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Research Article

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Examining the Impact and Perception of Thermal Comfort on Student Performance in Architectural Studios

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Abstract

Well-designed and thermally comfortable educational environments significantly enhance academic performance, concentration, and general well-being. The thermal conditions within these spaces are closely linked to students' learning outcomes and health. In tropical Nigeria, rising temperatures, particularly during the dry season, have negatively affected the thermal comfort of educational facilities. Architecture students, who spend considerable time in design studios, often encounter uncomfortable thermal conditions intensified by climate change and insufficient design considerations. This research explored how thermal comfort influences students' productivity and well-being, aiming to enhance students' academic performance and physical, mental, and social health. A structured questionnaire was distributed to 185 architecture students, and 171 responses were collected for analysis. Descriptive and inferential statistical methods were employed to evaluate the data at different research levels. The results reveal that environmental factors such as temperature, ventilation, and humidity impact productivity, performance, and concentration levels. Lower temperatures, especially during the harmattan season, may improve the performance. Ventilation and air quality also affect performance, but the concentration is situation-dependent. The study concludes that insufficient thermal comfort adversely affects productivity, contributing to psychological challenges and decreased student performance. It is recommended that architects adopt design features that ensure proper ventilation and incorporate passive design strategies to enhance the thermal quality of learning spaces.

Keywords Architectural Studios · Performance · Productivity · Thermal Comfort · Wellbeing

Author Note

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Introduction

Globally, thermal comfort significantly impacts individuals' productivity and well-being across various environments, making it a vital aspect of everyday life (Siwczuk et al., 2024). As society evolves and climate conditions change, the importance of thermal comfort in building design and environmental human-environment studies is increasingly recognized. In architectural design studios, thermal comfort is key to enhancing students' performance and well-being, particularly in diverse climates such as those in the Mediterranean, India, and other places (Khambadkone et al., 2022). Thermal comfort encompasses individuals' satisfaction and well-being regarding their thermal surroundings, shaped by elements such as air temperature, humidity, clothing, and activity levels (Fan et al., 2023). The process involves a complex thermoregulation process in humans, which includes both autonomic and behavioral responses aimed at balancing heat produced by metabolism with heat exchanged with the environment (Zeyad et al., 2022).

Recent research has underscored the important role of indoor environmental quality (IEQ) in influencing students' comfort, performance, and productivity within architectural design studios. Thermal comfort has been recognized as a vital element impacting student performance across various ventilation systems and seasons (Ranjbar, 2019; Elnaklah et al., 2023). Studies have indicated that HVAC systems create the most favorable indoor conditions, improving student performance (Ranjbar, 2019). Nevertheless, there is a necessity for tailored thermal comfort guidelines for educational facilities, as comfort levels among students differ between design studios and lecture halls (Elnaklah et al., 2023).

Various indoor environmental quality (IEQ) factors, including noise, humidity, lighting, and air quality, are crucial in shaping students' comfort and academic success (Al-Jokhadar et al., 2023); (Munonye & Ifebi, 2018). Furthermore, physical and administrative elements greatly affect students' productivity in design studios, with thermal comfort emerging as the most significant factor throughout all design stages (Alhusban et al., 2024). These insights highlight the necessity of addressing multiple IEQ aspects to improve students' learning experiences and productivity in architectural education.

In warmer climates, common adaptation strategies include opening windows, wearing lighter clothing, and using fans (Chali et al., 2023); (Munonye et al., 2023). Moreover, Yousef et al. (2016) stressed the importance of monitoring variables such as temperature, humidity, and noise levels to improve comfort in studio settings. Recognizing and applying adaptive strategies tailored to local climate conditions is vital for fostering effective global learning environments in architectural studios. It is essential to investigate the impact of thermal comfort on student performance and well-being in educational contexts, particularly within architectural studios.

Moktan and Uprety (2023) highlighted the significance of thoughtfully designed classrooms with optimal thermal conditions to boost academic performance, focus, and productivity. A study comparing various university hall types revealed that students in design studios and lecture halls experienced different levels of thermal comfort, which influenced their perceived learning effectiveness (Elnaklah et al., 2023). Furthermore, research conducted in primary schools indicated a disparity in thermal comfort perceptions between students and teachers, emphasizing the necessity for customized design strategies to cater to the unique comfort needs of various age groups in warm and humid environments (de la Cruz Chaidez et al., 2022). Understanding and applying suitable passive design techniques can enhance thermal comfort in educational facilities, thereby benefiting students' overall well-being and learning results.

