

Comparative Analysis of Comfort Temperature of School Children and Their Teachers

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Abstract: Thermal comfort in learning environments influences the student's focus and learning productivity. This study aims to evaluate and compare the adaptive thermal comfort of schoolchildren and their teachers in naturally ventilated primary schools in some selected cities in Imo State Nigeria. To achieve these objectives, the study analyzed the data collected from 330 pupils and 44 teachers in six surveyed classrooms in two types of classroom buildings. The recorded data in the surveyed classrooms consisted of four environmental factors and two personal factors. At the same time, the subjects filled out the questionnaires asking them about thermal sensation and thermal preferences against the classrooms' thermal requirements. The results of the measurements showed that the indoor mean air temperature, relative humidity, and air velocity were 29.1°C, 71.2%, and 0.19m/s, respectively. The mean thermal sensation votes of the children were +0.16 while that of their teachers was +0.58. The preferred temperatures were 27.4°C and 29.4°C for the schoolchildren and the teachers, respectively. Furthermore, the comfort range of the students was between 25.8°C - 31.6°C, and that of the teachers was between 28.0°C - 29.9°C. Based on the results of this study conducted in primary school buildings located in warm and humid climates, the thermal comfort perception of children and adults differ. This information will serve as a guide to professionals in the built environment, especially architects when designing primary school buildings in the warm and humid climates.

Keywords: Classrooms, Schoolchildren, Teachers, Temperature, Thermal Comfort

1. Introduction

The continuous increase in the global surface temperature, caused by climate change, is of great concern as it impacts the health and the academic performance of children during class lessons. Young children coming out fresh from their various homes in quest of education are exposed to different indoor classroom environments. The indoor environments in classrooms are vital for pupils' perception, health, and performance, especially thermal comfort [1], considering that these children spend many hours inside classrooms having class lessons. At the level of primary education, children are exposed to becoming an integral part of society and adapting to situations outside of the home. Children are shaped by their physical, social, and emotional changes throughout their childhood. Because they are vulnerable, they could be

negatively impacted by climate change-induced problems such as heat stress and other environmental problems. In primary schools, teachers, rather than students, are believed to control the internal environment by opening the windows, and doors and by putting on and offing the fans (where electricity is available) when they wish to do so. They do these considering their comfort first, believing that schoolchildren will perceive the comfort perception the way they perceive it. The opportunity to control an environment affects the thermal perception of the occupants making those who do not have control over the environment bear to the uncomfortable indoor conditions [2]. But children likely have a different comfort temperature than adults [3].

Various research works have been probing if there is any difference between the thermal perception of adults and children. This argument has been going on with empirical

data backing the various arguments. Because the metabolic rate and activity levels between these two groups of people (children and teachers) vary, their thermal perception may differ [4, 1]. The metabolic heat generated by an elderly person is lower than that generated by a young person because of age and the lower inactivity of the elderly. Compared with adults, children have a lower sweat rate in all environmental conditions [5]. Furthermore, the difference between children and adults, including differences in surface-area-to-mass ratio, and blood volume may affect their different perceptions of thermal comfort. The lower thermal neutrality of children (compared with adults) is attributed to their higher metabolic rates because of their smaller surface (body) area [6]. Because of these perceived differences between children and adults, the thermal perception between these two groups of people may differ and the class teachers may be oblivious of this fact when the indoor environments are under their control. The current comfort standards produced from fieldwork and climate chamber experiments are based on the study conducted with only adults as subjects [7]. The comfort guidelines are contained in ISO 7730, EN 15251, and ASHRAE 55 [8].

The above reasons prompted various research studies across the globe to determine the thermal comfort temperature of children and to compare the findings with that of adults. Meanwhile, some pieces of empirical data about the thermal comfort perception of schoolchildren are available from studies done in Europe, America, and Asia, [9, 10]. But in Africa this information is limited. The results from fieldwork in these continents may not apply to African countries. This is because, as social background, traditional way of life, culture, buildings, and climates are distinct from one geographical place to another, comfort study done in a geographical area may not be generalized to apply to a different geographical area [11, 12, 7, 14]. This information was confirmed by the fieldwork that found correlation between thermal comfort temperature and the socioeconomic backgrounds of the participants [15]. The comfort models specific to an area should be developed based on the indoor and outdoor temperature, relative humidity, and clothing pattern of people of the region.

Because of these issues raised in this paper, this study aims to determine the perception of the thermal environment by the primary school children and that of their teachers and to compare the thermal perception between these two groups of people. To achieve these objectives, fieldwork was carried out to determine the thermal sensation, thermal preference, comfort range, and sensitivity of school children aged (7-11 years) and their school teachers.

