South American Publishing

SAP Land and Architecture. 2024; 3:103
doi: 10.56294/la2024103

ORIGINAL

Improving thermal comfort in educational environments: an innovative approach

Mejorando el confort térmico en entornos educativos: un enfoque innovador

Jeniffer H. Aitken Gutierrez[1], Carlos Ernesto Gamonal Torres[1], Carlos A. Ordoñez Mejia[1], Sandra X. Fernández Gastelo[1]

[1]Universidad Tecnológica del Perú. Chiclayo, Perú.

Cite as
Aitken Gutierrez JH, Gamonal Torres CE, Ordoñez Mejia CA, Fernández Gastelo SX. Improving thermal comfort in educational environments: an innovative approach. SAP Land and Architecture. 2024; 3:103. https://doi.org/10.56294/la2024103

Publication History
Submitted: 18-05-2023
Revised: 27-09-2023
Accepted: 04-01-2024
Published: 05-01-2024

Corresponding Author
Jeniffer H. Aitken Gutierrez

ABSTRACT

Thermal comfort in educational environments is essential to promote an environment conducive to learning and student well-being. This article presents an innovative approach to improve thermal conditions in classrooms, integrating bioclimatic design strategies, natural ventilation and efficient use of materials. It analyzes how building orientation, the selection of materials with high thermal inertia and the implementation of cross-ventilation systems can contribute to regulate indoor temperature effectively. In addition, the importance of creating spaces that are not only functional, but also promote students' academic performance and emotional health is discussed. Through case studies and empirical data, the impact of these strategies in various educational institutions is evaluated. The results indicate that an improvement in thermal comfort translates into a significant increase in concentration and school performance. This comprehensive approach not only seeks to optimize the physical conditions of the classroom, but also to inspire educators and architects to adopt sustainable practices that will benefit future generations. The research highlights the need to prioritize thermal comfort as an essential component of modern educational design.

Keywords: Thermal Comfort; Educational Environments; Bioclimatic Design; Natural Ventilation.

RESUMEN

El confort térmico en entornos educativos es fundamental para promover un ambiente propicio para el aprendizaje y el bienestar de los estudiantes. Este artículo presenta un enfoque innovador para mejorar las condiciones térmicas en aulas, integrando estrategias de diseño bioclimático, ventilación natural y uso eficiente de materiales. Se analiza cómo la orientación del edificio, la selección de materiales con alta inercia térmica y la implementación de sistemas de ventilación cruzada pueden contribuir a regular la temperatura interior de manera efectiva. Además, se discute la importancia de crear espacios que no solo sean funcionales, sino que también fomenten el rendimiento académico y la salud emocional de los estudiantes. A través de estudios de caso y datos empíricos, se evalúa el impacto de estas estrategias en diversas instituciones educativas. Los resultados indican que una mejora en el confort térmico se traduce en un aumento significativo en la concentración y el rendimiento escolar. Este enfoque integral no solo busca optimizar las condiciones físicas del aula, sino también inspirar a educadores y arquitectos a adoptar prácticas sostenibles que beneficien a las futuras generaciones. La investigación destaca la necesidad de priorizar el confort térmico como un componente esencial del diseño educativo moderno.

Palabras clave: Confort Térmico; Entornos Educativos; Diseño Bioclimático; Ventilación Natural.

© 2024; The Authors. This Open access article is distributed under the Creative Commons Attribution 4.0 license (https://creativecommons.org/licenses/by/4.0), which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.