Nonetheless, there is a call for additional research into the relationship between thermal comfort, indoor air quality, and energy consumption for ventilation in educational settings (Jia, 2021). Additionally, the significance of prioritizing students' well-being and performance in designing and operating educational buildings has been stressed (Shan, 2018). Currently, there is a lack of research exploring thermal comfort in architectural studio environments and the adaptation strategies used by occupants in various climates, as noted in studies from India and Turkey (Khambadkone et al., 2022).

This research gap emphasizes understanding the impact of environmental factors on thermal comfort in studio classrooms by researching temperature, humidity, air quality, and airflow in architectural studio classes. The objectives of the study are: (i) to identify the environmental factors that affect thermal comfort. (ii). Determine the environmental factors that affect student performance in the studio (iii). Establish a relationship between thermal comfort and student performance. The research examines the following two hypotheses:

H0: No significant relationship was observed between thermal comfort and performance.

H1: A significant relationship between thermal comfort and performance.

H0: There is no significant relationship between thermal comfort of air quality/airflow and performance.

H1: There is a significant relationship between the thermal comfort of air quality and airflow and performance.

Literature Review

An architectural studio plays a crucial role in architectural education, providing a setting where students can hone their design skills, enhance their critical thinking, and improve their problem-solving abilities (Alfredo, 2002; Shanthi-Priya et al., 2020). It serves as a center for interdisciplinary and intercultural collaboration, supported by advancements in information and communication technologies that facilitate virtual interactions and design activities, overcoming geographical and temporal limitations (Vecchia *et al.,* 2009). The studio environment encourages students to participate in collaborative design processes, enriching their educational experiences and equipping them with modern design practices (Niculae, 2011).

Architecture studios ensure students' thermal comfort and enhance learning outcomes (Ifebi et al., 2020). Research from various locations, including Izmir, Turkey, and Tumkur, India, underscores the importance of adaptive thermal comfort in educational environments (Elnaklah et al., 2023; Pekdogan & Avci, 2022). Multiple studies (Guevara et al., 2021; Khambadkone et al., 2022) have indicated that design studio students often experience different thermal sensations than traditional lecture halls, with temperature fluctuations affecting their perceived productivity and comfort. These findings highlight the necessity of understanding and optimizing thermal conditions in architecture studios to foster environments that promote students' well-being and academic success.

Thermal comfort has a vital role in the performance and productivity of students in educational environments. Research across different contexts underscores the necessity of maintaining ideal classroom thermal conditions to improve learning results. Surveys conducted in Malaysia reveal a positive relationship between thermal sensation and student performance, suggesting that students achieve better results when they feel cooler and when air velocity is appropriately managed (Chong et al., 2023; Mohamad et al., 2022). Furthermore, these studies stress the importance of various factors, including indoor temperature, air velocity, and relative humidity, in fostering an effective learning atmosphere (Mohamad et al., 2023).

Research in Nepal highlights the importance of passive design strategies in enhancing thermal comfort and boosting students' concentration and productivity (Moktan & Uprety, 2023). Additionally, studies in Jordan indicate variations in thermal comfort between design studios and lecture halls, with students noting increased productivity when they feel cooler (Elnaklah et al., 2023). Furthermore, investigations in Nigeria reveal differing perceptions of thermal comfort between children and adults, underscoring the necessity for customized design solutions in warm and humid climates to improve learning environments (Jastaneyah et al., 2023; Munonye et al., (2023). In summary, ensuring suitable classroom thermal conditions promotes students' focus, performance, and overall productivity.

In Nigerian architecture studios, thermal comfort, especially in warm, humid climates, is essential for creating a favorable learning environment for students. According to studies by Okafor et al. (2022), Nwalusi et al. (2022), Elshafei (2021), and Qays and associates (2023) in warm, humid places like Southeastern Nigeria, traditional buildings typically provide higher indoor thermal comfort than modern ones. To lower energy consumption and achieve the highest levels of thermal comfort in African nations, including Nigeria, Verma (2023) highlighted the integration of passive solar systems with bioclimatic architectural solutions. Additionally, building orientation is important for maximizing thermal comfort; for commercial buildings in warm-humid climates like Uyo Urban, Nigeria, the S-N orientation is thought to be ideal (Bello et al., 2022; Gottkehaskamp & Willmann, 2022).