2. Assessing Comfort Temperature

Thermal comfort is defined by the American Society of Heating, Refrigerating, and Air Conditioning Engineers (ASHRAE) as the 'condition of mind that expresses satisfaction with the thermal environment' [16]. For one to be thermally comfortable, the excess heat in the body produced

by metabolism must be transferred into the surroundings for the body's core temperature to be kept constant. The human body strives to maintain its core body temperature at 37°C to be thermally comfortable. In other words, someone is thermally comfortable when the person feels neither 'too hot nor too cold' or thermally neutral when in an environment. The person has to be healthy and wears a normal amount of clothing at the time of assessment. However, because the heat transferred to the environment differs from one individual to another, the temperature acceptable varies among individuals, even when they are exposed to the same indoor environment. This is attributed to the differences in age, health, status, type of clothing worn, and rate of activity. Thus, it will be difficult to establish a condition or standard that will satisfy everyone because of these differences. Because of this unlikeliness to satisfy 100% of the people at the same time in the same indoor space. ASHRAE Standard 55 suggested that when 80% or more of building occupants accept the indoor thermal conditions such an indoor space is deemed to be accepted by the occupants [16].

To assess the thermal comfort of a group of people, two models are popularly adopted. The first model is the Heat Balance Model (HBM) which uses the Predicted Mean Votes (PMV) as an index to define acceptable indoor environments. The HBM is also called a steady-state or a rationale model, and it is a laboratory experiment where the subjects do not have control over six factors (four environmental factors and two personal factors). The environmental factors are; Air temperature, mean radiant temperature, Air velocity, and Relative humidity while the personal factors are; Activity rate and Clothing insulation. The Adaptive Comfort Model, developed by Professor Ole Fanger was based on data collected from North American and Danish subjects and was developed specifically for air-conditioned spaces predominantly found in Western countries. Thus, the model is not popular in tropical countries where many buildings are naturally ventilated. The second model is the Adaptive Comfort Model (ACM) which is based on adaptation to environmental parameters. According to the adaptive principle, people often resort to behavioral adaptations, such as clothing change, posture adjustment, etc, to fit into the local conditions they find themselves in and so are capable of regulating the environmental parameters to be comfortable. Figure 1 shows the adaptive comfort chart with zones where 80% and 90% of building occupants may be thermally comfortable.

This model was considered as an assessment approach because of oil shock in the 1970s. There was energy crisis during the oil shock causing high cost of heating indoor spaces in the cold regions. The ACM considers the relationship between the indoor temperature and the outdoor temperature in determining the thermal performance of building. People who are indoors, in free running buildings, do adapt to the external temperature around the building mediated through its walls and operable windows, and roofs and floors [13]. ASHRAE Standard 55 adaptive comfort model is the preferred choice adopted by researchers to check the thermal comfort in NV buildings in the tropics, especially

in Sub- Sahara African countries. This is because ASHRAE RP-884 data was obtained from climate zones that covered all the four continents including Africa. Adaptive chart,

represented graphically in Figure 1, shows the zone where 80% and 90% of building occupants may be thermally comfortable.

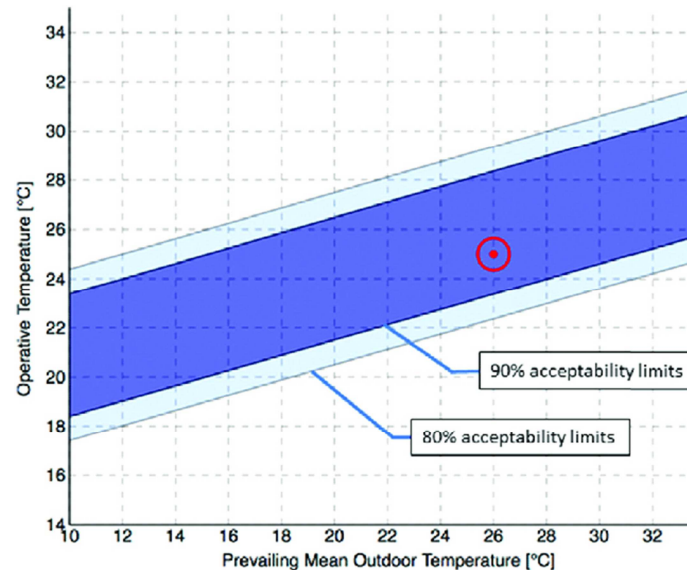


Figure 1. Adaptive thermal comfort chart according to ASHRAE Standard 55-2017 (Adapted from [16]).

