Bioclimatic Design as a Strategy for Thermal Comfort in Academic Buildings: A Focus on Caleb University Architecture Building

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ABSTRACT

Thermal discomfort remains a critical challenge in academic buildings located in tropical climates, where high temperatures, intense solar radiation, and humidity significantly affect user comfort and productivity. This study investigates bioclimatic design as a sustainable strategy for enhancing thermal comfort in academic environments, with a specific focus on the Architecture Building at Caleb University, Lagos State, Nigeria.

The research adopts a case study approach, integrating both qualitative and quantitative methods, including site observation, user perception surveys, and environmental assessment of building orientation, materials, ventilation, and surrounding landscape elements. Findings reveal that inadequate shading, poor building orientation, heat-retaining materials, and insufficient integration of passive cooling strategies contribute significantly to thermal discomfort within and around the building.

The study demonstrates that bioclimatic design strategies—such as optimized building orientation, enhanced natural ventilation, integration of vegetation, use of climate-responsive materials, and shading systems—can significantly improve both indoor and outdoor thermal conditions.

The research concludes that adopting a holistic bioclimatic design approach is essential for improving thermal comfort, reducing energy dependence, and enhancing the overall environmental quality of academic buildings in tropical regions.

Keywords: Academic Buildings, Bioclimatic Design, Caleb University, Passive Cooling, Thermal Comfort, Tropical Climate

INTRODUCTION

Background of the Study

Thermal comfort is a fundamental factor influencing the performance, health, and well-being of building users, particularly in academic environments where prolonged occupancy is required. In tropical regions such as Nigeria, buildings are exposed to high temperatures, intense solar radiation, and elevated humidity levels, which often result in overheating and discomfort.

Rapid urbanization and contemporary construction practices have led to increased reliance on artificial cooling systems due to poor integration of climate-responsive strategies. Many academic buildings are designed without adequate consideration of local climatic conditions, resulting in inefficient energy use and uncomfortable indoor environments.

Bioclimatic design offers a sustainable solution by integrating climate-responsive strategies into building design. These strategies include proper building orientation, natural ventilation, shading devices, thermal mass control, and vegetation integration to regulate indoor and outdoor thermal conditions (Olgyay, 1963; Givoni, 1998).

Problem Statement

The Architecture Building at Caleb University experiences significant thermal discomfort due to poor ventilation, inadequate shading, suboptimal building orientation, and the use of heat-absorbing materials. These factors negatively impact students' learning experience, reduce productivity, and increase dependence on mechanical cooling systems.

Aim and Objectives

Aim:
To evaluate bioclimatic design strategies for improving thermal comfort in the Architecture Building at Caleb University.

Objectives

1. To assess the existing thermal conditions of the building.
2. To identify factors contributing to thermal discomfort.
3. To evaluate the effectiveness of existing passive design features.
4. To propose bioclimatic design strategies for improving thermal comfort.

1.4 Research Questions

1. What are the thermal conditions within the Architecture Building at Caleb University?
2. What factors contribute to thermal discomfort in the building?
3. How effective are existing bioclimatic design features?
4. What strategies can improve thermal comfort using bioclimatic design principles?

LITRATURE REVIEW

2.1 Concept of Thermal Comfort

Thermal comfort is a fundamental concept in environmental design and refers to the condition in which occupants' express satisfaction with their surrounding thermal environment. According to ASHRAE (2017), thermal comfort is “that condition of mind which expresses satisfaction with the thermal environment,” emphasizing its subjective nature.

Thermal comfort is influenced by a combination of environmental variables and personal factors. The primary environmental variables include air temperature, relative humidity, air velocity, and mean radiant temperature. These factors interact to determine how heat is exchanged between the human body and its surroundings. For instance, high air temperatures combined with high humidity levels reduce the body's ability to dissipate heat through sweating, thereby increasing discomfort.

In addition to environmental parameters, personal factors such as metabolic rate (activity level) and clothing insulation also play a significant role. For example, individuals engaged in physically demanding activities or wearing heavy clothing are more likely to experience thermal discomfort in warm environments.

Vegetation and landscape design play a crucial role in modifying microclimate and improving thermal comfort. Studies have shown that well-designed green spaces significantly reduce ambient temperatures, enhance user well-being, and improve environmental quality (Brown & Gillespie, 1995; Oke, 1987).

In the Nigerian context, Afolabi et al. (2026) demonstrate that landscape elements such as shaded areas and green infrastructure improve not only thermal comfort but also learning outcomes and community engagement. Similarly, Babamboni et al. (2025) found that access to well-designed urban green spaces enhances user comfort, psychological well-being, and environmental satisfaction.