Passive design strategies, such as double skin facades, have been proposed to increase buildings' natural ventilation, internal thermal comfort, and overall comfort levels (Pekdogan & Avci, 2022). Research has also emphasized the significance of incorporating climate-responsive design elements and principles to address the challenges presented by hot and humid climates. Specifically, architects and designers must prioritize functional building requirements for energy-efficient and climate-responsive structures (Adaji et al., 2022; Santos et al., 2022; Obi-George et al., 2024). Nigerian architects and designers must consider these findings when global warming worsens and apply design techniques that improve thermal comfort to produce sustainable and comfortable architectural studio spaces (George et al., 2022).

Active and passive design techniques can be used to create thermally comfortable buildings (Emechebe & Eze, 2019; Ming et al., 2023). However, because of Minna, Nigeria's intermittent power outages, it is challenging to maintain suitable thermal comfort conditions in schools, particularly when active measures like artificial ventilation, cooling, and heating are used. When combined with the current power shortfall, the demand for electricity rises during the hottest dry season, leading to an intolerable indoor temperature (Hachem-Vermette & Yadav, 2023). The optimum method for achieving thermal comfort in educational buildings at the study location under the circumstances is passive design.

To create a comfortable building environment while lowering the need for active design techniques, passive design effectively utilizes climate conditions and natural energy sources like wind gusts and thermal buoyancy (Bulbaai & Halman, 2021). A well-designed building uses air movement for optimal cooling and solar heat gain (Gassar et al., 2021). A building cannot be considered effective if it uses too much energy to provide thermal comfort. On the other hand, zero-net energy buildings are inadequate if they do not provide a comfortable environment for their occupants (Gokce & Touraj, 2024). In hotter climates, passive design techniques described in the literature are essential for improving thermal comfort in architecture studios.

Factors Affecting Thermal Comfort

The concept of thermal comfort describes how people feel about the temperature, humidity, airflow, and heat in indoor spaces. ASHRAE Standard 55 defines thermal comfort as "that state of mind which expresses satisfaction with the thermal environment." This occurs when the heat produced by the body is balanced with the heat it loses or gains to maintain a steady core body temperature. Several factors, such as air temperature, humidity, air movement, and radiant temperature, must be balanced to achieve thermal comfort in buildings. Variables such as time of day, tenant activity, building design, and temperature can all impact these factors. Arowoiya et al. (2024) posited that achieving thermal comfort requires careful consideration of the HVAC system, building materials, room layout, and other elements affecting the interior temperature and humidity.

Both personal and environmental factors influence thermal comfort. Environmental parameters included air temperature, mean radiant temperature, air velocity, and humidity. The degree of clothing and metabolic rate are examples of personal factors. Human thermoregulation is a complicated process involving behavioral and autonomic reactions (Fan et al., 2023). Personalized solutions and energy-efficient designs are the focus of adaptive thermal comfort, which encourages behavioral psychological and physiological acclimation (Luo, 2023). According to Jia et al., (2021), static standards and HVAC control strategies frequently impede indoor thermal comfort in building design, resulting in imprecise assessments of occupants' thermal demands and energy consumption. In contrast, dynamic control strategies can maximize comfort while minimizing energy consumption. Knowing the thermal demands of inhabitants is essential for designing comfortable spaces with less energy waste, particularly in non-uniform thermal conditions where both local and general comfort must be considered (Xiaowen et al., 2024).

