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Thermo-Hygrometric Comfort of Naturally Ventilated Classroom Building as a Function of the Openings Positioning and Orientation

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Abstract The basic functional requirement of a classroom environment suggests a safe, delightful and relaxing place for the learners' physical and psychological well-being and vigor such that there will be an aligned expression of satisfaction with the thermal environment. This study assessed the operational thermal comfort of naturally ventilated one-side-window oriented classroom building in Abeokuta, Ogun state, Nigeria using objective and subjective research approaches. The objective research technique involved the use of standardized measurement devices in the assessment of associated environmental factors which were relative humidity, airflow rate, ambient and mean radiant temperatures. The human factor aspect of thermal comfort was subjectively assessed using a questionnaire structured on ASHRAE scale. The measurements were taken at the height of 130 cm at the time intervals of 7:50 – 8:30 am (morning session) and 2:20 – 3:00 pm (Afternoon session) from the month of March 2016 through to February 2017, Mondays to Fridays, excluding days of any form of holidays. The descriptive statistics of the environmental factors data obtained showed that the indoor environment of the assessed classrooms was warm and stale with an average ambient temperature range of 29.37 - 30.08 ℃, mean radiant temperature 29.24 - 31.28 ℃, relative humidity 67.81 - 68.99 % and wind speed 0.022 - 0.037 m/s. The multiple linear regression analysis gave an *R*-value of .943 with .889 chances that the average ambient temperature of the classrooms will be affected by time-invariants and microclimate variables which was an indication of good level of prediction. The human factors of the thermal comfort observed a variation between the perceived and the preferred thermal sensation with respect to the time of the day and seasons which was unsatisfactory for the teaching and learning process.

Keywords: Thermal comfort, mean radiant temperature, ambient temperature, airflow rate, relative humidity

1.0 Introduction

Physical classroom environment as part of the students' environment is a function of the structural design and mode of construction of the building. The most fundamental design choice in the building's orientation improves and advances designs for better performances (Azodo, 2017). The fundamental features of classroom building environment and its structure is described in terms of capacity, form, and openings (Yacan, 2014 and Wahab, 2015). The needs of an educational building for instance, prior to implementation are determined before designed and built to meet already determined needs (Wahab, 2015). This implies that buildings are meant to basically provide and maintain a comfortable indoor environment at thermal equilibrium with the surroundings for human activities and aspirations (Gallardo et al., 2016 and Croome, 1991). This explains why comfort issues should always be considered a major role in the design stage of building for the maximal daily operation of the buildings.

Thermal comfort is a conceptual whole made up of complicated and related parts, and it is partly subjective. It essentially integrates human, environmental and contributing factors (Wahab, 2015 and Gado and Mohamed, 2009, Szokolay 1985, De Dear et al., 1991 and Mors, 2010). Broadly speaking, actual operating conditions with variable elements or parameters such as air temperature, air humidity, relative airflow rate, mean radiant temperature, thermal insulation of clothing, physical activity, person's age, gender, food, drink, body shape, subcutaneous fat, colour of internal surfaces and lighting system defines the thermal comfort of an indoor environment (Szokolay 1985, Chenvidyakarn, 2007, Gado and Mohamed, 2009 and Majewski et al., 2017). An individual's physical and psychological well-being and vigor in a pleasing environmental condition express satisfaction with the thermal environment, the state of physical and mental well-being of the individual (Hyde, 2000, Ho et al., 2009 and Pino et al., 2012). Although individual's adaptive behavior can be very versatile having the capacity to adapt to wide variations in their physical environment while continuing to function, their performance, productivity, and efficiency do vary according to the conditions in their immediate environment (Bradshaw, 2006; Akande and Adebamowo, 2010). For the classroom environment to meet up with the basic function which among other things is learning, it should be a delightful and relaxing place to learn, safe, with lots of natural light and fresh air. Benefits associated with comfortable thermal environment found in the literature include physical and psychological wellness, the relative better health of occupants, increased attentiveness and fewer errors, increased productivity and reduced rates of absenteeism (Bradshaw, 2006 and Marino et al., 2016).

