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(Research Article)

Evaluating energy consumption, indoor air quality, and student productivity

Zulai Jarmai Baba-Girei [1, *], Binta Fatima Yahaya [2] and Ruth Rakiya Martins [3]

[1] *Nigerian Building and Road Research Institute Abuja.*

[2] *Department of Architecture, Kano University of Science and Technology, Wudil, Nigeria.*

[3] *Department of Architecture, Bingham University, Karu, Nigeria.*

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Abstract

Smart energy conservation research is gaining traction in a variety of industries throughout the world. The current research is projected to cut energy consumption in the construction sector, which has already reached 49% globally and is expected to rise by 2% annually, costing millions of dollars per month. Balancing energy savings with thermal satisfaction is a current difficulty, as most researchers have concentrated on attaining energy savings without reaching the thermal contentment of the occupant, which could pose a health risk to both young and old occupants. To address the problem, we conducted empirical studies with 193 participants in the Northern part of Nigeria, where they were exposed to an indoor temperature of 22°C to determine their thermal environment, choice and comfort votes, viewed and favored control, and overall thermal satisfaction, which will help calculate and define the unused thermal satisfaction thermostat and later.

Keywords: Evaluating; Energy; Indoor Air Quality; Productivity

1. Introduction

Indoor environmental factors have been shown to harm public health, comfort, and productivity [1]. Given that developed nations spend over 80% of their time indoors, and those youngsters are a vulnerable group of people who spend a significant portion of their time in classrooms, school environments are one of the most important indoor areas to ensure children's health, classroom management, and well-being. Recent research has attempted to investigate the subjective experience of IEQ, considering all four major components: IAQ, thermal, acoustical, and lighting environments. Several types of research have looked at enlightenment [2]. Talebi [3] discovered a strong connection between temperature readings and personal thermal condition evaluations, which is supported by the findings of this investigation. According to [4], thermal assessments were reported to be outside the acceptable comfort level of ASHRAE standard 55, and residents perceived permissible setpoint ranges were also outside the acceptable comfort level. Moreover, compared to adults, youngsters were more susceptible to higher temperatures [5]. IAQ, lighting, acoustics, and the thermal environment have all been evaluated in schools, households, and business settings.

In recent years, the research establishment has become increasingly interested in the association between academic achievement and indoor air quality [6]. Several recent studies have demonstrated links between productivity and HVAC ventilation rates [7], but further research is needed. [8] discovered a linear association between breathing rates and student achievement scores; however, a comprehensive explanation of the correlation between the independent variables remained elusive. The research found that learning performance was linked to students' perceptions of the interior environment [9], although HVAC systems and indoor air pollution levels were not included. Besides the IEQ,

* Corresponding author: Zulai Jarmai Baba-Girei; Email: layhamoh@gmail.com
Nigerian Building and Road Research Institute Abuja.

numerous studies [10] have examined the energy efficiency of school buildings, with [11] using a more integrated method to analyze the energy efficiency in connection to students' perceptions of the IEQ.

2. Material and methods

Even though various components of the IEQ have been researched separately in the international literature, no holistic method integrating all its pylons has yet been published. The goal of this study is to analyze the entire IEQ of classrooms, which includes monitoring, students' perceptions, health consequences, performance evaluation, and energy auditing. The campaign was run in elementary schools as an experiment. The inspection occurred during the summer season to analyze pollution concentrations and students' perceptions in an available mode of the school buildings because temperature and relative humidity variances from a compressed air conditioning system would affect pollutants' natural climate fluctuations and students' perceptions.

The term "free-running mode" refers to a state in which the building's heating and cooling systems are turned off. During the observation period, important IEQ metrics such as air contaminants, ventilation rates, and comfort conditions were measured. Previously, the methods for IAQ observations were published in detail, as well as a description of the sample site [12]. The primary features of the schools, as well as the precise days of measurement, are summarized in the table below (Table 1). It is worth noting that all the schools have wall insulation and double-paned windows with an aluminum frame. There was no roof insulation in any of the schools. [9] observed in a previous publication of the same research that ultrafine matter contents were notably high in schools utilizing chalkboards, whereas VOC levels were higher in classrooms using marker whiteboards.

Table 1 Participant and their college

School	No of students	Aircon	Fan
Adamu Sulemain	145	3	7
Magawata	110	3	7
Elm College	223	5	9
Amry Academy	197	7	7
Kalif College	134	2	13
Utama Institute	202	7	8
Zara Academy	*103*	3	8
Shiafa University	124	2	14
Dawan College	143	1	10
Alison Academy	123	2	8
Pine College	329	4	5
Oak Institute	153	2	11
Total	**1986**	**908**	**90**

3. Measurement Strategy

Simultaneous observations of ventilation rates, carbon dioxide (CO_2), temperature, and humidity were made to define the indoor comfort of the selected schools accurately. Indoor air and several parameters were also observed. The results [13] matched the description of the assessment equipment used to capture the variables as well as the measurement ranges in a prior article [13].