Research Methodology

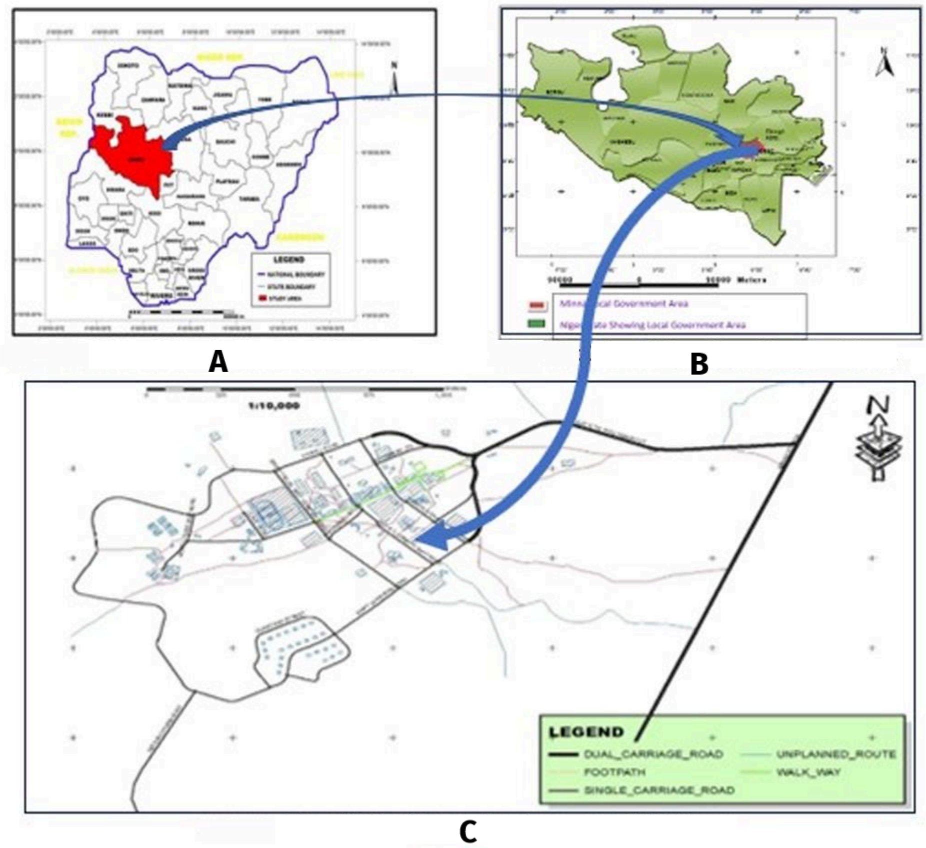
A research technique is essential to any research project involving a methodical strategy for analyzing research problems and gaining knowledge (Swarooprani, 2022). This entails understanding the different procedures researchers take to study their research problems, choosing acceptable methods and techniques, and properly analyzing data. Methodology changes depending on the study subject at hand; therefore, researchers must modify their approach accordingly (Swarooprani, 2022). Conventional methods for gathering primary data in quantitative and qualitative research include questionnaires, documents, and observations. Mixed-method research can provide a full understanding of the effects of thermal comfort by combining qualitative and quantitative research methodologies. Mixed-method research allows for the collection, analysis, and interpretation of both quantitative and qualitative findings from focus groups and interviews.

Study Area

The study area Federal University of Technology is located in a Gidan kwano, which lies southwest of Minna, located along the Minna-Kateregi-Bida Road, between latitude 9 0 26′15′′N; 9 0 37′30′′N and longitude 6 0 23′15′′E; 6 0 28′45′′E. Minna is Niger State capital city and is located in Nigeria's north-central geopolitical zone. It is a huge neighborhood that links the cities of Abuja, Kano, Ibadan, and Lagos. It has a land area of 76,363 square kilometers. It is located between latitude 9.58 and longitude 6.54 east of the Greenwich Meridian (Figures 1A, B and C). Minna was chosen as the study's data collection site because it accurately depicts the North-central Nigerian ecotype. The climatic conditions in Minna is characterized by high temperatures throughout the year, resulting in insufficient thermal conditions for school building occupants. The research area is rather warm and receives moderate amounts and durations of rainfall, creating a typical tropical ecological context. Minna has two distinct seasons: rainy (May to October) and dry (December to March), with transition periods in April and November. While the dry season often peaks in February and March due to unusually hot temperatures, rains usually peak in August. From November to January, the northeast trade wind produces chilly and dry weather conditions (known as the harmattan).

Figure 1

A: Map of Nigeria Showing Niger State. B: Map of Niger State Showing Minna. C: Map of Gidan Kwano Showing Campus FUT Minna



Survey

The study used a quantitative survey approach that included primary and secondary data. The primary data were gathered using a field survey that used a questionnaire to determine the thermal effects in the indoor environment of the studios. Akande et al., (2018) stated that questionnaires can efficiently and effectively sample a wide population. The secondary data collection strategy comprised thoroughly examining and analyzing scientific literature from journals, conferences, Google Scholar, Science Direct, Scopus, and Web of Science. This study uses a survey of students with substantial experience of the thermal conditions of an architectural studio environment in a studio setting. Questionnaires were administered to students who use or stay in architectural design studios to enhance the data's accuracy and validity. The survey was conducted from November to December, and data were collected during school hours from 8:00 am to 4:00 pm. These periods are the peak periods when students use the studios.