The human body metabolizes continuously which require heat rejection from the body in order to maintain thermal equilibrium. Consequently, this essentially maintains a constant normal internal body temperature of about 98.6°F (37.0°C) (Bradshaw, 2006). Should the core body temperature decrease or increase by more than about one degree Celsius, either hypothermia or hyperthermia respectively set in (Alder, 1999). Therefore, for an individual to remain healthy, the heat loss must be maintained within a very narrow range of body temperature at a controlled rate (not too fast or too slow). If heat loss is as a result of combined effects of conduction, convection, radiation, and evaporation owing to the environmental condition, the body's rate of heat production, the excess heat must be stored in body tissue. But body heat storage is always small because the body has a limited thermal storage capacity. Therefore, as its interior becomes warmer, the body reacts to correct the situation by increasing blood flow to the skin surface and increasing perspiration (Bradshaw, 2006). As a result, body heat loss is increased, thereby maintaining the desired body temperature and balance (Bradshaw, 2006).

Thermal discomfort in an academic or educational building has the tendency to create unsatisfactory conditions for the teaching and learning process (Bradshaw, 2006). This is often manifested in the learners' attentiveness, concentration, efficiency, productivity, and performance reduction (Bradshaw, 2006 and Wahab, 2015). Prescott (2001) stated that students in thermal discomfort environment are vulnerable to hyperthermia also known as heat stress. Heat stress deals with a combination of air temperature, air movement, radiation, humidity, clothing as well as behavior which induces a physiological inability of the body to maintain its temperature within limits that permit normal physiological performance (Aynsley, 1996). This thermoregulation failure of the body system that occurs when more heat is absorbed or produced by the body than it dissipates can negatively influence an individual learning capacity (Bradshaw, 2006). The higher the activity level one is subjected to, the more heat such a person will produce. If the heat produced by the body becomes too much, sweating happens, which causes discomfort (Havenith et al., 2002).

Just as stated earlier in this study that thermal comfort has been found to be a combined effect of many complicated and related parts. However, air temperature is considered an indicator of thermal comfort with regard to the environmental and personal factors (Nevin, 2003). That's why most times air temperature is considered the main design parameter in building construction so that energy exchange between the occupants and the surroundings can be an effortless adaption to the prevailing climatic condition for a comfortable and conducive internal and external environment for its inhabitants (Herrington and Vittum, 1977 and Akande and Adebamowo 2010). In a literature (Bradshaw, 2006), it was found that thermal performance of a building is liable influenced by the building's ability to modify the prevailing outdoor climate to a unique indoor environment. It then makes factors such as shape, orientation, location, absorption of solar radiation, window to wall ratio and materials be necessary to feature when considering the functional adequacy of any building space and the suitability of the built environment, contribute to the way buildings are able to respond to their external environment (Bradshaw, 2006 and Adunola, 2015). Additionally, orientation, window placement, and spatial organization affect the natural ventilation and solar radiation reception ability of a building (Bradshaw, 2006). Heat gain through the window openings accounts for 25 - 28% of the total heat admitted into the indoor space (Al-Tamimi, 2011). Therefore, in other to minimize solar admittance and at the same time maximize ventilation in an indoor space, buildings orientation should be an imperative issue for interception of prevailing winds and face the direction of the strongest solar radiation (Bradshaw, 2006). The result is the achievement of effective ventilation while thermal impact from solar radiation is minimized (Koranteng and Abaitey, 2010). According to Wahab (2015) buildings constitute a substantial percentage of most educational institutions' assets, user needs, and operating costs. The performance level of this resource is therefore very critical to educational effectiveness (Wahab, 2015). This form the conceptual basis of this study as it quantifies the thermal comfort of students in one-side-window oriented classroom building structures in Abeokuta, Nigeria.