INTRODUCTION

Thermal comfort is a fundamental aspect that refers to the perception of environmental conditions, such as temperature, humidity, and air speed, and their influence on people's well-being, especially in educational settings. Students in their developmental stage are particularly susceptible to inadequate thermal conditions, which can negatively impact their health and cognitive performance. In the district of Llama, where high temperatures prevail throughout most of the year, the Félix Montenegro Zulueta Primary School faces severe difficulties due to a lack of adequate insulation and the absence of green spaces, exacerbating the adverse thermal conditions. This context motivates research on improving the thermal comfort in this institution, considering the impact of high temperatures on students' daily activities. To address this issue, five specific objectives have been set: first, to analyze the orientation and accessibility characteristics of the school; second, to study the environmental conditions related to temperature and solar perception; third, to evaluate the technological construction factor in terms of form and materiality; fourth, to identify conditioning strategies; and fifth, to investigate cooling strategies applicable in the school context. The research is based on quantitative studies that demonstrate the influence of the physical school environment on learning. Identified that classroom layout and access to green spaces directly affect student behavior and academic performance. Salas et al.[1] used simulation models to demonstrate how air quality and temperature influence student comfort and concentration. Jia et al.[2] conducted a systematic review highlighting the need to integrate thermal comfort with air quality and energy consumption in future research. Miao et al.[3] developed a predictive model that confirms the relationship between air quality and thermal comfort in naturally ventilated classrooms. In addition, a qualitative analysis was conducted by Rocha et al.[4], who reviewed studies on thermal comfort in tropical schools and examined examples of Brazilian institutions that have implemented bioclimatic strategies and sustainable technologies. These strategies include considerations regarding orientation, shape, and building materials that improve thermal comfort, reduce operating costs, and promote environmental education on sustainability. According to information from the WMO, a significant increase in global temperatures is expected in the coming years, making it even more urgent to address these issues. Finally, several studies have adopted mixed methodologies to assess air quality and thermal comfort in educational buildings, concluding that no single solution exists to optimize these conditions. Recent research López et al.[5], Karakas et al.[6], Zhang et al.[7], Aparicio-Ruiz et al.[8], Mechado de Azevedo Correia et al.[9] has shown that natural ventilation combined with architectural elements such as atriums and courtyards is a promising strategy for improving thermal comfort. However, results vary according to geographical and climatic factors, highlighting the importance of considering multiple criteria when designing interventions to improve these conditions.

METHOD

This research project employs a mixed methodology, combining qualitative and quantitative methods to supplement the information gathered and provide a more comprehensive and in-depth view of the situation under study. According to Hamui-Sutton[10], mixed methods use various sources of information combined in different ways to support more comprehensive analyses of the educational issues raised. Research using mixed methodology goes beyond the sum of quantitative and qualitative data. In the process of interfacing between them, the limitations of both are overcome. At the same time, a broader picture is drawn that strengthens the validity of the interpretation of the results. This methodology not only allows for the analysis of statistics and data but also an understanding of the perceptions, opinions, and experiences of the people involved, such as the students and teachers of the Félix Montenegro Zulueta Primary School 1010000 in the village of La Ramada in the district of Llama. The result is a healthier, more welcoming school environment conducive to learning and the well-being of the people who spend more than five hours a day in the school.

Furthermore, the scope of the research will focus on describing the characteristics and conditions of the school infrastructure to assess whether the spaces provide comfort and an adequate environment for both students and teachers at the primary school. This descriptive scope will provide a comprehensive and detailed overview of the quality of the school infrastructure and how it contributes to the learning and working environment. The findings and observations will make it possible to identify areas for improvement and possible interventions to optimize the comfort and functionality of educational spaces to benefit the school community. As Samperi et al.[11] stated, descriptive research seeks to specify important properties and characteristics of any phenomenon being analyzed. It describes trends in a group or population.

Furthermore, the research design of this document will be non-experimental, quantitative, and descriptive since this type of design collects detailed data on the characteristics of spaces at a single point in time without performing experimental interventions or manipulations. This information is analyzed and presented in a way that allows the observed characteristics to be described objectively. From the point of view of Samperi et al.[11], non-experimental research is a watershed for many quantitative studies such as opinion polls, retrospective and prospective ex post facto studies, etc. The research design also has a qualitative form since it exhaustively analyzes the relevant aspects of the Felix Montenegro educational institution temporarily. According to Gallardo[12], qualitative research does not study reality but rather contributes to reality. This involves studying it from the people's point of view and emphasizing the researcher's process of understanding.

According to the research method, existing theories related to comfortable thermal sensation and techniques used to improve educational environments are used. These theories will serve as a fundamental basis for establishing more specific research hypotheses and objectives regarding applying these techniques at the Félix Montenegro Zulueta Primary School 1010000 in the village of La Ramada in the district of Llama. In other words, a deductive method will be used to identify the most appropriate and practical techniques to improve the thermal sensation in the school, taking into account the particular conditions of the place and the specific needs of the students and academic staff, which will allow us to base our recommendations and conclusions on solid theoretical evidence. According to Gallardo[12], deduction is the logical reasoning opposite of induction, which allows particular

conclusions to be drawn from general facts or situations. It operates from the general to the particular.