Thermal comfort can be assessed by adopting both objective and subjective procedures. The objective procedure involves the use of measuring instruments to record the environmental parameters while the subjective procedure involves using a questionnaire to collect data about how the subjects feel about the internal environment. Teachers are capable of responding to the questionnaire by filling them appropriately. But for the students, it will not be easy for them to understand the wording of the questionnaire. For this reason, researchers are allowed to make minor modifications to the ASHRAE-approved standardized questionnaire and scale to suit the cultural background, language, and age of the subjects. In thermal comfort research works done on children aged 6-11 years, the same standardized thermal comfort questionnaires used for adults were adopted but some of the studies reduced the number of questions and modified the wording so that the children could understand them better. For example, the original word 'neutral' used by Professor Fanger P. O to determine the central category of the 7-point ASHRAE scale was changed to the word 'good' [17]. In the survey conducted by Karyono the word 'comfort' was adopted in place of 'neutral' [18]. The word 'ok', instead of 'neutral' was used in these works [19, 8, 20, 21]. The word 'keep constant' instead of 'no change' was adopted in the thermal preference question, and 'temperature' instead of 'thermal comfort' was used in the thermal sensation question [22].

Furthermore, the Indonesian language was used to investigate the thermal comfort conditions of primary school students in Tangerang, Indonesia [18]. In adopting a different language, what is important is ensuring that the language is translated correctly to comply with the ASHRAE standard. While investigating the thermal comfort perception of

primary school children, some numbers were dropped in the questionnaire, to avoid confusing them while filling the questionnaire [23, 14].

3. Method

3.1. Study Area

This study is based on a large experimental campaign survey carried out during the rainy and dry seasons from 2017 to 2019 in Imo State, Nigeria. Imo State, is located in the South East of Nigeria and categorized according to the climatic classification of Koppen- Geinger in the group of tropical [20]. The State is located between latitude $4^{\circ} 45'N$, $7^{\circ} 15'N$, longitude $6^{\circ} 50'E$, and $7^{\circ} 25'E$, and represents one of the five South Eastern states in Nigeria. The state lies in the rainforest zone of the warm humid tropics. It is characterized by high temperatures and high relative humidity for most periods of the year. Mean annual rainfall ranges from 2500 to over 4000 mm, with mean maximum temperature of about $30^{\circ}C$.

3.2. Data Collection and Analysis

This study was carried out in two case study classroom types; open-space classroom type and enclosed plan classroom type. In total, six naturally ventilated classrooms were investigated during the survey. A total of 330 pupils and 44 teachers participated in the survey. The period of the survey was from 7.30 am to 2.45 pm. Both subjective and objective evaluations of the subjects were adopted in this study. The questionnaire, shown in table 1, adopted the ASHRAE 7- point thermal sensation scale (-3=colder, -2=cooler, -1= a bit cold, 0=okay, +1= a bit warm,

+2=warmer, +3= hotter), to assess the occupant's degree of satisfaction with their thermal environment. Following Fanger's approach, the central three categories of the scale which represent the range of 'a bit cold' (-1) to 'a bit warm' (+1), are taken to indicate the sensations at which an occupant will be 'satisfied' with the thermal environment. This approach was adopted to determine the thermal sensation of the subjects. Voting on these 4 categories (-3, -

2, +2, +3) is assumed to indicate 'dissatisfaction', with the most extreme ratings of 'colder' (-3) and 'hotter' (+3) suggesting the highest level of dissatisfaction. The thermal preference is based on 3-point McIntyre thermal preference scale which asks the subjects whether they prefer to be 'cooler' or 'okay' or 'warmer' to the temperature in the classrooms.

Table 1. Rating scales used in thermal comfort.

ASHRAE Thermal Sensation	-3 (cold)	-2 (cool)	-1 (a bit cold)	0 (okay)	+1 (a bit warm)	+2 (warm)	+3 (hot)
McIntyre Thermal Preference	Cooler		okay			Warmer	

Source: ([16]).

Before the students were asked to respond to the questions (by way of filling out the questionnaire) they were to be seated and be writing or reading or listening to their teachers for about 30 minutes. In any of these states, their activity was estimated at 1.2 MET, representing sedentary activity as recommended by ASHRAE Standard 55. It is at this stage that the questionnaire can be administered to the students to fill. The teachers will equally fill out their questionnaires when they were seated and were also engaged in sedentary activity.

The objective survey involved the collection of

environmental parameters. In each of the surveyed classrooms, TinyTag Ultra 2 Gemini Logger was placed at the center of the classroom at a height of approximately 0.9 meters above the floor level. The logger measured the indoor air temperature and indoor relative humidity. The WetBulb Globe Temperature (WBGT) Heat Stress Meter measured the globe temperature. Kestral 3000 pocket wind meter measured the airspeed at various spots in the surveyed classrooms. Tiny Plus 2 Gemini Loggers measured the outdoor temperature. Table 2 shows the technical details of these instruments.