Bioclimatic Design Principles

Bioclimatic design is an approach to architecture that seeks to create comfortable indoor and outdoor environments by responding intelligently to local climatic conditions. Rooted in the works of pioneers such as Victor Olgyay and Baruch Givoni, this design philosophy emphasizes the use of passive strategies to reduce reliance on mechanical systems and improve energy efficiency.

The core objective of bioclimatic design is to achieve thermal comfort through the optimization of natural environmental resources, including sunlight, wind, and vegetation. Rather than resisting the climate, buildings are designed to adapt to and work with it.

Key principles of bioclimatic design include:

- Building Orientation: Aligning the building to minimize heat gain and maximize natural lighting and ventilation.
- Natural Ventilation: Utilizing wind patterns to enhance airflow and remove excess heat from indoor spaces.
- Solar Control: Managing solar radiation through shading devices, building form, and façade design.
- Thermal Mass Utilization: Using materials that can store and release heat to regulate indoor temperatures.
- Integration of Vegetation: Incorporating landscape elements to provide shading, cooling, and microclimate regulation.

These principles are particularly relevant in tropical regions, where high solar radiation and temperatures demand effective passive cooling strategies. When properly applied, bioclimatic design not only improves comfort but also reduces energy consumption and enhances environmental sustainability.

Building Orientation and Solar Control

Building orientation is a critical factor in determining the thermal performance of a structure. It influences the amount of solar radiation received by different building surfaces and plays a significant role in controlling heat gain and daylight penetration.

In tropical climates, where solar radiation is intense throughout the year, proper orientation can significantly reduce indoor temperatures. Buildings oriented along the east–west axis tend to minimize exposure to low-angle morning and evening sun, which is more difficult to control. By contrast, north–south orientations allow for better control of solar gain through shading devices such as overhangs and louvers.

Solar control strategies are essential in bioclimatic design and include:

- Use of shading devices (e.g., canopies, brise-soleil, louvers)
- Window placement and sizing to reduce direct heat gain
- Reflective or low-emissivity glazing
- Incorporation of vegetation as natural shading

Effective solar control reduces cooling loads, improves indoor comfort, and enhances energy efficiency. In academic buildings, this is particularly important for maintaining comfortable learning environments during peak daytime hours.

Natural Ventilation and Airflow

Natural ventilation is one of the most effective passive cooling strategies in bioclimatic design. It involves the intentional movement of air through a building to regulate temperature, remove heat, and improve indoor air quality.

There are two primary mechanisms of natural ventilation:

- Cross Ventilation: This occurs when air flows through a space from one side to another, typically facilitated by openings such as windows and doors placed on opposite walls. Cross ventilation is highly effective in removing heat and maintaining air movement within indoor spaces.
- Stack Effect (Buoyancy Ventilation): This occurs when warm air rises and escapes through higher openings, creating a pressure difference that draws cooler air into the building from lower openings. This vertical airflow is particularly useful in multi-storey buildings.

The effectiveness of natural ventilation depends on several factors, including:

- Building orientation relative to prevailing wind direction
- Size and placement of openings
- Internal layout and spatial configuration

In academic buildings, adequate ventilation is crucial not only for thermal comfort but also for maintaining a healthy indoor environment. Poor airflow can lead to heat buildup, increased humidity, and reduced occupant satisfaction.

Role of Materials in Thermal Performance

Building materials play a significant role in determining the thermal behavior of a structure. Different materials respond differently to heat, affecting how buildings gain, store, and release thermal energy.

Materials with high thermal mass, such as concrete, brick, and stone, have the ability to absorb heat during the day and release it gradually at night. This property can help stabilize indoor temperatures, particularly in climates with significant day–night temperature variation. However, in consistently hot climates, excessive thermal mass without proper ventilation can lead to heat retention and discomfort.

On the other hand, low thermal mass and reflective materials are effective in reducing heat gain. Light-colored or reflective surfaces minimize solar absorption, thereby lowering surface and indoor temperatures. According to Mat Santamouris (2015), the use of cool materials and reflective surfaces can significantly mitigate heat accumulation in buildings.

Material selection in bioclimatic design should therefore consider:

- Thermal conductivity
- Heat capacity
- Surface reflectivity
- Permeability

By carefully selecting and combining materials, designers can enhance thermal performance and improve occupant comfort.

Microclimate Modification

Microclimate refers to the localized climatic conditions within a specific area, which may differ from the broader regional climate. In the context of building design, microclimate plays a crucial role in influencing thermal comfort in both indoor and outdoor spaces.