2.0 Materials and Methods

The classroom building environments assessed were on the same location, having same window placements as well as orientation (sun path). The classrooms arrangement is linear viewed from the building design. The fenestration is such that the windowless side faces the east while the windowed side faces the west. The building is a bungalow consisting of offices, library, laboratory and classrooms, however only five classroom were assessed in this study (Figure 1). There were no trees shading effects on the outdoor environment. The orientation scenario of the study site location effect on the classroom building is solar radiation on the windowless side (East facing) morning hours due to sun rise and in the afternoon at the windowed side due to sun set. The various dimensions of the studied classrooms are shown in table 1. The school in which the study was conducted is located in Abeokuta, Ogun state. The geographical of study location is of wooded savanna with the coordinate of 7° 9' North latitude and 3° 21' East longitude (Hoiberg, 2010). The climatic condition of Abeokuta are average ambient temperature 28°C, average relative humidity 74%, wind speed ranges from 2.9 - 4.0 m/s, and annual rainfall 750 mm (Ajayi et al., 2017). The elevation of Abeokuta is 66 meters above sea level.

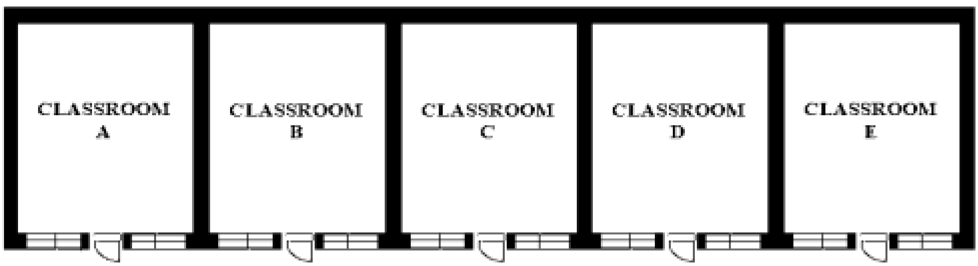


Figure 1 The diagrams of the classrooms assessed

Objective and subjective research approaches were adopted in the conceptual assessment of the thermal comforts (environmental and human factors). The objective approach involved the quantification of environmental factors namely mean radiant and ambient air temperatures, relative humidity, and airflow rate.

Table 1 Design dimensions of the studied classroom building

Classrooms capacities (m^3)		Area of First Window (m^2)	Area of Second Window (m^2)	Area of Doors (m^2)
A	87.12	5.20	3.60	2.06
B	87.56	5.46	3.47	2.09
C	87.56	5.47	3.60	2.07
D	87.79	4.93	3.40	2.04
E	89.10	4.93	3.40	2.20

Factory calibrated instruments used for environmental factor data collection included GM816 digital anemometer for the airflow rate, the digital LCD thermometer hygrometer temperature measured relative humidity and air temperature. The mean radiant temperature was measured using an infrared thermometer. The measurements were taken twice daily during school hours 7:50 – 8:30 am (morning session) and 2:20 – 3:00 pm (Afternoon session) from the month of March 2016 through to February 2017, Mondays to Fridays, excluding days of any form of holidays. This measurement interval was considered as they represent the period of greatest use or sensitivity to discomfort (Arens and Ballanti, 1977). The environmental parameters were measured at the center of the classrooms and at a height 130 cm, which represents the height of a sitting person's head. The measurements and recordings were carried out five times at the intervals of 60 seconds in each of the five assessed classrooms with the use of a stopwatch giving 5 minutes reading per study point (classroom). The human factors were subjectively assessed using a questionnaire structured on ASHRAE 7-point scale (cold, very cold, slightly cold, neutral, slightly warm and very warm) to quantify individual's adaptive behavior of the students in their physical environment. The assessment of human factors aspect of thermal comfort comprises the participants' perceived and preferred thermal sensation in the morning and afternoon sessions as well as the seasons (wet and dry). The effects of ambient temperature, relative humidity, and airflow rate were factored into the occupants' thermal sensation. Consistent perceived occupants' thermal sensation with their preferred thermal sensation is termed satisfied otherwise unsatisfied. The subjective responses were obtained from thirteen (13) participants randomly selected from each of the assessed classrooms. Participation was free as no incentive was offered. The collected data were analyzed using Microsoft Excel 2007 and SPSS 16.0.