Instruments

Questionnaires are simply forms that contain a collection of questions designed to collect data for a survey. In this research, questionnaires were considered the most effective instrument for contacting respondents quickly, economically, and efficiently to collect the necessary data. The surveys were distributed to 200, 300, and 500-level architecture students through architectural design studios. Before distributing the questionnaire, a pilot survey was conducted among the 20 respondents interviewed using a structured questionnaire to ensure that the questionnaire was understandable to the respondents. The study sample was drawn from an architectural design studio at the Department of Architecture. The research assistant administered some of the questionnaires while the researcher administered the rest. Constant surveillance was used to secure respondents' consent to participate in the questionnaires. Furthermore, questionnaires were carefully distributed to respondents in the morning and midday (during school hours) to determine their thermal perception during these periods.

Validity and Reliability of Instruments

Cronbach's alpha was used to verify the instrument. The questionnaire was distributed to students who only used the design studio environment to determine and improve the device's dependability and to collect exact and valid data on their thermal perception of the studio environment. Cronbach's alpha was calculated for each scale using SPSS 23. Table 1 displays reliability statistics. The scales had satisfactory values, and the internal reliability coefficients of the respondents' responses were 0.724. This is considered highly reliable.

Table 1

Reliability Statistics

Cronbach's Alpha	Number of Items
0.724	29

Reliability test

To verify the reliability of the measurement, the scales employed in this study's analysis, the data were analyzed, and reliability tests were carried out. Using Cronbach's standardized alpha (Table 2), the reliability of the instruments was determined to ensure one-dimensionality between the test scales. From the data set, 14 variables were observed because these are the variables with numeric values, and the reliability coefficient of all 14 parameters is 0.878. This implies high data reliability.

Table 2

Reliability Statistics

Variable	Items	Reliability	Interpretation
Thermal Comfort	12	0.822	Highly reliable
Influence of thermal factors on productivity	5	0.788	Highly reliable
Level of Productivity	6	0.534	Moderately reliable
Health Evaluation	6	0.746	Highly reliable
Overall	29	0.724	Highly reliable

Results and Discussion

Sociodemographic Characteristics of Respondents

A total of 185 questionnaires were distributed among architecture students who use the studio using a random sampling method, with 171 returned, with a frequency of 121 male respondents to 50 female respondents (Table 3). The response rate was 92.4% as a result, the sample size is deemed sufficient.

Table 3

Respondents' background characteristics

Variable	Frequency	(Percentage)
Male	121	(70.8)
Female	50	(29.2)
Age		
14-20	49	(28.7)
21-30	118	-69
31-40	4	(2.3)
Level		
100L	15	(8.8)
200L	83	(48.5)
300L	27	(15.8)
500L	46	(26.9)
Hours worked in studio		
1-2 hrs	9	(5.3)
2-4 hrs	51	-2981
4-6 hrs	56	(32.7)
6-8 hrs	34	(19.9)
Greater than 8 hours	21	(12.3)

Table 3 provides a detailed overview of a sample population's demographic and behavioral factors, highlighting their frequency and percentage distribution. The sample is primarily composed of males, with 121 (70.8%) identifying as such and females accounting for 50 (29.2%). This considerable gap points to a male-dominated sample, which may influence research outcomes. The bulk of participants, 118 (69%) were between the ages of 21 and 30. The younger age group of 14-20 years contains 49 members (28.7%), while only 4 people (2.3%) were between the ages of 31 and 40. This age distribution shows a young demographic, which may represent the study's context, which could be focused on a younger group involved in specific activities or environments.