Bioclimatic design strategies often focus on modifying the microclimate to create more favorable environmental conditions. One of the most effective ways to achieve this is through the integration of vegetation and landscape elements.

Vegetation contributes to cooling through:

- Shading: Trees and plants block direct solar radiation, reducing surface and air temperatures.
- Evapotranspiration: The process by which plants release moisture into the air, resulting in a cooling effect.
- Wind modulation: Vegetation can direct, filter, or block wind flow depending on its placement and density.

Research by Timothy R. Oke (1987) and Robert D. Brown & Gillespie (1995) highlights the significant impact of vegetation in reducing urban heat and improving thermal comfort.

Additional microclimate modification strategies include:

- Use of water features for evaporative cooling
- Reduction of impervious surfaces
- Incorporation of shaded outdoor spaces

In academic environments, improving the microclimate enhances not only thermal comfort but also the usability and attractiveness of outdoor learning and social spaces.

RESEARCH METHODOLOGY

Research Design

This study adopts a case study research design supported by a combination of qualitative and quantitative methods. The case study approach is appropriate because it enables an in-depth investigation of thermal comfort conditions within a defined spatial and environmental context, specifically, the Architecture Building at Caleb University.

The study integrates building performance assessment with environmental and user-based evaluations, allowing for a holistic understanding of thermal comfort. Unlike conventional studies that focus solely on landscape elements, this research expands its scope to include:

- Building form and orientation
- Indoor environmental conditions
- Passive design features
- Surrounding landscape and microclimate

This combined approach ensures that both indoor and outdoor thermal environments are adequately examined.

Study Area Description

The study is conducted at the Architecture Building, Caleb University, Imota, Ikorodu, Lagos State, Nigeria. The region is characterized by a tropical wet-and-dry climate, with the following features:

- High average temperatures (25°C – 34°C)
- High relative humidity
- Intense solar radiation
- Seasonal rainfall patterns

The study area includes both:

a. Building Components

- Lecture halls
- Studios
- Corridors and circulation spaces
- Offices

b. Surrounding Environment

- Walkways and access routes
- Courtyards and open spaces
- Landscape elements (trees, lawns, shrubs)
- Paved and unpaved surfaces

This dual focus allows for a comprehensive assessment of how building design and outdoor environmental conditions interact to influence thermal comfort.

Data Collection Methods

To achieve the objectives of this study, multiple data collection methods were employed to capture both objective environmental conditions and subjective user perceptions.

Site Observation (Building + Surroundings)

Systematic site observation was conducted to evaluate the physical and environmental characteristics of both the building and its surroundings.

Building Assessment

- Orientation of the building relative to the sun
- Window placement and size
- Ventilation openings and airflow paths
- Shading devices (if any)
- Roof and wall materials

Surrounding Environment Assessment

- Vegetation distribution and density
- Shaded vs exposed areas
- Surface materials (concrete, asphalt, grass)
- Solar exposure patterns
- Wind movement and airflow obstruction

This method helped identify heat-prone zones, ventilation deficiencies, and areas lacking bioclimatic interventions.

Questionnaire Survey

A structured questionnaire was administered to 60 respondents, including:

- Undergraduate students
- Postgraduate students
- Academic and non-academic staff

The questionnaire captured user perceptions of thermal comfort in both indoor and outdoor spaces.

Key Areas Covered:

- Thermal sensation (hot, comfortable, cool)
- Indoor vs outdoor comfort levels
- Airflow and ventilation perception
- Impact of shading and vegetation
- Duration and timing of discomfort
- User preferences and improvement suggestions

This method provided human-centered data, which is essential in thermal comfort studies.

Photographic Documentation

Photographs were used to document:

- Building façade conditions
- Shading availability
- Ventilation openings
- Landscape features
- User behavior in response to thermal conditions

This method provided visual evidence to support analysis and discussion.

Secondary Data

Secondary data sources included:

- Published literature on bioclimatic design
- Climate data for Lagos State
- Previous studies on thermal comfort in tropical environments

These sources provided a theoretical foundation and supported interpretation of findings.

Environmental Assessment (Non-Instrumental)

Due to limited instrumentation, environmental assessment was conducted through observational and descriptive techniques, including:

- Identification of solar intensity zones
- Heat-retaining surfaces
- Airflow direction and obstruction
- Indoor heat accumulation patterns

These observations were supported by existing climate data for Lagos State and relevant literature.