The population for this research will be the students and teachers of the educational institution, as we are basing our study on the same actors within the context of the study, knowing that the institution has 96 students, six teachers, and six classrooms in use. In this sense, Rocha et al.[4] describe the school space as a territory for multiple actions that guarantee fundamental rights to working families, thus making the quality of this space fundamental to ensuring the universal principles of citizenship.[13,14]

The sample for this research will be 4th, 5th, and 6th grade students, their three classrooms, and six teachers from the Félix Montenegro Zulueta Primary School 1010000 in the village of La Ramada in the district of Llama. This is to obtain a complete and representative perspective of the school community in relation to the infrastructure and learning environment.[15,16]

It should also be mentioned that different research techniques will be used. One of these is direct observation, as we want to describe and report on user behavior with reliable data. We will also use surveys to obtain accurate data, as this information will be essential for the research and the techniques that could be implemented in the school.

The research will use observation sheets as its primary tools, allowing us to collect data on the physical and functional differences found in the Félix Montenegro Zulueta school spaces. We will also use structured questions to obtain specific or closed answers and open-ended questions to allow users to express themselves more freely.[17]

Finally, the analysis technique will initially be observation, which describes and explains behavior with reliable data. Finally, surveys will be conducted to obtain accurate information based on concrete facts. With these combined techniques, we will obtain relevant results and get closer to the reality of the Félix Montenegro Zulueta Primary School (I.E. 1010000) in the village of La Ramada in the district of Llama.[18]

RESULTS

Orientation and accessibility at Félix Montenegro Zulueta Primary School 1010000 in the district of Llama.

Orientation and accessibility



Figure 1. Primary institution 1010000 Félix Montenegro Zulueta satellite view

Note: the figure shows the limitations of the institution and the location of the fourth, fifth, and sixth grade classrooms

In the educational setting, orientation and accessibility are linked to how school facilities are located to optimize natural light, ventilation, and thermal comfort. This ensures that all students have a healthier and more effective learning environment.

Figure 1 shows the location of the 4th, fifth, and 6th-grade classrooms within the boundaries of the educational institution. The figure shows that the 4th and 5th grade classrooms face west, which means they are directly exposed to sunlight in the afternoon. The orientation of the windows favors the capture of indirect natural light during the morning, which is adequate to avoid excessive heat in the early hours of the day. However, due to the orientation of the classrooms, sunlight at midday can cause an increase in temperature, causing discomfort for students and teachers.

The sixth-grade classroom also faces west, and both the general orientation of the classroom and the windows in this direction can expose students to excessive direct sunlight at midday, negatively affecting the comfort of teachers and students.

Teachers

Figure 2 summarizes the questions asked to teachers regarding the impact of classroom orientation on perceived thermal comfort. 100 % of teachers surveyed agree that classroom layout significantly influences indoor temperature during the school day. This reflects unanimous agreement on the importance of orientation for thermal comfort. On the other hand, only 22 % of teachers consider classrooms suitable for avoiding direct exposure to the sun. In comparison, 78 % perceive that the current orientation of classrooms is inadequate for solar incidence, which could contribute to an increase in indoor temperature. This table also shows

that 33 % of teachers consider that classroom access facilitates adequate ventilation; however, 44 % believe this objective is not achieved, and 22 % indicate that ventilation is sometimes insufficient. These results suggest that most teachers perceive limitations in cross-ventilation capacity, which could affect thermal comfort and air quality in the learning environment.

Aspecto Evaluado	Pregunta	Respuestas	Docentes (n)	Porcentaje (%)
Impacto de la orientación en la sensación térmica	¿Considera que la orientación de los salones influye en la temperatura percibida?	Si	9	100%
Ubicación y exposición de los salones al sol.	¿Los salones están bien ubicadas para evitar la exposición directa al sol durante todo el día?	Si	2	22%
		No	7	78%
Percepción de la ventilación en los salones.	¿Considera que el acceso a los salones facilita una ventilación adecuada?	Si	3	33%
		No	4	44%
		A veces	2	22%

Figure 2. Teachers' perceptions of thermal comfort and ventilation in the orientation and accessibility of classrooms at primary school 1010000 Félix Montenegro Zulueta

Note: figure 2 shows the percentage of responses regarding teachers' perceptions

Students

Figure 3 shows that most students (66 %) perceive that their classrooms receive abundant sunlight. However, a significant 91 % prefer to avoid direct exposure to the sun in their study spaces, evidencing a preference for cooler conditions. In addition, 80 % of students report that classroom temperature is higher at midday, indicating heat accumulation at this time of day. These data suggest the need to consider classroom design and ventilation strategies to improve thermal comfort and adapt to student preferences

Environmental factors at the rural school in Llama include temperature, transmittance, and users' perception of sunlight.

