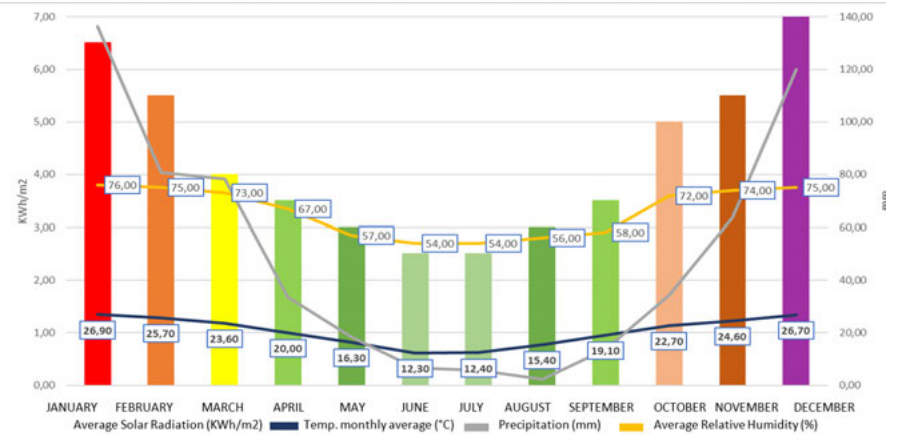


Figure 2. Climatic Data of Monthly average values . Source: self made

effect of these on the increase in temperatures and the percentage of Relative Humidity (% RH), and vice versa, in the months of April to September, the abrupt decrease in global solar irradiation values can be seen along with the decrease in rainfall and correspondingly the decrease in temperature and (% RH).

3.2. Systematization of geometric data of the case study through in situ survey

The building of the Faculty of Medical Sciences CM is a rectangular free-standing volume, whose major-main axis is oriented North (N)-South (S), so the largest surface area of walls is oriented towards East (E) and West (O), which are unfavorable orientations for sunlight in this area (fig. 1). The work, inaugurated in 2019, has been executed with a load-bearing structure of columns, beams and Reinforced Concrete slabs (Hº Aº) with lateral closure of non-load-bearing hollow brick masonry, plastered on both sides. One of the most important aspects of the envelope towards the main façade is that towards the W orientations it has a significant overhang that protects the access sector. Then, towards the SW, the same vertical enclosure also continues, which is of the non-type opaque, that is, simple, colourless glass as a curtain wall. This only has 3 openings per floor, which allow a minimum opening for ventilation, due to the collision with the fixed protections mentioned, which means there is no natural ventilation or renovation. Towards the outside, it has fixed vertical slats of Hº Aº as sunshades, arranged at 45°, however, it does not obstruct solar insolation efficiently. For this reason, in warm months it causes overheating of the interior temperature of the circulation sector, since long-wave solar radiation is trapped in the circulation sector. Towards the opposite front with NE-E-SE directions, there is a gallery that does not adequately protect from solar radiation in the area of openings in classrooms on the ground floor, due to the angle of incidence of the sun during the mornings. The aluminium profile carpentry and simple, colourless glass on the first and second floors do not have solar blocking of any kind (figure 3). With respect to the ventilation of classrooms, although they have openings on the front and back, cross ventilation is not effective due to having fixed panels and opening tilting panels on the opposite front. Therefore, air renewals

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are not adequate, and ventilation is limited. investment of these additional openings to only the entry of natural light. With respect to natural lighting during the mornings, in classrooms it is excessive, it generates a lack of visual comfort since glare occurs due to the reflection of the light beams on side walls, floors, and working planes, and also due to the lack of possibility of darkening, complicates the projections of presentations with cannon and screen in class. It is therefore recommended to add total sun protection against the front. Next, the geometric data of the building is systematized in tables 1 and 2.