Table 2. Technical characteristics of the measuring instruments.

Instrument and Make	Measured parameter	Range	Resolution	Accuracy
Tinytag ultra 2 (TGU-4500) logger	Indoor air temperature	-25 to +85°C	±0.01°C	±0.3%
	Indoor relative humidity	0% to 100%	±0.3%	±1.8% RH
Tinytag Plus 2 (TGP-4017) loggers	Outdoor Temperature	25 to +85°C	±0.01°C	-
Kestrel 3000 Pocket wind meter	Air velocity	0.30 to 40.0m/s	-	±1.66%

Source: (Data Logger technical details, 2016).

After the subjective and objective data have been collected they were analysed with SPSS program and the results are presented in tabular and in graphical forms.



Figure 2. Dress Code in School (left) and Children filling in Questionnaire in their classroom (right).

4. Results and Discussions

4.1. Measured Thermal Variables in the Classrooms

Table 3 presents a detailed statistical summary of the

minimum, maximum, mean, standard deviation and coefficient variation of the measured indoor and outdoor thermal variables in the surveyed classrooms at occupied school hour time that spanned from 7.30 am to 2.45 pm. While Figure 3 shows a sampled graphical presentation of temperature from the data logger. The indoor operative

temperature extracted from the data loggers for all the combined classrooms in both seasons was within the range 22.5-35.6°C. The studied pupils and the teachers experienced a mean indoor temperature of 29.1°C (SD=1.7), with 5.8% as the coefficient of variation.

The outdoor temperature for all the 6 classrooms averaged

29.6°C during the same survey period falling within the range 23.0-37.4°C with (SD=1.7). The relative humidity varied from 24.0 to 94.2% with a mean value of 71.8% (SD=12.4). Spots checks of the airflow in the classrooms show that the maximum air velocity in the combined classrooms all season was 0.30m/s, with a mean value of 0.19m/s.

Table 3. Mean, standard deviation, min and max values of the main environmental parameters and 0 mean thermal sensation votes.

Classroom	All Open	All Enclosed	Combined Open and Enclosed
Air Temperature (°C)			
Mean	28.8	29.3	29.1
S.D.	1.6	1.5	1.7
Min	22.5	22.9	22.5
Max	35.6	35.1	35.6
Operative Temperature (°C)			
Mean	28.9	29.3	29.1
S.D.	1.6	1.5	1.7
Min	22.5	22.9	22.5
Max	35.6	35.1	35.6
Outdoor Temperature (°C)			
Mean	29.6	29.6	29.6
S.D.	1.7	1.7	1.7
Min	23.0	23.0	23.0
Max	37.4	37.4	37.4
Relative Humidity (%)			
Mean	71.8	70.8	71.2
S.D.	13.1	11.8	12.4
Min	24.0	27.4	24.0
Max	94.2	93.5	94.2
Air velocity (m/s)			
Mean	0.19	0.14	0.19
S.D.	-	-	-
Min	-	-	-
Max	0.30	0.28	0.30