Sampling Technique

A random sampling technique was used to ensure unbiased selection of respondents within the study area. The population for this research is all the users of the department. This includes both undergraduate and postgraduate students, academic staff as well as non-academic staff who have access and use the outdoor and semi-outdoor spaces within the study area.

Data Analysis Methods

The collected data were analyzed using both qualitative and quantitative techniques.

Descriptive Statistics: Descriptive statistics were used to summarize questionnaire responses in terms of:

- Frequencies
- Percentages
- Distribution patterns

This helped identify dominant trends in thermal comfort perception.

b. Likert Scale Analysis: A Likert scale was used to evaluate the effectiveness of environmental and design variables.

Scale	Weight
Very Adequate	4
Adequate	3
Inadequate	2
Very Inadequate	1

Mean scores were calculated to assess:

- Shade availability
- Ventilation effectiveness
- Material performance
- Overall comfort level

c. Comparative Analysis (Indoor vs Outdoor): A comparative approach was used to evaluate:

- Indoor thermal conditions vs outdoor conditions
- Effectiveness of building design vs landscape elements

This helps establish the relationship between architecture and microclimate.

d. Observational Analysis: Findings from site observations and photographs were analyzed qualitatively to identify:

- Design deficiencies
- Environmental challenges
- Opportunities for bioclimatic intervention

Scope of the Study

This study focuses on:

- The Architecture Building at Caleb University
- Its immediate outdoor environment
- Thermal comfort conditions influenced by design and climate

The study does not include:

- Advanced simulation modeling
- Detailed instrumental measurements

3.7 Limitations of the Study

- Lack of advanced measuring instruments
- Limited sample size
- Dependence on user perception
- Time constraints

Despite these limitations, the study provides reliable insights through triangulation of multiple data sources.

RESULTS AND DISCUSSION

Overview of Findings

The findings of this study align with Afolabi et al. (2026), who observed that insufficient landscape integration in school environments leads to increased thermal discomfort and reduced usability of outdoor spaces. Furthermore, Babamboni et al. (2025) highlight that inadequate green infrastructure contributes to heat accumulation and reduced user satisfaction in urban environments.

A majority of respondents reported experiencing high levels of heat, particularly during afternoon periods, which corresponds with peak solar radiation. These findings confirm that thermal discomfort is influenced by a combination of building design deficiencies and unfavorable microclimatic conditions.

Thermal Comfort Perception

Analysis of questionnaire responses indicates that approximately 70% of users perceive the environment as hot or very hot, while only a small percentage reported comfortable conditions. This aligns with findings by Rohinton Emmanuel (2005), who noted that outdoor and semi-outdoor spaces in tropical climates often experience thermal stress due to high solar exposure and humidity.

The high level of discomfort suggests that the existing design does not meet acceptable thermal comfort standards as defined by ASHRAE (2017).

Influence of Building Design on Thermal Comfort

The study reveals that the Architecture Building exhibits several bioclimatic design limitations, including:

- Poor building orientation, resulting in excessive solar heat gain
- Inadequate shading devices, leading to direct solar exposure on walls and windows
- Limited natural ventilation, restricting airflow and heat dissipation
- Use of heat-retaining materials, increasing indoor temperatures

These findings are consistent with the principles established by Victor Olgyay (1963) and Baruch Givoni (1998), who emphasized that building orientation and passive design strategies are critical in achieving thermal comfort.

Role of Surrounding Environment (Microclimate)

The surrounding environment significantly contributes to thermal conditions within the study area. Key issues identified include:

- Insufficient vegetation, resulting in limited shading and cooling
- Large expanses of paved surfaces, which absorb and re-radiate heat
- Poor airflow patterns, caused by spatial arrangement and lack of wind corridors

These conditions contribute to the formation of localized heat zones, consistent with the urban heat island effect described by Timothy R. Oke (1987).

Additionally, the absence of adequate landscape elements reduces the cooling benefits of evapotranspiration, as highlighted by Robert D. Brown and Gillespie (1995).

Integration of Building and Landscape Factors

One of the key findings of this study is that thermal discomfort cannot be attributed solely to either building design or landscape conditions; rather, it is the result of a lack of integration between the two.

The building and its surrounding environment function as a combined thermal system, where:

- Poor building design amplifies heat gain
- Ineffective landscape design fails to mitigate environmental heat

This supports the argument by Mat Santamouris (2015) that effective thermal comfort strategies in warm climates must combine architectural and environmental interventions.

Implications for Academic Buildings

The findings highlight significant implications for academic environments:

- Reduced student concentration and productivity
- Limited use of outdoor and semi-outdoor spaces
- Increased dependence on mechanical cooling systems
- Higher energy consumption and operational costs

These outcomes emphasize the need for climate-responsive design strategies in educational facilities.