Aspecto evaluado	Pregunta	Respuesta	Cuarto	Quinto	Sexto	Total	% Total
Iluminación Solar en los salones	¿Los salones reciben mucha luz del sol?	Si	6(14%)	10(23%)	13(30%)	29	6%
		No	5(11%)	5(11%)	5(11%)	15	34%
Preferencia de Luz Solar en los salones	¿Prefieren tener luz solar en sus salones?	Si	2(5%)	1(2%)	1(2%)	4	9%
		No	9(20%)	14(32%)	17(39%)	40	91%
Percepción del Calor en los salones	¿En qué momento sientes más calor en el salon?	Por la mañana	1(2%)	7(16%)	1(2%)	9	20%
		Al mediodía	10(23%)	8(18%)	17(39%)	35	80%

Figure 3. Students' perceptions of lighting and heat in terms of orientation and accessibility in classrooms at primary school 1010000 Félix Montenegro Zulueta

Note: figure 3 shows the percentage of responses regarding student perceptions

Temperature

In November, an average temperature of 24,7°C was recorded, while the outside temperature did not exceed 26,6°C. Considering that it is recommended to maintain a temperature range between 18°C and 24°C, the temperature inside the school is comfortable for most users. It allows for optimal concentration on academic activities (figure 4)

Temperatura		
Salón	Interior	Exterior
Salón 4°	24.6°C	26.6°C
Salón 5°	24.1°C	
Salón 6°	25.6°C	
Temperatura promedio	24.7°C	26.6°C

Figure 4. Indoor and outdoor temperature of the rooms

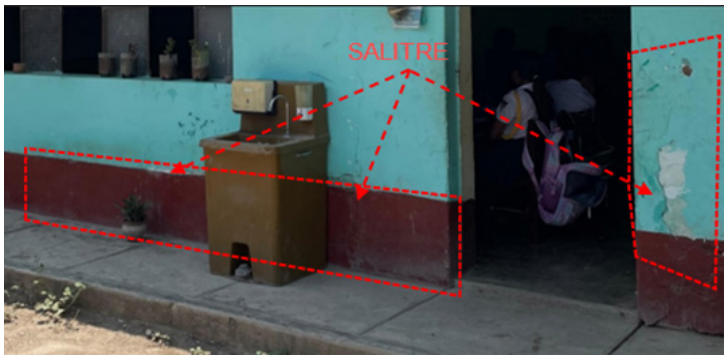


Figure 5. Walls with saltpeter stains

Note: the figure shows the condition of the exterior of the living room, where deterioration of the surfaces is evident due to the influence of external factors and abiotic agents, such as the presence of salt efflorescence

In figure 5, you can see the walls, which have saltpeter stains, indicating accumulated moisture due to exposure to rain and the lack of adequate protection in the construction. This defect is present in the three classrooms investigated. On the other hand, in figure 6, looking more broadly at the school itself, we note that the classrooms are located around the courtyard, which suggests that the noise generated by school activities such as physical education classes directly affects the classrooms, as they are very close and do not have adequate sound insulation.



Figure 6. Central courtyard where school activities take place, with classrooms next to it

Note: the figure shows the single playground where students usually play sports or games during recess

Teachers

Teachers consistently perceive classroom thermal conditions as uncomfortable, especially during seasons with more significant temperature variation. During the summer, 78 % of teachers describe classrooms as "very hot," while 22 % consider them "moderately hot." None of the respondents perceive classrooms as comfortable this season, suggesting a lack of ventilation or cooling measures to mitigate high temperatures. In winter, perceptions are more balanced: 33 % of teachers describe classrooms as "very cold," while 44 % consider them "moderately cold." Only 22 % of teachers perceive classrooms as comfortable this season, indicating that

classrooms may lack adequate insulation to maintain a comfortable temperature during cold weather. Regarding humidity levels, 33 % of teachers consider them to significantly affect student well-being, while 44 % perceive them to have a moderate effect. Only 22 % of teachers believe that humidity does not affect students; this suggests that the presence of humidity is a factor that can influence student comfort and is likely also to have an impact on health and academic performance.