FCM Building	Geometric Data	Unit	Measurements
	Area	m^2	2656.88
	Volume	m^3	30022.74
	Height	m	11.30
	Perimeter	m	191.20
	Form Factor (FF)	m^2/m^3	0.62
	Opaque Surface	m^2	1416.12
	Window´s Tranparent Surface	m^2	97.50
	Glass curtain wall´s Tranparent Surface	m^2	262.20

Table 1. Geometric and thermal data of the Building of Faculty of Medicine Science. Source: self made

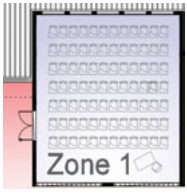
Classroom Nr.1	Geometric Data	Unit	Measurements
	Area	m^2	90.00
	Volume	m^3	315.00
	Height	m	3.05
	Perimeter	m	38.00
	Opaque Surface	m^2	108.90
	Transparent Surface	m^2	7.00

Table 2. Geometric and thermal data of Classroom Nª 1. Source: self made



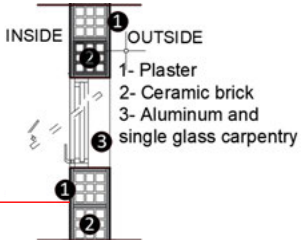


Figure 3-Left. Photographs of the Locals or Therm Zone number 1, 2 and 3 in Faculty of Medical Sciences
Figure 3- Right. Detail of the vertical envelope of classroom Nº. 1. Source: self made

3.3. Energy rehabilitation proposal

The energy rehabilitation proposal is achieved according to the results of the steady-state energy balance analysis according to IRAM 11,900 (2019), passive architectural design strategies (EPDA) by its Spanish acronym. In the first instance, it is possible to determine the level of use of the passive strategies of the base case. From there, the possibilities for improvements are detected and a new percentage value is obtained that indicates the use of passive strategies in the case of improvement. To determine their weighting, a series of characteristic parameters are identified, called Architectural-Construction Resources (ACR), which would reduce energy demand and optimize hygrothermal comfort through the natural conditioning of the building in the summer and winter periods. There are 7 EPDAs: thermal insulation; thermal inertia; sun protection; natural ventilation; solar collection; humidification and environment. The RAC possible to evaluate include: the thermal insulation of the envelope, the thermal inertia of the interior and exterior construction elements, solar protection and collection, orientation, shape and building grouping, natural ventilation, the characteristics of the environment, among others, according to standard (IRAM, 11,900 modif.1). The relevance of each RAC varies depending on the climatic characterization of the area being analyzed and its interrelation with the rest of the RACs applied (Fernández et al., 2020). The evaluation of the base case and the improved one is carried out by contrasting with a theoretical building model. In figure 4, it is observed that the greatest failure in the base case is due to insufficient thermal insulation of the envelope with only 31.1%, followed by 18.8% in solar protection due to its lack, 12.5% due to lack of thermal inertia and 11. 3% incidence in the item, the lack of solar protection with a value of 11.3%, and the inadequate solar collection of 7.7%. In the improved case proposal, these four items highlighted for their greater negative impact on the university building, improve their value by reducing the gap, in relation to the percentages corresponding to the reference model. With the data obtained, the total level of use of the EPDA is assessed, being 35.5% for the base case and perfecting for the improved case up to 55.5% of 100% of the reference value. It should be noted that the retrofitting involves the incorporation of thermal insulation with a thickness of 0.10m on the inside of the walls, and a 0.01m gypsum cardboard rock plate. In addition, figure 4 shows the proposed to change frame windows with a thermal bridge breaker, introducing hermetic double glazing (DVH), which allows improving the level of airtightness and thermal transmittance by 50%, which together with other resources such as solar protection in windows. Finally, it is proposed to increase natural night ventilation in summer to 4 renewals per hour replacing the fixed carpentry on the west front of the classroom with mobile ones.