3.0 Results and Discussions

The descriptive statistics of the measured classroom environmental factors during the survey were presented in table 2. The measured environmental variables which included airflow rate, relative humidity, ambient and mean radiant temperatures for students' physical and psychological wellness in the classroom environment were of an approximate range of values for the five assessed classrooms with an average ambient temperature range of 29.37 - 30.08 ℃, mean radiant temperature 29.24 - 31.28 ℃, relative humidity 67.81 - 68.99 % and wind speed 0.022 - 0.037 m/s. Considering that students spend most of their time in a seated position at schools (Samani and Samani, 2012), comparing the data obtained with the standard values required for sedentary activities which are 26.00 – 28.00 ℃ for indoor ambient temperature and 40.00 - 70.00 % for relative humidity (CIBSE, 1999) the indoor air temperature was higher while the relative humidity fell within the range. The environment variables are the basic factors in the determining the impacts of the indoor thermal environment on human body physiology as such has been found to affect the motor nerve conduction velocity, sensory nerve conduction velocity and skin temperature (Liu et al., 2007). The necessity of adequate relative humidity in maintaining thermal comfort is in its effect as high levels of humidity inside buildings prevent the evaporation of sweat from the skin which is the main method human body losses heat (Givoni, 1976). On the contrary, low humidity levels can cause symptoms such as dryness of throat and skin, and can cause irritation of the mucous membranes, where the heat loss is greater than the heat produced by the body, issues like shivering are the resultant effects. In addition, the human body has a thermal interaction with the environment with different grades of thermal sensation. The temperatures of the surfaces surrounding an enclosed space in relation to the temperature of a body within the space determine the rate and direction of radiant heat flow between the body and the surrounding surfaces (Bradshaw, 2006). The obtained average ambient temperature range of 29.37 - 30.08 ℃ in this study fell within the range 29 – 35 ℃ considered warm (Matzarakis and Mayer, 1996) as well in the presence of inadequate air circulation, the space stales. The airflow rate function in maintaining thermal comfort is in the effect heat loss from the human body by convection, an evaporative capacity of the air and consequently the cooling efficiency of sweating, though when excessive causes the sensation of draught (Givoni, 1976; McMullan, 2002). The significant contribution of the mean radiant temperature to the thermal comfort of an indoor environment of an occupant is by the radiant exchange of heat from surrounding surfaces. This makes it useful to consider the design and creation of adequate ventilation space of a classroom enclosure innate radiant heat exchange.

Table 2 The Summary of the Descriptive Analysis of the Measured Environmental Factor

Measured environmental factor variables	Descriptive analysis	CLASSROOM				
		A	B	C	D	E
AT (℃)	Minimum	20.30	23.30	22.90	23.10	23.00
	Maximum	35.20	36.80	36.50	37.40	41.80
	Mean	29.37	29.49	29.84	29.87	30.08
	Std. Deviation	4.45	4.52	4.39	4.78	5.30
RH (%)	Minimum	51.00	50.00	50.00	51.00	51.00
	Maximum	89.00	88.00	89.00	89.00	88.00
	Mean	68.07	67.81	68.99	68.70	68.22
	Std. Deviation	13.15	12.49	13.13	12.02	11.87
WS (m/s)	Minimum	0.000	0.000	0.000	0.000	0.000
	Maximum	0.400	0.400	0.100	0.400	0.400
	Mean	0.027	0.035	0.037	0.031	0.022
	Std. Deviation	0.047	0.077	0.040	0.063	0.060
MRT (℃)	Minimum	23.30	23.30	23.30	23.30	23.10
	Maximum	35.30	35.10	35.60	35.20	35.70
	Mean	29.24	31.28	29.24	29.37	29.32
	Std. Deviation	4.65	4.00	4.75	4.78	4.82