Condición	Respuesta	Total	%
Condiciones térmicas en verano	Muy calientes	7	78%
	Moderadamente calientes	2	22%
	Cómodas	0	0%
Condiciones térmicas en invierno	Muy frías	3	33%
	Moderadamente frías	4	44%
	Cómodas	2	22%
Percepción de los niveles de humedad.	Afecta significativamente	3	33%
	Afecta de manera moderada	4	44%
	Sin impacto	2	22%

Figure 7. Teachers' perceptions of thermal conditions and temperature in summer in the environmental factors of primary school 1010000 Félix Montenegro Zulueta

Note: figure 7 shows the percentage of teachers' responses regarding their perception of environmental factors

Students

As for students, their perception of thermal conditions shows that, in general, they frequently experience heat. The data in figure 8 shows that 89 % of fourth, fifth, and sixth graders reported feeling "very hot" in classrooms, while only 2 % reported feeling "very cold." Furthermore, during the summer, 95 % of students said they feel hotter in the classroom compared to other times of the year.

Aspecto Evaluado	Pregunta	Respuesta	Cuarto	Quinto	Sexto	Total	% Total
Condiciones térmicas en el salón	¿A veces sientes que hace mucho calor o mucho frío en el salón?	Sí, mucho calor	10 (23%)	13 (30%)	16 (36%)	39	89%
		Sí, mucho frío	0 (0%)	2 (5%)	2 (5%)	4	9%
		no	1 (2%)	0 (0%)	0 (0%)	1	2%
Percepción de temperatura en verano	¿Crees que en el verano hace más calor en el salón?	Si	10 (23%	15 (34%)	17 (39%)	42	95%
		No	1 (2%)	0 (0%)	1 (2%)	2	5%

Figure 8. Students' perceptions of thermal conditions and temperature in the classroom at primary school 1010000 Félix Montenegro Zulueta

Note: figure 8 shows the percentage of responses regarding the environmental factors dimension

Construction technology factors according to the shape and materials of the 1010000 Félix Montenegro Zulueta primary school in the district of Llama

Construction technology refers to the tools, materials, and techniques used to construct educational spaces. This factor directly

impacts how students feel and learn in classrooms. In addition, adequate natural lighting and the use of environmentally friendly materials create a pleasant environment and promote student health.Figure 9 shows spaces covered by a roof structure composed of corrugated iron sheets supported by exposed beams. The metal roof, which has additional cladding, suggests deficiencies in terms of the thermal and acoustic comfort of the space. The windows, which appear to be small, provide natural lighting and ventilation, albeit in a limited way, which could affect indoor environmental quality. Figure 9 shows a section of the façade where adobe is the predominant material. Signs of wear and surface detachment can indicate prolonged exposure to the elements without adequate waterproofing. Figure 10 provides a close-up view of the corrugated iron sheets that make up the classroom roof, showing advanced deterioration with visible corrosion on the edges and joints. Furthermore, the classrooms are arranged in a continuous linear structure, which could limit cross ventilation. Finally, the roof is made of metal sheeting, which causes heat to accumulate in the ceiling, affecting thermal comfort, as the heat would be transferred to the interior.



Figure 9. Classrooms 4, 5, and 6 of Primary School 1010000 Félix Montenegro Zulueta
Note: the figure shows the environment in which students receive their classes



Figure 10. Exterior of the 4th grade classroom at Institution 1010000 Félix Montenegro Zulueta
Note: the figure shows the materiality of the exterior of the fourth-grade classroom where students attend classes



Figure 11. Detailed view of the roof in the classroom of Felix Montenegro, 5th grade
Note: the figure shows the deteriorated condition of the corrugated iron roof

https://doi.org/10.56294/la2024103

Teachers

Aspecto Evaluado	Pregunta	Respuesta	Docentes	% Total
Diseño de salones y confort térmico.	¿Los salones están adecuadamente diseñadas para minimizar el impacto del calor o frío?	Si	1	11%
		No	8	89%
Calidad de materiales de construcción	¿Considera que la calidad de los materiales de construcción del colegio es adecuada para garantizar un confort térmico durante todo el año?	Si	1	11%
		No	8	89%
Ventilación adecuada en los salones.	¿Las ventanas y puertas permiten una ventilación adecuada?	Si	2	22%
		No	5	56%
		A veces	2	22%