Aside from screening, the experimental program included a survey questionnaire for students to subjectively evaluate the IEQ of the classes. There were three sections to the questionnaire: The pupils were requested to provide personal details such as their age and gender in the first part. They were required to determine the IEQ settings (IAQ and thermal comfort) of their respective classrooms at that specific moment in the second portion. As indicated in Appendix E of the ASHRAE 2010 CBE Occupant questionnaire, a 7-point response scale was supplied for the bulk of the concerns. Fanger's

7-point thermal sensitivity scale was used to record responses to thermal feelings [14]. Clear answer questions were used to address SBS symptoms. Participants were given the questionnaires once a day at nearly the same rate and allowed 10 minutes to complete them.

A record of 193 participants participated in the study, and 665 surveys were gathered in total since some participants filled out the survey more than once, depending on the number of days the survey was open at each school (Table 2). All of the kids that participated in the study were 11 years old [15]. the participant answer is based on the ASHRAE scale presented in Figure 1.

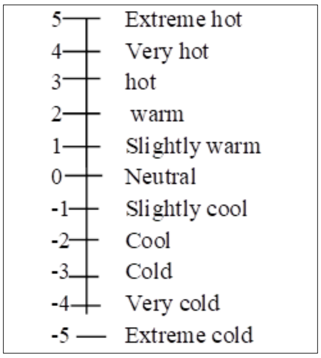

Figure 1 ASHRAE Thermal Sensation Scale

Researchers employed the RayMan application (https://www.urbanclimate.net/rayman/) to compute PET, PMV, and PPD to determine the thermal satisfaction index based on respondent comments. Each PET index, variation of thermal sensation frequency (ASV), and participant thermal satisfaction were generated as a sample in Table 1 at a specific time (morning, afternoon, and evening).

Table 2 Student Perception on Thermal Comfort Based on ASHRAE Standard

Time	Temperature (^{0}C)	Humidity	CO2	PET	Thermal perception	Grade of physiological stress
9:20-am12:00pm	28	29	10671	1	Slightly warm	Warm stress
12:30pm-:00pm	31	32	22901	0	Neutral	Comfortable
6:00pm-8:00pm	25	32	23905	-2	cool	Slight cold stress
1200:am-5:30am	24	25	21998	-3	cold	Moderate cold stress

Table 1 shows the temperature indexes for the predicted mean vote (PMV) and physiological equivalent temperature (PET) for various degrees of thermal awareness caused by individual physiological stress. The participant's profiles were also categorized according to their condition of belonging. Elm College accounted for 39%, Utama Institute accounted for 30%, and Pine College accounted for 31%.

Even though individuals' life of the locals are subjected and acclimated to high temperatures (thermal sensation), 193 percent of participants reported feeling cold after 10 minutes of air-conditioning operation at 22°C and 20 minutes at 27-30°C. It is because individuals' impacts on the native are exposed and acclimated to high temperatures (thermal sensation) (see figures 2 and 3). The individual influence of psychological viewpoint is mostly responsible for this contentment and warm sensation. When we repeated the experiment at the same temperature, we received comparable results. However, air conditioners that are directly exposed to sunlight take a substantially longer time to stabilize the room and result in thermal segregation. In such conditions, participants had a predilection to request a lot of time, particularly in the afternoon when the outside temperature was around 34°C, which resulted in a fluctuation in determining correct thermal satisfaction and demonstrated a thermal sensation of "warm," which we tried to avoid as much as possible.