Structure designs by making modify the microclimatic condition and as such affect the thermal comfort of the environment. Adunola (2015) stated that buildings irrespective of whatever location are meant to provide convenient requisite thermal indoors environment for conducive human activities. Passive buildings act as a filter between the outside conditions imposed by the weather, which is determined by the location, and the indoor conditions that need to meet occupant comfort requirements (Lenoir, 2013). Natural ventilation, through the adoption of cross ventilation by appropriate building openings (window and doors) placements is a passive cooling method for buildings make the building occupants safe, clean and comfortable as well it has a strong influence on their productivity, physical and mental well-being (Hyde, 2000; Ohba and Lun, 2010; Bradshaw, 2006). The considered variables which were measurement intervals and seasons showed that the relative humidity was high in the morning hours compared with the afternoon session for all the classrooms. The average ambient temperature was low in the morning but high in the afternoon. A similar observation was made for mean radiant temperature as it was for the ambient temperature (Table 2). The similar observation obtained for the five assessed classrooms was ascertained to be as a result of the similar orientations, openings and same location.

Table 3 Descriptive statistics of the environmental factors of assessed classroom with consideration to measurement interval and seasons

Seasons	Classroom	Measurement intervals							
		MORNING				AFTERNOON			
		RH	AT	MRT	AFR	RH	AT	MRT	AFR
Wet	A	79.97	25.62	24.89	0.029	60.32	33.34	32.80	0.038
	B	78.81	25.56	24.95	0.084	61.39	33.22	33.12	0.015
	C	78.75	27.21	24.83	0.011	66.50	33.13	32.96	0.048
	D	78.06	25.81	25.05	0.071	63.08	33.31	33.19	0.017
	E	76.69	26.09	24.62	0.049	60.75	33.21	33.21	0.013
Dry	A	80.46	24.59	24.89	0.026	51.26	34.94	33.95	0.025
	B	80.14	24.71	24.94	0.020	51.03	35.17	34.48	0.020
	C	80.43	24.70	24.83	0.031	50.75	34.48	34.33	0.026
	D	80.97	24.88	25.05	0.017	52.42	35.44	35.47	0.021
	E	81.88	24.47	24.62	0.016	53.44	35.20	36.42	0.010

Studies have shown that the combined effect the environmental factors such as ambient temperature, mean radiant temperature, relative humidity and air circulation or airflow rate in a natural ventilated space offers comparatively higher comfort to occupants (Busch, 1990) which is a function of the design. Although variation in temperature or heat is an important indicator that should be taken into account in the investigation of the environmental condition of a space, air temperature alone is neither a valid nor an accurate indicator of thermal comfort or thermal stress (Hayatu et al., 2015). However, it's easy to relate with and use has made it the most commonly indicator for thermal comfort. Going by Hayatu et al. (2015) opinion that ambient temperature should always be considered in relation to other environmental and personal factors started up from the basis that the average ambient temperature of an environment is dependent on its microclimatic variables such as mean radiant temperatures, air circulation or flow rate, and relative humidity. Therefore, is often taken as the main design parameter for thermal comfort (Hayatu et al., 2015). The effects of mean radiant temperatures, air circulation and relative humidity on the ambient temperatures of the classrooms were evaluated using multiple linear regression analysis. The analysis showed a multiple correlation coefficient (*R*-value) of .943 which was an indication of good level of prediction of the ambient temperature from predictors with .889 chances that the average ambient temperature of the classrooms will be affected by regressor variables (measurement intervals, seasons, airflow rate, mean radiant temperature, relative humidity) (Table 4).