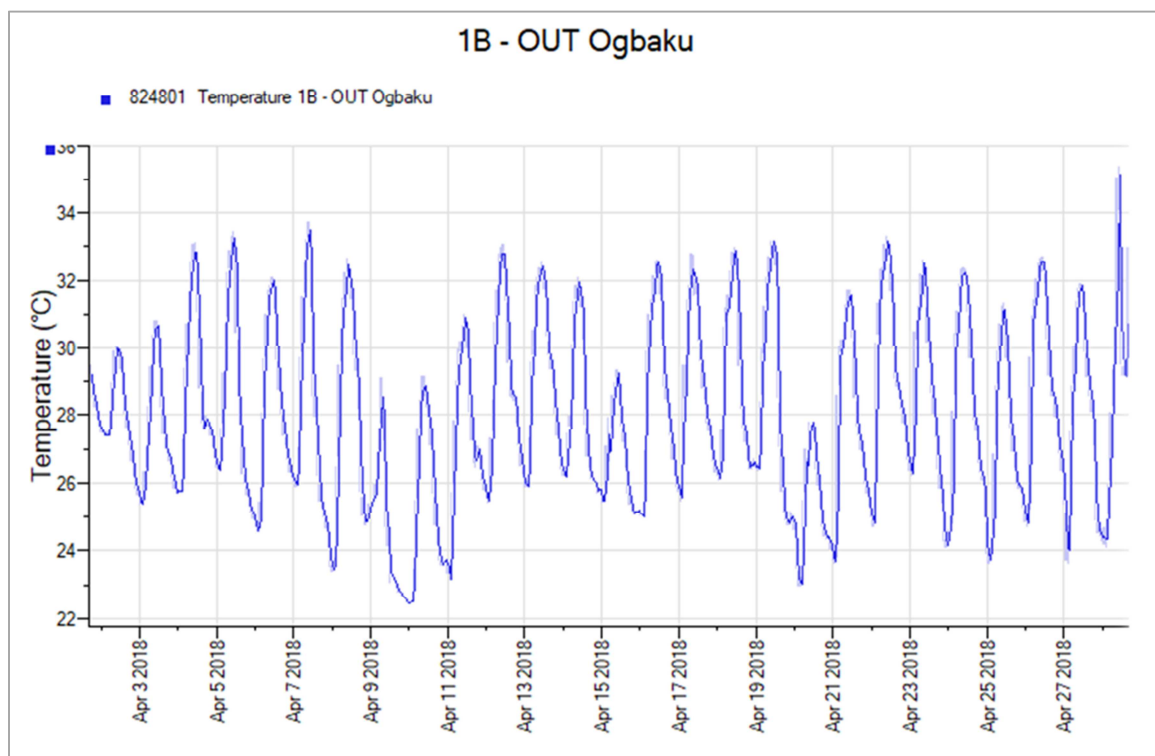


Figure 3. Sample of graphical presentation of temperature from data logger.

4.2. Children's Comfort Temperature

4.2.1. General Characteristics of the Sampled Pupils

There were 7050 valid returned questionnaires drawn from 330 primary school children aged 7-12 years in the rainy season and dry season. A total of 164 visits were made to the surveyed schools; rainy season 64 visits and dry season 100 visits. Each day, two surveys were conducted; morning and afternoon. All the classrooms in the study area were naturally ventilated and none had any active ventilator such as an air conditioning system or fan.

The number of children in each classroom ranged from 25 to 30. A set of 158, representing 47.9% of the children participated during the dry season survey, while 172 children, representing 52.1%, participated during the rainy season survey. Further details show that the number of female participants was more (58%) compared to the number of male (42%) during both seasons. According to the season, females constituted; 55.1% and 61.0% for the rainy season and the dry season, respectively, against 44.9% and 59.0% for the rainy season and dry season respectively for men. Most of the participating children (56.0%) were within the age range of 9-10 years, with 9 years as the mean age. Of all the participants that were surveyed, none was less than 7 years or more than 12 years.

4.2.2. Thermal Sensation of the Children

Table 4 summarizes the thermal sensation votes of the children in the six surveyed classrooms. With the mean thermal sensation vote of +0.16 all season in combined classrooms. The mean thermal sensation lay between 'okay' and 'a bit warm' on the ASHRAE 7-point thermal sensation scale. Generally, the thermal sensation spread during the

survey was from -2 to +1.8 (SD=0.66).

A further breakdown of the thermal sensation votes according to season indicates that the subjects felt cold in the rainy season at the mean thermal sensation with the value of -0.01. The vote was slightly above neutral (0), an indication that the subjects found the indoor thermal conditions comfortable in the rainy season. During the dry season, the thermal sensation votes were between 'okay' and 'a bit warm', with a mean value of +0.31, and ranged from -1.4 to 1.8, SD (.56). This suggests that the subjects felt warmer in the dry season compared to the rainy season. However, the mean value of the vote suggested that they were comfortable with the indoor thermal conditions.

Table 4. Children's mean thermal sensation votes.

Thermal Sensation	All open	All enclosed	All classrooms
Mean	0.09	0.29	0.16
S.D.	.60	.70	.66
Min	-1.7	-1.5	-1.7
Max	1.7	1.8	1.8

The results of the thermal sensation votes are further illustrated in relative frequency in Figure 4. The percentage of children's votes that fell on neutrality (okay) was 51% for the combined classrooms all season. The percentage of children who voted on ASHRAE three central categories (-1, 0, 1) of the thermal sensation scale was 82%. The percentage of votes on the two extreme ends of the ASHRAE scale that indicates discomfort (-2, -3, +2, +3) totaled 18%. However, the discomfort was more on the warmer side (15%) than on the colder side (3%).