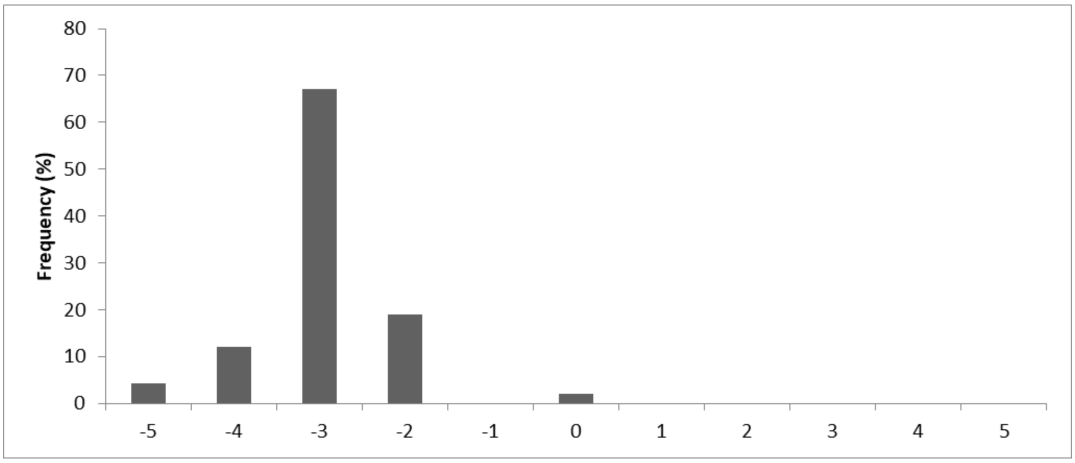

Figure 2 ASV Frequency of participant

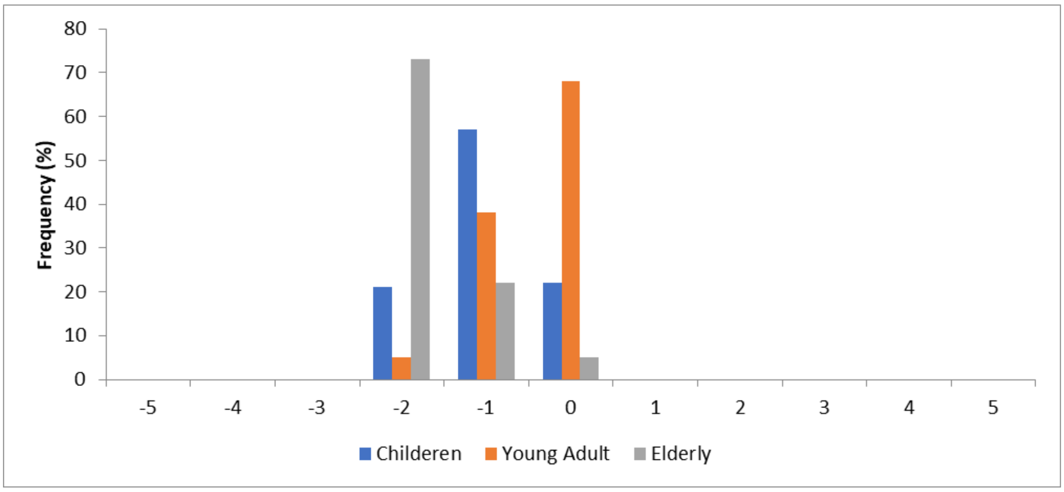

Figure 3 Thermal Preference frequency of participant based on age group

Figure 3 depicts the frequency of Actual Sensation Votes (ASV) over time and analyzes ASV concerning age group (21 percent), (5 percent), and (73 percent) respectively do not feel comfortable at 22°C in the morning and want it to be warmer, while in the afternoon, 57 percent, 68 percent, and 5 percent felt comfortable when the temperature is at 22°C in the same vein 22 percent, 38 percent, and 5 percent felt comfortable when the temperature is at 22°C in the same vein In general, the majority of participants prefer to leave during the day when the indoor temperature is 22°C and do not want to adjust the temperature frequently.

Based on the above data, it is essential to identify and classify the range of temperature comfort values for each vote sensation, as shown in Figure 3, which depicts PET data that has been grouped based on ASV, concerning total participant and age group variation, to be ideal at 21-28°C thermal comfort, with a median value of 24°C. This means that optimal PET levels are higher than those previously established in [15; 16].On the other hand, younger adults exhibit greater tolerance to heat, with neutrality for PET values ranging from 25.1 to 30°C and a median value of 26.5°C, according to the results of the age category study.

4. Conclusion

In past years, the world has worked hard to address the problem of energy scarcity, and computer systems have made significant contributions to this endeavor. Recent HVAC system research has centered on proposing solutions to minimize energy consumption while maintaining occupant thermal satisfaction, which is an important part of smart home design. We performed a thermal comfort demographic survey in the schools of Northern Nigeria based on their age group at an interior temperature of 22°C since individual thermal satisfaction varies depending on their demographic location and ages. This would assist us in determining the best thermal satisfaction temperature preference of residents in the area. This might assist us in determining the best thermal satisfaction temperature preference of residents in the area. This allows us to model and design a bespoke control that provides a comfortable and healthy indoor temperature environment.

This is because creating a smart HVAC control system without considering thermal comfort and age can pose major health risks. Younger adults can tolerate cooler temperatures, which are considered a treat for elderly people since their bodies are less able to limit the amount of heat they lose and are poor at producing their heat. The stress created by the increased requirement to circulate blood to the extremities to cool down is too much for elderly people to handle, and the increased possibility of pre-existing cardiovascular and pulmonary disorders that develop with age might raise the risk of complications.