Figure 12. Teachers' perceptions of classroom design and quality of materials in classrooms at primary school 1010000 Félix Montenegro Zulueta

Note: figure 12 shows the percentage of responses regarding the technological construction factor

As a result, in figure 12 teachers at the primary school consider that classrooms are not adequately designed or built to ensure the thermal comfort of students. Eighty-nine percent believe that the design of the classrooms does not minimize the impact of extreme heat or cold, and the same percentage believe that the construction materials do not promote thermal comfort. Furthermore, only 22 % of teachers consider that the windows and doors provide adequate ventilation, while 56 % say that they do not fulfill this function. This suggests that classroom design, materials, and ventilation need improvement to ensure a thermally comfortable environment.

Students

Regarding ventilation and thermal insulation in classrooms at educational institutions, figure 12 shows that many students (98 %) say that their classrooms have windows that allow air to enter. Regarding the effectiveness of the walls and ceilings for thermal insulation, 82 % of students consider that they provide adequate protection. However, 18 % believe that this protection is not sufficient. In addition, 89 % of students expressed a desire to have window coverings, suggesting a concern about regulating sunlight or temperature in the classroom.

Aspecto Evaluado	Pregunta	Respuesta	Cuarto	Quinto	Sexto	Total	% Total
Ventilación natural en los salones.	¿Tu salón tiene ventanas que se abren para que entre aire	Si	10 (23%)	15 (34%)	18 (41%)	43	98%
		No	1 (2%)	0 (0%)	0 (0%)	1	2%
Eficacia de paredes y techos en aislamiento térmico.	¿Las paredes y el techo de tu salón te protegen bien del calor o frío	Si	10 (23%)	11 (25%)	15 (34%)	36	82%
		No	1 (2%)	4 (9%)	3 (7%)	8	18%
Necesidad de cubiertas para ventanas.	¿Te gustaría tener más ventanas o ventiladores en el salón	Si	10 (23%)	13 (30%)	16 (36%)	39	89%
		No	1 (2%)	2 (5%)	2 (5%)	5	11%

Figure 13. Students' perceptions of natural ventilation, wall and ceiling effectiveness, and the need for roofing in classrooms at primary school 1010000 Félix Montenegro Zulueta

Note: figure 13 shows the percentage of responses regarding the constructive technology factor dimension

In summary, the evaluation of the Félix Montenegro Zulueta school reveals that, despite some successes in its design, there are significant deficiencies in its construction that directly affect the quality of life of the entire educational community. Using inadequate materials compromises the comfort and health of students and teachers, creating a less effective learning environment. To solve these problems, a comprehensive intervention is needed to improve materials, finishes, and training for the staff involved.

DISCUSSION

The current discussion compares research findings on classroom conditions at Félix Montenegro Zulueta Primary School (I.E. 1010000) in the village of La Ramada in the district of Llama with the results of several previous studies. This analysis highlights the importance of the physical environment in the educational process and how environmental conditions influence students' academic performance. First, an analysis of the orientation and accessibility characteristics of the Félix Montenegro Zulueta Educational Institution in the district of Llama revealed that west-facing classrooms optimize natural light in the mornings but generate high temperatures at midday. This negatively affects the thermal sensation, as reflected by 78 % of teachers and 80 % of students who reported thermal discomfort during this time. These findings coincide with Salas et al.[1], who emphasize the need to adjust the orientation and resize windows to improve thermal comfort and reduce the incidence of solar radiation. Likewise, Rocha et al.[4] highlight that deficiencies in orientation can intensify dependence on active cooling systems, which contradicts recommended sustainable strategies.

Likewise, studying the environmental conditions related to temperature, solar transmittance, and user perception allowed us to establish that the average indoor temperature (24,7°C) is mostly comfortable. However, the heat accumulated at midday causes discomfort for 78 % of teachers and 89 % of students, especially during the summer. This situation is consistent with the findings of Zhang et al.[8], who highlighted that semi-open spaces offer a more favorable thermal perception in hot climates. In addition, the humidity problems detected in the school's walls and ceilings reflect the need to improve construction finishes, as suggested by the studies by Rocha et al.[4] and Mechado de Azevedo Correia et al.[10]. Similarly, the analysis of the construction technology factor, considering form and materiality, revealed deficiencies in the institution's design and use of materials. The corrugated iron roofs and adobe walls show wear and tear and poor thermal insulation, which 89 % of teachers perceive as inadequate.