Participants' educational levels were also documented, with second-year students (200L) accounting for 83 individuals (48.5%). First-year students (100L) comprised a smaller section, with 15 (8.8%), while third-year (300L) and fifth-year (500L) students comprised 27 (15.8%) and 46 (26.9%), respectively. This distribution indicates that responders are primarily in the early to mid-phase of their academic careers. Finally, the table shows the hours spent in the studio working, demonstrating that the majority of participants devote 4-6 hours to their job, with 56 (32.7%) falling into this category. 2-4 hours was the second most common response, with 51 individuals (29.8%). Fewer participants report spending 6-8 hours (34 persons, 19.9%) or more than 8 hours (21 individuals, 12.3%) in the studio, with only a few (9 individuals, 5.3%) working for 1-2 hours. This distribution demonstrates a high level of studio work among the participants, which may be relevant to the study objectives. Overall, the data presented in the table provide useful insights into the sample population's demographic traits and behaviors, which are critical for understanding the context and implications of the research results.

Table 4

Evaluate the environmental factors that affect student performance in the studio

Variable	VL	BA	A	AA	VH	Mean score	Decision
Level of sensitivity to temperature	8(4.7)	17(9.9)	59(34.5)	51(29.8)	36(21.1)	3.5	AA
Performance and concentration levels at high studio temperature	61(35.7)	45(26.3)	45(26.3)	10(5.8)	10(5.8)	3.82.197	BA
Performance and concentration levels at low studio temperature	19(11.1)	40(23.4)	62(36.3)	43(25.1)	7(4.1)	2.88	A
Performance and concentration levels in relation to the current ventilation and air quality of the studio	8(4.7)	30(17.5)	84(49.1)	40(23.4)	9(5.3)	3.07	A
Concentration when airflow in the studio is low	48(28.1)	68(39.8)	39(22.8)	11(6.4)	5(2.9)	2.16	BA
Concentration at high humidity	15(8.8)	55(32.2)	66(38.6)	28(16.4)	7(4.1)	2.75	A

NOTE VL= Very Low, BA= Below Average, A= Average, AA= Above Average, VH= Very High, Sample size = 171, Percentage value in bracket.

Table 4 presents an analysis of various environmental factors affecting performance and concentration levels in a studio setting, based on a sample size of 171 participants. Each variable was categorized into five distinct levels of sensitivity or impact: Very Low (VL), Below Average (BA), Average (A), Above Average (AA), and Very High (VH). The mean scores for each variable provide a quantitative measure of the participant's responses, which are further interpreted to determine the overall decision regarding each factor's influence. The first variable assessed was the level of sensitivity to changes in temperature, where a significant majority of respondents (59, or 34.5%) rated their sensitivity as Average (A), leading to a mean score of 3.5, classified as Above Average (AA). This show that temperature fluctuations notably affect the participants' comfort and performance.

In terms of performance and concentration when the studio temperature is high, the results indicate that a substantial portion of respondents (61, or 35.7%) experienced a Very Low (VL) level of productivity, with a mean score of 3.82, categorized as Below Average (BA). This finding highlights the harmful effects of elevated temperatures on cognitive functioning and task performance. Conversely, when the studio temperature was low, the responses showed a more favorable outcome, with 62 participants (36.3%) rating their performance and concentration as Average (A), resulting in a mean score of 2.88. These results shows that cooler temperatures may enhance focus and efficiency in the studio environment.

The analysis of performance and concentration levels with the current ventilation and air quality revealed that 84 respondents (49.1%) rated their experience as Average (A), with a mean score of 3.07. This indicates that adequate ventilation and air quality are crucial for maintaining optimal productivity levels. When examining concentration under low airflow conditions, the results indicate a concerning trend, with 68 participants (39.8%) reporting a Below Average (BA) concentration level, reflected in a mean score of 2.16. This underscores the importance of sufficient airflow in promoting cognitive performance.

The impact of high humidity on concentration levels showed that 66 respondents (38.6%) rated their concentration as Average (A), with a mean score of 2.75. This shows that although high humidity does not severely hinder concentration, it still warrants consideration in the studio environment. The findings from this table illustrate the complex interplay between environmental factors such as temperature, ventilation, and humidity on productivity, performance and concentration levels. The varying mean scores and classifications indicate that while some conditions may enhance performance, others can significantly detract from it, emphasizing the need for careful management of the studio environment to optimize cognitive functioning. This finding agrees with the study conducted by Asaju et al. (2024), in which the result revealed a strong relationship between good studio indoor environmental quality (IEQ) and architectural students' academic performance concerning the season. The study also recommended that a good IEQ should be provided to enhance academic performance.