Table 4 Summary of the Model

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.943[a]	.889	.888	1.57398

a. Predictors: (constant), measurement intervals, seasons, wind speed, mean radiant temperature, relative humidity

Analysis of variance for the dependent variable (ambient temperature) which was used to determine if the overall regression model is a good fit for the obtained variables showed that the independent variables statistically significantly predicted the dependent variable, $F(5, 702) = 1119.829$, $p < .0005$ (Table 5). This implies that the regression model was a good fit of the regressor variables.

Table 5 Analysis of variance for the dependent variable: ambient temperature

Model		Sum of Squares	Df	Mean Square	F	Sig.
1	Regression	13871.449	5	2774.290	1119.829	.000[a]
	Residual	1739.150	702	2.477		
	Total	15610.599	707			

a. Predictors: (constant), measurement intervals, seasons, airflow rate, mean radiant temperature, relative humidity

The general form of the estimated model coefficients to predict the ambient temperature of a classroom space from the mean radiant temperature, air circulation, relative humidity, measurement interval which has to do with the time of the day (measurement interval) and the season gave an expression

$$AT = 24.869 - (.104 \times RH) - (.924 \times AFR) + (.167 \times MRT) - (.268 \times S) + (4.992 \times MI) \quad (1)$$

Where

AT = Ambient temperature
RH = Relative humidity
AFR = Airflow rate
MRT = Mean radiant temperature
S = Seasons
MI = Measurement intervals

The unstandardized coefficients indicated how much the dependent variable (ambient temperature) varies with each of the independent variable or the predators when all other independent variables (measurement intervals, seasons, airflow rate, mean radiant temperature, relative humidity) are held constant (Table 6). The table showed that for an increase in the ambient temperature of the classroom environment the unstandardized coefficient, such as relative humidity, wind speed and season of the year decrease in the ambient temperature. The dependency on the ambient temperature on the microclimatic variables in the expression is supported by studies in literature (Stein and Reynolds, 2000; Hussein et al., 2002; Klein and Schlenger, 2008). The relative humidity as described by Stein and Reynolds (2000) is the ratio the water vapor density in the air to water vapor density at the same total pressure and temperature. This was stated to affects the rate of evaporation from the skin of an individual in a space (Stein and Reynolds, 2000). At ambient temperatures as high as imminent to the average skin temperature of 34°C, necessitates evaporation heat loss so as to maintain comfort. However, study has shown that exposure to low relative humidity conditions which results in increased evaporation rate from the skin disposes an exposed person to dry and irritated skin sensation (Klein and Schlenger, 2008). The sensitivity of the human body in a space according to Hussein et al. (2002) is to the temperature variation rather than relative humidity as there is still scarce categorical evidence that demonstrated and supported that there is detrimental impact from either high or low humidity to the health of normal people. Likewise Hou (2018) study maintained that rate of airflow and its circulation in an environment account for the temperature rise effect that might result in human thermal sensation and discomfort.

Table 6 The multiple regression tests for prediction of the effects of regressor variables on the ambient temperature in the classroom environment