This coincides with the findings of Salas et al.[1] and Rocha et al.[4], who recommend incorporating materials with greater thermal inertia and better bioclimatic design to reduce dependence on mechanical systems and ensure comfort throughout the year. In addition, the lack of adequate cross-ventilation was identified as a significant limitation.

Similarly, when identifying conditioning strategies in the institution, it was found that the existing natural ventilation is insufficient, according to 67 % of teachers who considered adequate airflow not achieved. López et al.[5] and Miao et al.[3] highlight the effectiveness of hybrid strategies, combining natural and mechanical ventilation to optimize both thermal comfort and indoor air quality. These strategies would be applicable in the school context, as their implementation can be adapted to the particular needs of each classroom. On the other hand, the absence of active or passive measures in classrooms was highlighted when studying applicable cooling strategies. Students' perceptions reflect a need for additional coverings (89 %) to control sunlight and temperature. Salas et al.[1] suggest solutions such as night ventilation, shading, and efficient materials to mitigate heat in warm areas. Machado de Azevedo Correia et al.[10] propose adaptive strategies based on thermal simulations. These interventions could be integrated into the institution to address current challenges and ensure a more comfortable environment.

Finally, the research results and their comparison with the state of the art reflect the need to intervene in several aspects of the infrastructure and design of the Félix Montenegro Zulueta Educational Institution. Orientation, building materials, and the lack of conditioning and cooling strategies are critical areas for improvement. Authors such as Salas et al.[1], Rocha et al.[4], Zhang et al.[8], López et al.[5], Miao et al.[3], and Mechado de Azevedo Correia et al.[10] provide approaches and methodologies that can be adapted to address these challenges.

CONCLUSIONS

The analysis of orientation and accessibility at the Félix Montenegro Zulueta Primary School (1010000) reveals significant problems affecting thermal and acoustic comfort, negatively impacting student learning. The 4th and 5th-grade classrooms, which face west, are exposed to direct sunlight during critical hours, causing an increase in temperature and discomfort despite having good visual lighting. Although the average temperature is acceptable (24,7°C) at the rural school in Llama, humidity and lack of sound insulation create an unfavorable environment. Salt stains on the walls indicate problems with accumulated moisture, and environmental noise makes it difficult to concentrate. Although some teachers perceive the classrooms as comfortable, it is clear that interventions are needed to improve these conditions. In addition, the adobe material used in construction has thermal advantages, but it also accumulates excessive heat in enclosed spaces and limits cross ventilation due to its linear distribution. Metal roofs intensify this problem by retaining heat and being deteriorated, which aggravates indoor conditions. The lack of effective strategies to mitigate solar heat gain and improve indoor air quality is critical; therefore, it is suggested that solar protection and natural ventilation strategies, such as cross and zenithal, be implemented. These measures are essential to optimize thermal and acoustic comfort in an educational environment that faces extreme conditions and deteriorated infrastructure. The study highlights the urgent need to improve the school environment through design and construction strategies that ensure a healthy, sustainable, and conducive educational space for academic development. Implementing these interventions will benefit students› and teachers› physical well-being. However, it will also facilitate a more effective learning process, highlighting the importance of a comprehensive approach to educational planning that considers both construction and environmental aspects.

FINANCING
None.

CONFLICT OF INTEREST
Authors declare that there is no conflict of interest.

AUTHORSHIP CONTRIBUTION
Conceptualization: Jeniffer H. Aitken Gutierrez, Carlos Ernesto Gamonal Torres, Carlos A. Ordoñez Mejia, Sandra X. Fernández Gastelo.

Data curation: Jeniffer H. Aitken Gutierrez, Carlos Ernesto Gamonal Torres, Carlos A. Ordoñez Mejia, Sandra X. Fernández Gastelo.

Formal analysis: Jeniffer H. Aitken Gutierrez, Carlos Ernesto Gamonal Torres, Carlos A. Ordoñez Mejia, Sandra X. Fernández Gastelo.

Drafting - original draft: Jeniffer H. Aitken Gutierrez, Carlos Ernesto Gamonal Torres, Carlos A. Ordoñez Mejia, Sandra X. Fernández Gastelo.