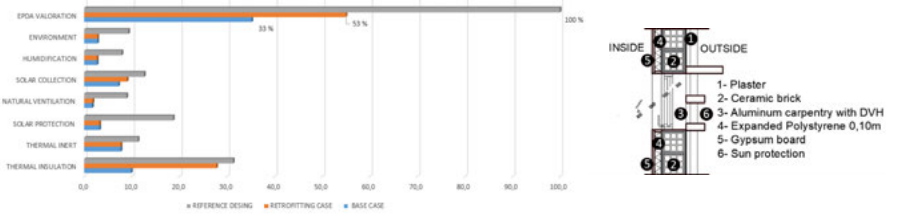


Figure 4-Left. Valuation of EPDA: base case, retrofitting case and reference case on the RAC.
Figure 4- Right. Improved detail of vertical envelope of Classroom. Source:1: self made

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3.4. Comparative Evaluation of Winter and Summer Comfort of Base and Improved Cases

A thermal simulation of the typical classroom is carried out in real conditions of use, to know its behavior in the base case situation and its proposal for improvement, to evaluate the comfort situation in the summer and winter seasons. In the final model, the classroom under study is represented -as thermal zone 1 called local 1- and its adjoining premises, access hall -as thermal zone 2 called local 2- and the rest of the classrooms as thermal zone 3-. The average number of people per classroom is between 40 and 60 students. The activity considered is that of people sitting studying, therefore, the metabolic activity is 1.2 MET and the effective work is 1 MET. The wind speed considered is 0.1 m/s. As for winter clothing, 1.5 CLO is considered and 0.5 CLO for summer. Figure 5 shows the results of the MVP values expressed 24 hours a day over a period of 15 days, in the summer situation. At the top of the figure, the comfort conditions in 3 thermal zones considered in the base case are shown. There it is evident that Local 1, corresponding to Classroom 1, is the most unfavorable, since it presents values higher than 3 on the PMV scale from 7 a.m. to 11 p.m. Likewise, in none of the three zones is comfort present at any time of the day. In the three figures below, the feeling of comfort of the improved shell is presented, where the value considered out of range, according to the PMV for the sensation of heat, is reduced, and the need for thermomechanical cooling support is evident. Figure 6 shows the comfort situation during 15 days of winter. It is detected that in the base case, the sensation of cold is lower than in the improved case, considering the free float without collaboration of the heating system. However, with improved conditions, when heating is used, this situation can conserve the heat generated by the equipment for longer, due to the thermal insulation performance of the enclosure.