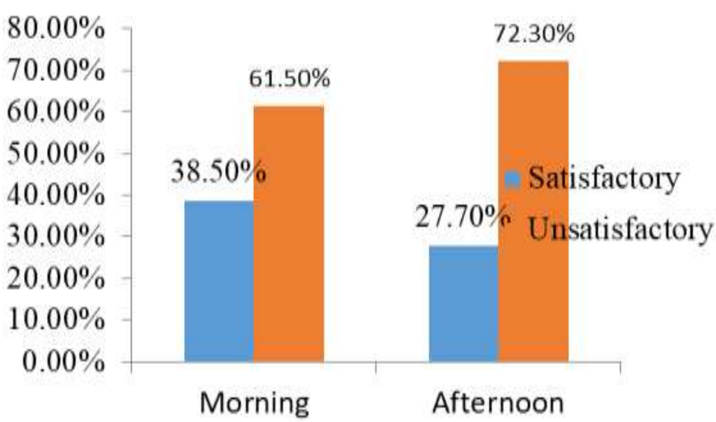
Model		Unstandardized Coefficients		Standardized Coefficients		
		B	Std. Error	Beta	T	Sig.
1	(Constant)	24.869	1.604		15.505	.000
	Relative humidity	-.104	.012	-.278	-8.408	.000
	Wind speed	-.924	1.029	-.012	-.899	.369
	Mean radiant temperature	.167	.029	.165	5.691	.000
	Seasons	-.268	.131	-.029	-2.055	.040
	Measurement intervals	4.992	.331	.532	15.098	.000

a. Dependent variable: ambient temperature

A simple and logical measure of thermal comfort is time-invariant as comfort or discomfort occurs on a given period of the day (Arens and Ballanti, 1977). The comfort or discomfort sensation is based on perception or interrelated perception of the sense organs such as the brain, eyes, nose, ears, tactile and heat sensors. The condition were the human body experiences thermal discomfort sensation in too hot or too cold condition, when the surrounding air is odorous and stale as well as when the body works too hard to maintain thermal equilibrium. In a space where the heat produced by an occupant's body is proportionate to the heat loss without any form of mechanical, ventilating and air conditioning control mechanism. When the comfort condition exists, the mind is alert and the body operates at maximum efficiency (Bradshaw, 2006). When the state of the mind is satisfied with the thermal environment that is if the environmental condition demands minimal stimulation of the skin's heat sensors and of the heat-sensing portion of the brain thermal comfort is assumed (Bradshaw, 2006). Physiologically comfort can be interpreted as the achievement of thermal equilibrium at our normal body temperature with the minimum amount of bodily regulation (Bradshaw, 2006). However, this situation is not absolute but rather varies with the individual's metabolism, peculiarity of engaged activity, and physiological adjustment and adaptability of the individual body over a narrower or wider range of ambient temperature. The human factor aspect of thermal comfort subjectively assessed using questionnaire structured on ASHRAE 7-point scale to quantify an individual's adaptive behavior of the students in their physical environment is presented in table 7. This comprises the students' sensation and the preferred sensation during the morning and afternoon sessions. The temperature, relative humidity, and airflow rate effects were all factored into the occupants' perceived thermal sensation. For the wet season, it was observed that the predominant thermal sensation perceived by the participants was cold (33.8%) which was as deserved by the same proportion of the participants. However, the predominant perceived thermal sensation by the participants was 26(40%) in the afternoon whereas the preferred thermal sensation was slightly cold 20(30.8%). During the morning hours of the dry season, most of the participants (43.1%) perceived warm thermal sensation while the preferred thermal sensation was slightly cold by 20(30.8%) participants. 42(64.6%) of the participants voted warm as the perceived thermal sensation whereas the predominant preferred thermal sensation by the participants was 19(29.2%) for afternoon sessions of the dry season (Table 7). Consistent perceived occupants' sensation with their preferred thermal sensation termed satisfied otherwise unsatisfied analysis showed that the design structure of the building created thermal discomfort with high unsatisfactory conditions for the teaching and learning process for both the time of the day (morning and afternoon sessions) and season (Figures 1 and 2). The observations in this study agreed with Bradshaw (2006) and Hayatu et al. (2015) studies. The dent in thermal comfort observed in this study that considered one-sided window classrooms was found to be an addition in studies that considered opposite sided windowed classroom (Witkowska and Gładyszewska-Fiedoruk, 2018). This could be attributed the cross ventilation effects which gave a melioration to the air circulation, indoor ambient temperature and relative humidity. This is because the negative effect of solar radiation which is increase the ambient temperature is taken care of by the air circulation and relative humidity.