Writing - proofreading and editing: Jeniffer H. Aitken Gutierrez, Carlos Ernesto Gamonal Torres, Carlos A. Ordoñez Mejia, Sandra X. Fernández Gastelo.

BIBLIOGRAPHIC REFERENCES
1. Salas-rondón R-S, Rodríguez-Sanchéz A, García-Muñoz J. Estudio de los índices de confort térmico de una escuela en la zona climática de los andes venezolanos. Dyna (Spain). 2019;94(4):363-7. DOI: 10.6036/9024.

2. Jia L, Han J, Chen X, Li Q, Lee C, Fung Y. Interacción entre confort térmico, calidad del aire interior y consumo energético de ventilación de edificios educativos: una revisión integral. Buildings. 2021;11:591. DOI: 10.3390/buildings11120591.

3. Miao S, Gangolells M, Tejedor B. Modelo basado en datos para predecir la calidad del aire interior y los niveles de confort térmico en edificios educativos con ventilación natural utilizando datos de fácil acceso para las escuelas. Journal Of Building Engineering. 2023;80:108001. DOI: 10.1016/j.jobe.2023.108001.

4. Rocha AACND, Nachez JL. School Space and sustainability in the tropics: The case of thermal comfort in brazil. Sustainability (Switzerland). 2023;15(18). DOI: 10.3390/su151813596.

5. López Carreño RD, Tugores Garcias J, Pardo Bosch F. Sistemas y estrategias de ventilación en edificios educativos: identificación y caracterización. Proceedings from the international congress on project management and engineering. 2023:1603-15.

6. Karakas F, Grassie D, Schwartz Y, Gong J, Bagkeris E, Mumovic D, et al. A multi-criteria decision analysis framework to determine the optimal combination of energy efficiency and indoor air quality schemes for english school classrooms. Energy and buildings. 2023;295. DOI: 10.1016/j.enbuild.2023.113293.

7. Zhongjun Z, Zhang Y, Jim L. Confort térmico en espacios interiores y semiabiertos de casas rurales en zonas calurosas húmedas. Building and Environment. 2018;128:336-47. DOI: 10.1016/j.buildenv.2017.10.028.

8. Aparicio-Ruiz P, Onieva L, Escudero-santana A, Muñuzuri J. Confort adaptativo aplicado a edificios escolares y aplicabilidad en el sur de España. Dirección y Organización. 2019;67:30-6. DOI: 10.37610/dyo.v0i67.541.

9. de Azevedo Correia CM, Amorim CN, Santamouris M. Uso de técnicas de enfriamiento pasivo y materiales súper fríos para minimizar la energía de enfriamiento mejorar el confort térmico en las escuelas brasileñas. Energy & Buildings. 2024;312:114125. DOI: 10.1016/j.enbuild.2024.114125.

10. Hamui-Sutton A. Un acercamiento a los métodos mixtos de investigación en educación médica. Investigación Educ Médica. 2013;2(8):211-6. http://www.scielo.org.mx/scielo.php?script=sci_arttext&pid=S2007-50572013000400006&lng=es&nrm=iso.

11. Serway RA, Jewett JW. Physics for scientists and engineers with modern physics. 10th ed. Brooks/Cole Publishing Company; 2019.

12. Gallardo Echenique EE. Metodología de la Investigación: manual auto formativo interactivo. Huancayo: Universidad Continental; 2017.

13. Aldaz saavedra TM. Estudio de las condiciones de habitabilidad de un estudiante: residencia universitaria, en la ciudad de

Lambayeque. 2018.

14. Borgato JB. Asoleamiento en la arquitectura. Editorial UNR; 2014.

15. Givoni B. Climate Considerations in Building and Urban Design. John Wiley & Sons; 1998.

16. Gómez AG, Bojórquez MG, Ruiz TR. El confort térmico: dos enfoques teóricos enfrentados. Palapa. 2007;2:45-57.

17. World Health Organization. Dampness and mould: Health effects and prevention. 2015. https://www.who.int/publications/i/item/9789289041683.

18. Korsavi SS, Alba FV. Operaciones en ventanas y puertas exteriores en escuelas primarias del Reino Unido y sus efectos en la calidad ambiental interior. Building and Environment. 2021;194:108416. DOI: 10.1016/j.buildenv.2021.108416.