Respondent Characteristics;

Category	Percentage (%)
Undergraduate Students	65
Postgraduate Students	20
Staff	15

Thermal Comfort Perception

Response	Frequency	Percentage (%)
Very Hot	24	40
Hot	18	30
Comfortable	9	15
Cool	3	5

Period of Maximum Discomfort

Time	Percentage (%)
Morning	15
Afternoon	70
Evening	15

Factors Contributing to Thermal Discomfort

Factor	Frequency	Percentage (%)
Lack of Shade	45	75
Excessive Sunlight	42	70
Heat from Pavement	40	68
Poor Airflow	33	55

Assessment of Landscape Elements (Likert Analysis)

Variable	Mean Score	Interpretation
Shade Availability	2.3	Low
Vegetation Cooling Effect	2.5	Moderate
Outdoor Comfort Level	2.2	Low

CONCLUSION AND RECOMMENDATIONS

Conclusion

This study reinforces the growing body of research emphasizing the importance of integrating landscape and architectural strategies in achieving thermal comfort. As demonstrated by Afolabi et al. (2026) and Babamboni et al. (2025), sustainable academic environments require a holistic design approach that combines passive architectural strategies with effective landscape planning.

Furthermore, the surrounding environment fails to provide sufficient microclimatic regulation due to limited vegetation and excessive use of heat-absorbing surfaces. The combined effect of these factors results in an environment that is thermally uncomfortable for users.

The study establishes that bioclimatic design is a viable and necessary approach for improving thermal comfort in academic buildings located in tropical climates. By integrating passive design strategies at both the building and environmental levels, it is possible to create more comfortable, energy-efficient, and sustainable learning environments.

Recommendations

Based on the findings of this study, the following recommendations are proposed:

Building Design Improvements

- natural ventilation through cross-ventilation design
- Use Reorient future buildings to minimize solar heat gain
- Incorporate external shading devices such as louvers and overhangs
- Improve high-performance and reflective materials to reduce heat absorption

Environmental and Landscape Strategies

- Increase tree canopy coverage around the building
- Introduce green spaces and shaded outdoor areas
- Replace impermeable surfaces with permeable and reflective materials
- Incorporate water features for evaporative cooling

Integrated Bioclimatic Approach

- Design buildings and landscapes as a unified system
- Incorporate courtyards and transitional spaces for passive cooling
- Enhance airflow corridors within the site

Policy and Design Practice

- Encourage adoption of bioclimatic design guidelines in academic institutions
- Promote sustainable building standards in tropical regions
- Integrate climate-responsive design into architectural education

Contribution to Knowledge

This study contributes to the existing body of knowledge on thermal comfort and sustainable architecture by advancing the understanding and application of bioclimatic design strategies in academic buildings within tropical climates.

Firstly, the research provides a context-specific evaluation of thermal comfort conditions in an academic environment in Nigeria, using the Architecture Building at Caleb University as a case study. While previous studies have largely focused on urban or residential environments, this study extends the discourse to educational facilities, where thermal comfort directly affects learning outcomes, productivity, and user well-being.

Secondly, the study adopts a holistic approach by integrating both building design elements and surrounding environmental factors in the assessment of thermal comfort. Unlike conventional studies that examine either architectural features or landscape elements in isolation, this research demonstrates that effective thermal comfort can only be achieved through the synergistic interaction between building form, materials, ventilation, and microclimatic conditions.

Thirdly, the research contributes by providing empirical evidence based on user perception and environmental observation, highlighting the gap between theoretical bioclimatic design principles and their practical implementation in existing academic buildings. This user-centered approach reinforces the importance of designing spaces that respond not only to climatic data but also to occupant experience.

Furthermore, the study proposes practical and adaptable bioclimatic design strategies tailored to tropical academic settings. These recommendations, such as improved building orientation, enhanced natural ventilation, integration of vegetation, and use of climate-responsive materials, serve as a framework for architects, planners, and policymakers aiming to improve thermal comfort and reduce energy dependence in similar contexts.

Finally, this research contributes to sustainable design knowledge by emphasizing the need for integrating bioclimatic principles into architectural education and practice. Given that the study focuses on an architecture school environment, it highlights the importance of using academic buildings as living laboratories for climate-responsive design.

In summary, this study bridges the gap between theory and practice by demonstrating how bioclimatic design can be effectively applied to improve thermal comfort in academic buildings, particularly within tropical regions.

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