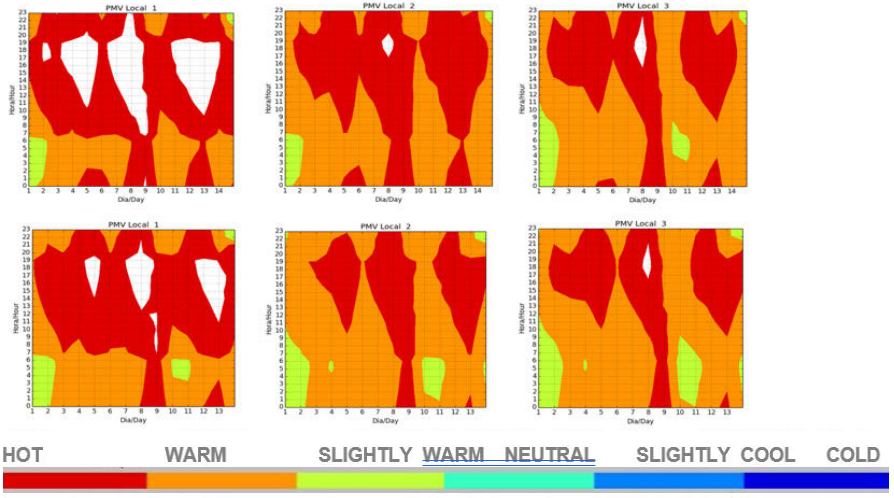


Figure 5. PMV of summer, in base and retrofitting case. Source: self made

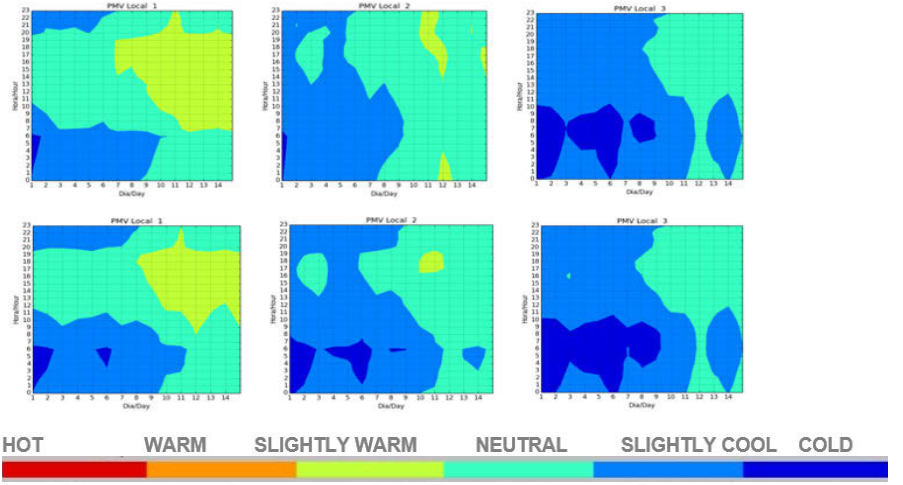


Figure 6. PMV of winter, in base and retrofitting case. Source: self made

In the comparative analysis between the current case and the improved case of hygrothermal conditions, notable differences in thermal comfort and energy efficiency are observed. The study shows that, in its current state, the classroom has deficiencies in terms of ventilation, thermal insulation and solar protection, which generates an unfavorable environment, both in summer and winter. This affects not only the health and well-being of students, but also their ability to concentrate and academic performance, given that the classroom experiences extreme temperatures and inadequate levels of relative humidity, similar to those observed in international and national studies on indoor air quality and thermal comfort in educational buildings. The improvement proposal includes passive strategies, such as the insulation of the envelope, the incorporation of glass with hermetic double glazing (DVH) and improvements in natural ventilation, which increases efficiency in the use of energy resources by 20% compared to the current case. In terms of thermal comfort, the analysis based on the predicted mean voting index (MVP) demonstrates a significant reduction in periods of thermal discomfort, reaching temperature ranges close to the values recommended by the WHO, between 18 and 24 °C, which reduces exposure to adverse cold or heat conditions (Ezratti and Ormandy,2015). This analysis reveals that the use of passive strategies in architecture, such as the proposed use of solar shading and cross ventilation, is essential to ensure a healthy and sustainable learning environment, aligning with previous research in Argentina and other countries on the importance of energy efficiency in educational buildings.

4. CONCLUSION

Regarding the analysis of hygrothermal conditions and thermal comfort in a classroom of the Faculty of Medical Sciences of the National University of Santiago del Estero, it is concluded that the classroom, in its current state, presents inadequate conditions of

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thermal comfort. The thermal envelope has a low adaptation to the climate with a low rate of use of passive strategies of only 35.5%. By implementing the proposal for improvements, the rate of use of passive strategies increases to 55.5%, which contributes to significantly reducing the levels of thermal discomfort during the summer, during daytime hours, where MVP values lower than 3 are recorded compared to values higher than 3 in the base case. This not only allows for the creation of a healthier and more suitable educational environment for learning, but also a reduction in environmental impact by increasing the energy efficiency of the envelope with passive guidelines. It is evident that the improvements implemented are necessary to guarantee adequate and healthy hygrothermal comfort conditions. The technologies used such as insulation and DVH, are obtained in the local environment and, therefore, with good management of the economic funds it is possible to replicate these improvements in the other classrooms of the building and in similar buildings in the national context. This approach contributes to the development of qualitative and quantitative indicators of environments, aligning with international standards of thermal comfort and health, and represents a viable and accessible strategy to promote sustainability in the Argentine educational infrastructure.

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