Table 5

Relationship between air quality/airflow performance and thermal comfort

			Performance and concentration at high studio temperature	Performance and concentration when the studio temperature is low
Kendal tau b:	Heat season indoor air temperature	Correlation Coeff	-.015	-.036
		Sig. (2-tailed)	.811	.572
	Harmattan season indoor air temperature	Correlation Coeff	.044	.154*
		Sig. (2-tailed)	.493	.017
	Use of the mechanical cooling system	Correlation Coeff	-.053	.109
		Sig. (2-tailed)	.405	.085
	Indoor temperature in the studio during a power outage	Correlation Coeff	.044	-.108
		Sig. (2-tailed)	.499	.097
		N	171	171

Table 5 presents a comparative analysis of performance and concentration levels in relation to indoor temperature variations within a studio environment, specifically during high- and low-temperature conditions. The data is analyzed using Kendall's tau-b correlation coefficient, which assesses the strength and direction of the association between two variables. In the context of high-temperature conditions, the correlation coefficients revealed a generally weak relationship between indoor air temperature and productivity and concentration. For the heating season indoor air temperature, the correlation coefficient is −0.015, indicating a negligible negative correlation, with a significance level (p-value) of 0.811, suggesting that this relationship is not statistically significant. Similarly, during the Harmattan season, the correlation coefficient is 0.044, also reflecting a weak positive correlation, with a significance level of 0.493, further indicating a lack of significant association.

When examining the use of mechanical cooling systems, the correlation coefficient is −0.053, which again points to a weak negative correlation, with a significance level of 0.405. These results shows that the use of cooling systems does not have a meaningful impact on the performance and concentration in high-temperature settings. Additionally, the correlation for indoor temperature during power outages was 0.044, with a significance level of 0.499, reinforcing the notion of a weak and statistically insignificant relationship. In contrast, the analysis under low-temperature conditions presents a different picture. The correlation coefficient for the Harmattan season indoor air temperature was 0.154, indicating a moderate positive correlation with productivity and concentration, and this relationship is statistically significant with a p-value of 0.017. This shows that lower temperatures during the Harmattan season may enhance the performance and concentration levels of the flora. Conversely, the correlation for the heat season indoor air temperature is −0.036, which remained weak and statistically insignificant (*p*=.572).

The use of mechanical cooling systems under low-temperature conditions has a correlation coefficient of 0.109, approaching significance with a p-value of 0.085, hinting at a potential positive influence on performance and concentration, although it does not reach conventional levels of statistical significance. Lastly, the correlation for indoor temperature during power outages is −0.108, with a significance level of 0.097, indicating a weak negative correlation that approaches significance but does not confirm a strong relationship. The findings shows that although high temperatures do not significantly affect performance and concentration, lower temperatures, particularly during the Harmattan season, may positively influence these outcomes. The data underscore the importance of temperature management in studio environments to optimize student performance. The above study is in line with the study by Jia et al. (2021) which clearly stated that the advantage of temperature management lower energy consumption and improves thermal comfort to achieve good indoor performance in educational buildings.

Table 6

Relationship between student concentration and airflow

			Productivity and concentration when the current ventilation and air quality of the studio	Concentration when airflow in the studio is low
Kendall's tau_b	The ventilation and air quality of the studio	Correlation Coefficient	.178**	-.074
		Sig. (2-tailed)	.006	.252
	Air flow in the studio	Correlation Coefficient	.161*	-.062
		Sig. (2-tailed)	.013	.334
	Use of the mechanical cooling system	Correlation Coefficient	.185**	.064
		Sig. (2-tailed)	.004	.317
	Air quality when mechanical cooling systems are not in use	Correlation Coefficient	.099	.130*
		Sig. (2-tailed)	.132	.048
		N	171	171

Table 6 presents a statistical analysis of the relationship between various factors related to ventilation and air quality and their impact on productivity and concentration within a studio environment. The analysis employs Kendall's tau-b, a non-parametric measure of correlation, to assess the strength and direction of these relationships.

The first row indicates a significant positive correlation between the ventilation and air quality of the studio and productivity, with a correlation coefficient of 0.178 (*p* = .006). This shows that productivity tends to increase as the quality of ventilation and air improves. Conversely, when examining the correlation between low airflow in the studio and concentration, the coefficient is negative at −0.074, with a p-value of 0.252, indicating no significant relationship.