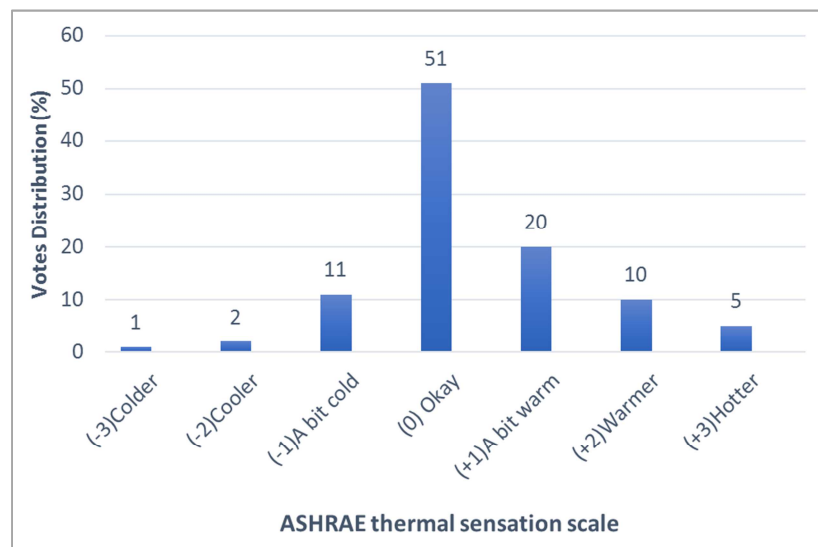


Figure 4. Distribution of the children's votes on ASHRAE scale in combined classrooms.

4.2.3. Thermal Preference of the Children

The thermal preference of the studied children illustrated in the histogram in Figure 5 shows that in the combined classrooms all seasons, 50% (half of the entire children)

preferred to be cooler than what the existing indoor thermal condition presented. 37% of the entire class preferred the thermal condition to remain in the condition they found it, while 13% preferred a warmer condition.

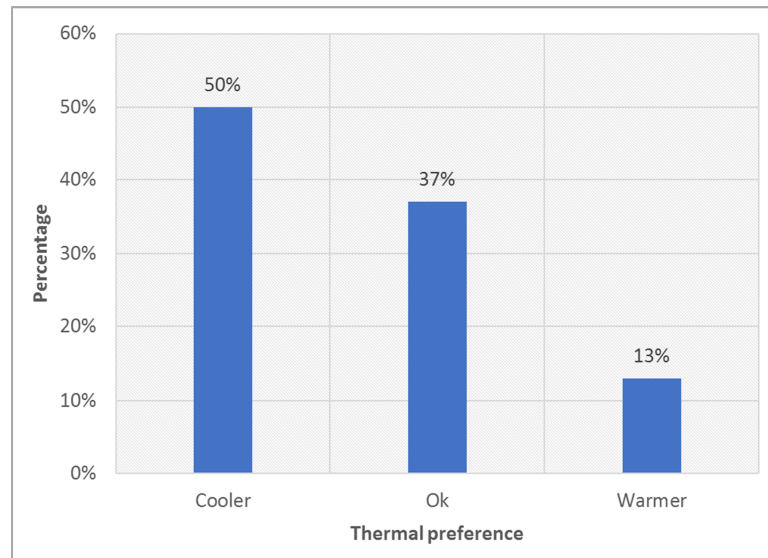


Figure 5. Distribution of subjects' thermal preference votes.

Near to half the entire class (45%) were satisfied with their thermal conditions in the rainy season and would rather prefer the thermal state to remain as they found it. A significant percentage (69%) was not satisfied with the thermal state during the dry season and would prefer the thermal condition to be either warmer or cooler. The preference for a cooler indoor thermal condition was higher during the dry season compared to the rainy season. For instance, during the dry season, 63% of the children in the combined enclosed classrooms preferred cooler thermal conditions, while the preference for the cooler environment during the rainy season, for the same subjects, was 36%. The trend was the same in the combined open classrooms where 56% of the children preferred a cooler environment in the dry season, compared to the 27% vote in the rainy season.

A higher percentage of the subject's votes were on 'okay' during the rainy season, while a lower percentage of the subject's votes on 'okay' was lower during the dry season. Of

the 19% of the children who preferred warmer conditions during the rainy season, only 8% of them preferred that during the dry season. Also, of the 20% of the children in the combined enclosed classrooms who preferred to be warmer during the rainy season, only 11% of them preferred that thermal state in the dry season survey.

4.2.4. Preferred Temperature

The preferred temperature of the students' was obtained through linear regression analysis of the votes of the children who wanted to be cooler and those who wanted to be warmer against the operative temperature. The result of the regression produced a preferred temperature. This temperature is where the intersection of the percentage of children who wanted to be warmer and those who wanted to be cooler meet. As illustrated in Figure 6, the two fitted lines intersected at a preferred operative temperature of 27.4°C.