Compliance with ethical standards

Acknowledgments

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Disclosure of conflict of interest

This manuscript has no conflict of interest among the authors.

References

[1] Acquaah Y, Steele JB, Gokaraju B, Tesiero R, Monty GH. Occupancy Detection for Smart HVAC Efficiency in Building Energy: A Deep Learning Neural Network Framework using Thermal Imagery. Paper presented at the 2020 IEEE Applied Imagery Pattern Recognition Workshop (AIPR). 2020.

[2] Li X, Chen Q. Development of a novel method to detect clothing level and facial skin temperature for controlling HVAC systems. Energy and Buildings. 2021: 239.

[3] Talebi A, Hatami A. Online fuzzy control of HVAC systems considering demand response and users' comfort. Energy Sources, Part B: Economics, Planning, and Policy. 2020; 15(7-9): 403-422.

[4] Javed A, Larijani H, Ahmadinia A, Gibson D. Smart Random Neural Network Controller for HVAC Using Cloud Computing Technology. IEEE Transactions on Industrial Informatics. 2017; 13(1): 351-360.

[5] Peffer T, Pritoni M, Fierro G, Kaam S., Kim J, Raftery P. Writing controls sequences for buildings: from HVAC industry enclave to hacker's weekend project. 2016.

[6] Serra J, Pubill D, Antonopoulos A, Verikoukis C. Smart HVAC control in IoT: energy consumption minimization with user comfort constraints. Scientific World Journal. 2014; 161874.

[7] Brager G, Zhang H, Arens E. Evolving opportunities for providing thermal comfort. Building Research & Information. 2015; 43(3): 274-287.

[8] Kontes G, Giannakis G, Horn P, Steiger S, Rovas D. Using Thermostats for Indoor Climate Control in Office Buildings: The Effect on Thermal Comfort. Energies. 2017; 10(9).

[9] Luo M, de Dear R, Ji W, Bin C, Lin B, Ouyang Q, Zhu Y. The dynamics of thermal comfort expectations: The problem, challenge, and implication. Building and Environment. 2016; 95: 322-329.

[10] Mishra AK, Loomans MGLC, Hensen JLM. Thermal comfort of heterogeneous and dynamic indoor conditions — An overview. Building and Environment. 2016; 109: 82-100.

[11] Salamone F, Belussi L, Danza L, Ghellere M, Meroni I. An Open Source "Smart Lamp" for the Optimization of Plant Systems and Thermal Comfort of Offices. Sensors (Basel). 2016; 16(3).

[12] Brennan C, Taylor GW, Spachos P. Designing learned CO-based occupancy estimation in smart buildings. IET Wireless Sensor Systems. 2018; 8(6): 249-255.

[13] Chen Z, Masood MK, Soh YC. A fusion framework for occupancy estimation in office buildings based on environmental sensor data. Energy and Buildings. 2016; 133: 790-798.

[14] Aliero MS, Qureshi KN, Pasha MF, Jeon G. Smart Home Energy Management Systems in the Internet of Things networks for green cities demands and services. Environmental Technology & Innovation. 2021; 22.

[15] Aliero MS, Qureshi KN, Pasha MF, Ghani I, Yauri RA. Systematic Mapping Study on Energy Optimization Solutions in Smart Building Structure: Opportunities and Challenges. Wireless Personal Communications. 2021.

Authors Short Biography

	**Zulai Jarmai Baba-Girei** is a chartered Architect since 2012 and a Principal Research officer working with the Nigerian Building and Road Research Institute (NBRRI), a Government Agency saddled with the responsibility of researching into but not limited to affordable construction techniques, affordable and available construction materials, local contents, solutions to housing issues as well as providing solutions to the housing collapse. Zulai's research interest is inclined towards sustainability, housing Solutions, achieving thermal comfort by optimizing energy efficiency, and reduction of carbon footprints to name a few.
	**Arc. Binta Fatima Yahaya** is currently a lecturer at the Kano University of Science and Technology, Wudil since 2001 till date. She is a member of Nigeria Institute of Architects and a member of the Association of Architectural Educators of Nigeria, and Community service and University Responsibilities: She is a recipient of many awards including the 2019 World Women Day Award, by Her Excellency, the Wife of Kano State Governor, for Outstanding Contribution to the profession of Architecture in Kano State.
	**Ruth Rakiya Martins** Current research interest: Architectural education, thermal comfort, space planning, and design. M.Sc. Architecture - 2007 to present.