The second row highlights the correlation between airflow in the studio and productivity, yielding a coefficient of 0.161 (*p* = .013), which again signifies a positive relationship; better airflow is associated with higher productivity levels. However, the correlation with concentration under low airflow conditions was slightly negative at −0.062, with a p-value of .334, showing no meaningful correlation.

The third row assesses the use of mechanical cooling systems, revealing a positive correlation with productivity (correlation coefficient of 0.185, p = .004). This finding implies that the implementation of mechanical cooling systems can enhance the studio performance. In contrast, the correlation between air quality when mechanical cooling systems are not in use and concentration shows a positive coefficient of 0.130 (p = .048), indicating a statistically significant relationship; better air quality in the absence of mechanical cooling appears to support concentration levels.

The sample size for these studies was 171, which provides a substantial dataset for examining these connections. The findings indicate that ventilation and air quality are important factors affecting performance although the effects on concentration are more complex and situation-dependent. These findings highlight the necessity of maintaining adequate air quality and ventilation in studio environments to enhance student performance and focus.

Table 7

Relationship between thermal comfort and performance.

Model		Unstandardized Coefficients		Standardized Coefficients			
		B	Std. Error	Beta	t	Sig.	R square
1	(Constant)	2321	.214		10859	.000	
	ThermalComfort	.108	.077	.107	1397	.164	.107

The results in Table 7 show a regression analysis examining the relationship between the independent variable, Thermal Comfort, and a dependent variable, which is not explicitly stated but can be inferred to be related to overall comfort or satisfaction levels. The first row of the table provides the constant term, which is the intercept of the regression equation. The unstandardized coefficient of the constant is 2.321, with a standard error of 0.214. This indicates that when the independent variable is zero, the expected value of the dependent variable is 2.321. The t-value associated with this constant is 10.859, with a significance level (p-value) of 0.000, showing that the constant is statistically significant.

The second row details the coefficient for the variable Thermal Comfort. The unstandardized coefficient (B) is 0.108, with a standard error of 0.077. This coefficient indicates that for each one-unit increase in Thermal Comfort, the dependent variable is expected to increase by 0.108 units, assuming that all other variables remain constant. The standardized coefficient (Beta) for thermal comfort was 0.107, allowing for comparison across different variables by standardizing the units. The t-value for thermal comfort was 1.397, and the significance level was 0.164. This p-value indicates that the relationship between Thermal Comfort and the dependent variable is not statistically significant at conventional levels (e.g., $p < .05$), suggesting that although there may be a positive association, it is not strong enough to be considered conclusive.

The R-squared value of 0.107 indicates that approximately 10.7% of the variance in the dependent variable can be explained by the independent variable, Thermal Comfort. This relatively low R-squared value shows that other factors not included in the model significantly influence the dependent variable. Overall, although the analysis indicates a potential positive relationship between Thermal Comfort and the dependent variable, the lack of statistical significance and the modest explanatory power highlight the need for further investigation into additional variables that may contribute to the observed outcomes.

Conclusion

This study investigated the effects of thermal comfort on students' productivity and well-being to improve their academic performance and physical and mental well-being. The study objectives were to identify the environmental factors that affect thermal comfort, determine the environmental factors that affect student performance in the studio, and establish the relationship between thermal comfort and student performance. A questionnaire survey approach was adopted and the finding shows 3 key points.: (1) Environmental factors such as temperature, ventilation, and humidity significantly influence productivity, performance, and concentration levels. (2) Although high temperatures do not greatly hinder performance and concentration, lower temperatures, especially during the Harmattan season, can positively affect these aspects. This highlights the need for effective temperature management in studio environments to enhance student performance. (3) Ventilation and air quality are crucial for performance, although their effects on concentration can vary depending on the situation. This research adds to the existing body of knowledge regarding the impact of thermal conditions on learning outcomes and student performance. The study recommends that thermal comfort be considered in building design and construction to create indoor environments that meet the needs of occupants. Ensuring thermal comfort is vital for users' health and well-being. Effective design, construction, and maintenance can reduce energy consumption while providing a comfortable indoor atmosphere. In addition, passive design strategies can enhance thermal comfort while minimizing energy use. These recommendations aim to guide future efforts and design considerations to improve the thermal comfort of learning environments, thereby promoting better productivity and performance among students.

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