Table 7 Participant's physical environment responses on ASHRAE 7-point scale

Participant's physical environment responses on ASHRAE 7-point scale	Wet Morning		Afternoon		Dry Morning		Afternoon	
	TS n(%)	TP n(%)	TS n(%)	TP n(%)	TS n(%)	TP n(%)	TS n(%)	TP n(%)
Cold	22(33.8)	22(33.8)	4(6.2)	9(13.8)	12(18.50	14(21.5)	3(4.6)	7(10.8)
Very cold	12(18.5)	5(7.7)	5(7.7)	7(10.8)	2(3.1)	2(3.1)	4(6.2)	8(12.3)
Slightly cold	10(15.4)	20(30.8)	6(9.2)	20(30.8)	8(12.3)	20(30.8)	4(6.2)	19(29.2)
Neutral	1(1.5)	5(7.7)	7(10.8)	7(10.8)	2(3.1)	7(10.8)	2(3.1)	7(10.8)
Slightly	14(21.5)	5(7.7)	17(26.2)	10(15.4)	4(6.2)	9(13.8)	10(15.4)	10(15.4)
Warm	6(9.2)	6(9.2)	26(40.0)	9(13.8)	28(43.1)	11(16.9)	42(64.6)	11(16.9)
Very warm	22(33.8)	2(3.1)	4(6.2)	3(4.6)	9(13.8)	2(3.1)	3(4.6)	3(4.6)



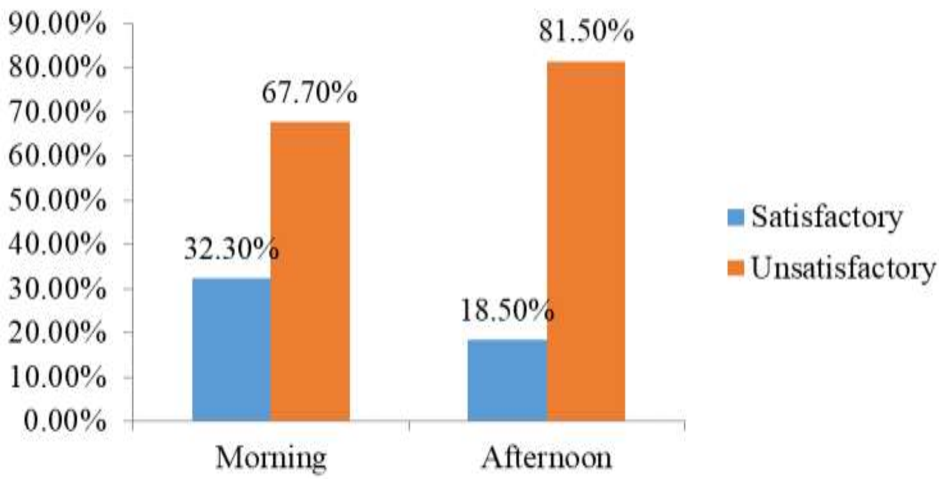


Figure 2b Thermal sensation of the participants during the dry season

Conclusion

The comfortable thermal classroom environment is relative to better health of occupants, increased attentiveness and fewer errors, increased productivity and reduced rates of absenteeism. The assessed operational thermal comfort of naturally ventilated classrooms environment in this study was carried out in a one-side-window oriented classroom building showed that the environmental factors were not in compliance with the microclimatic variables for an indoor environment for the sedentary activities required in an academic environment. The vote for the perceived and preferred thermal sensation among the participants observed variations. It was concluded that the design structure of the assessed building structures created thermal discomfort with high unsatisfactory conditions for the teaching and learning process for both the time of the day (morning and afternoon sessions) and season. For the maximization of natural ventilation effect that will guarantee thermal comfort for the design of passive classroom buildings, cross ventilation should put into consideration.

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