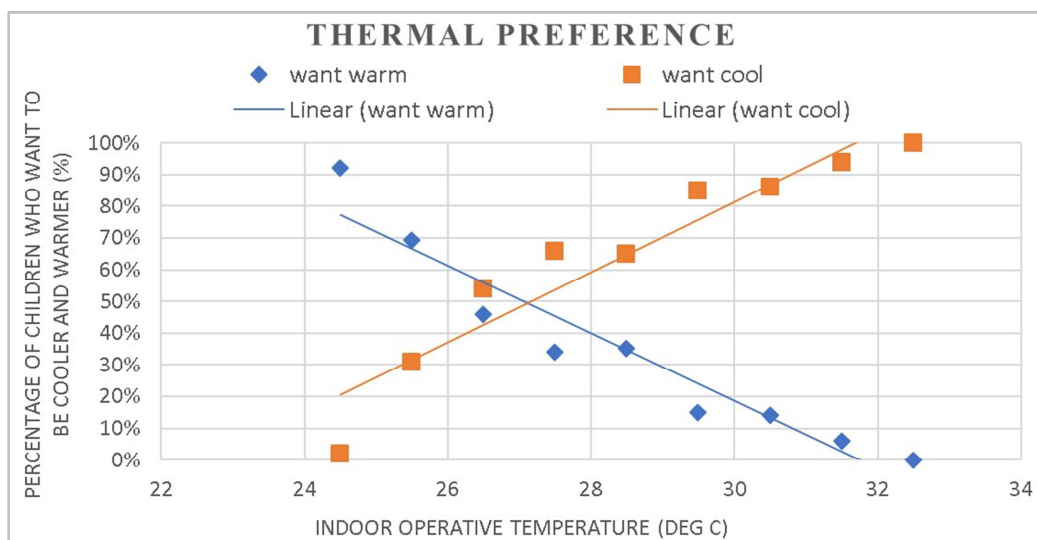


Figure 6. Linear regression models for preferred temperature.

4.2.5. Comfort Range of the Students

The mean thermal sensation votes were regressed against the indoor operative temperatures to establish a comfortable range of temperatures for the schoolchildren. This comfortable range of temperatures falls within the $0.85 \leq TSV \leq +0.85$ set by the Adaptive Comfort Model based

on 80% acceptability. The regression equation is $TSV = 0.29Top - 8.33$, which defines a comfort range of 25.8–31.6°C. The comfort range (acceptable indoor temperature) in the rainy season was from 25.1–31.4°C, while during the dry season the comfort range was from 25.4–30.2°C, for the 80% acceptability criterion.

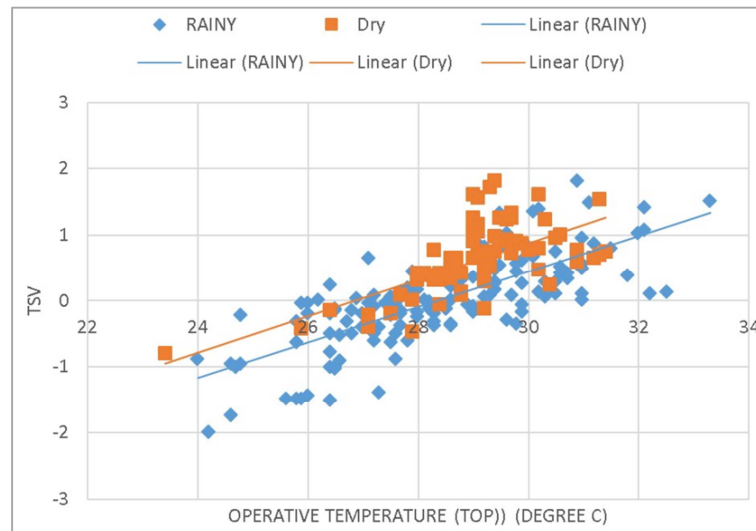


Figure 7. Regression analysis of thermal sensation upon Top according to season.

4.3. Comfort Temperature for Teachers

4.3.1. General Characteristics and Samples

As presented in table 5, a sample size of 21, representing 47.7% of the teachers participated during the dry season, while 52.3% representing 23 teachers participated during the

rainy season. There were by far a greater number of female teachers (88.6%) than their male counterparts (11.4%). The age of the teachers ranged from 19 to 59 with 37 years as the mean age. Majority of the teachers who participated (56.8%) were below 40 years in both seasons the survey were conducted.

Table 5. Summary of teacher's background.

		Total (n=44)		Dry season (n=21)		Rainy season (n=23)	
		Sample size	Percentage	Sample size	Percentage	Sample size	Percentage
Gender	Male	5	11.4%	2	9.6%	3	3.1%
	Female	39	88.6%	19	90.4%	20	86.9%
Age (years)	19-29	11	25.0%	4	19.1%	7	30.4%
	30-39	14	31.8%	7	33.3%	7	30.4%
	40-49	10	22.7%	6	28.6%	4	17.4%
	50-59	9	20.5%	4	19.0%	5	21.8%
Living in Imo State (years)	<1	3	6.8%	-	-	-	-
	1-5	12	27.3%	-	-	-	-
	>5	29	65.9%	-	-	-	-

4.3.2. Thermal Sensation of the Teachers

A mean thermal sensation vote of +0.58 was obtained, for the combined classrooms all season. The teachers evaluated their indoor thermal condition to lie in-between 'okay' and 'a bit warm', however tending more to 'a bit warm'. The range of the thermal sensation was from -0.7 to +1.9, SD (.79). The results of the thermal sensation votes of the teachers were further illustrated in the relative frequency distribution shown in Figure 8. The highest percentage of thermal sensation votes

(35%) was on 'a bit warm' section of the ASHRAE scale, while 10% of the votes were on the 'cold' (-1) side of the ASHRAE 7-point thermal sensation scale. Only 28% of the teachers cast their votes on okay (0). The percentage of the teachers who voted on ASHRAE's three central categories (-1, 0, 1), was 76%. The percentage of votes on the two extreme ends of the ASHRAE scale (-3, -2, +3, +2) totaled 37%. However, the discomfort was more on the warmer side of the scale (20%), than on the cooler side of the scale (17%).

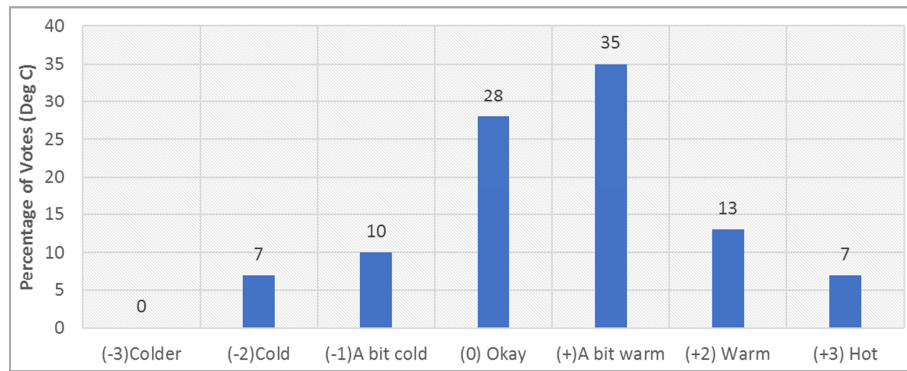


Figure 8. Histogram of thermal sensation of the teachers.

4.3.3. Thermal Preference of Teachers

The subjects were asked whether they would prefer 'warmer', 'cooler', or 'okay' (no change) to their indoor thermal conditions. Almost half (49%) of the teachers preferred the thermal conditions in the classrooms to remain

the way they found them during the survey period (Figure 9). 29% of the teachers preferred the classrooms to be cooler while 22% preferred it to be warmer. In other words, more teachers would prefer a cooler environment to a warmer environment during the survey.

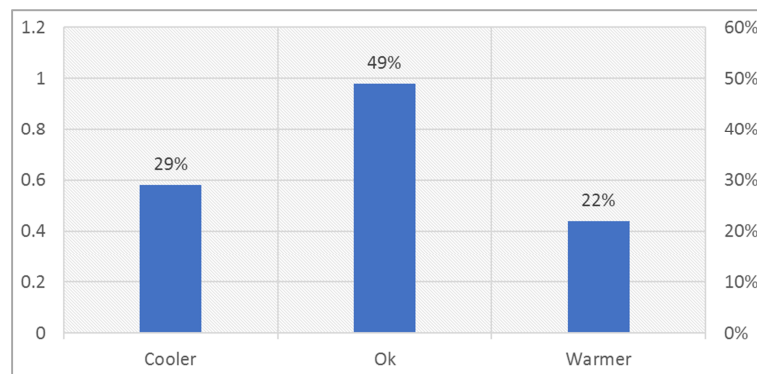


Figure 9. Histogram of thermal preference of the teachers.

4.3.4. Comfort Range of Teachers

ASHRAE adaptive comfort standard defines the 80% operative comfort range as $-0.85 \leq TSV \leq +0.85$. This corresponds to approximately 80% thermal satisfaction, where the Predicted Percentage of Dissatisfied (PPD) is less than 20%.

The acceptable range of temperature was determined from the linear equation based on thermal sensation in the range of $(-0.85 \leq TSV \leq +0.85)$ for 80% acceptable indoor thermal conditions. Based on the regression equation ($TSV = 0.87T_{op} - 25.2$) shown in Figure 10, a comfort range of 28.0-29.9°C was produced.

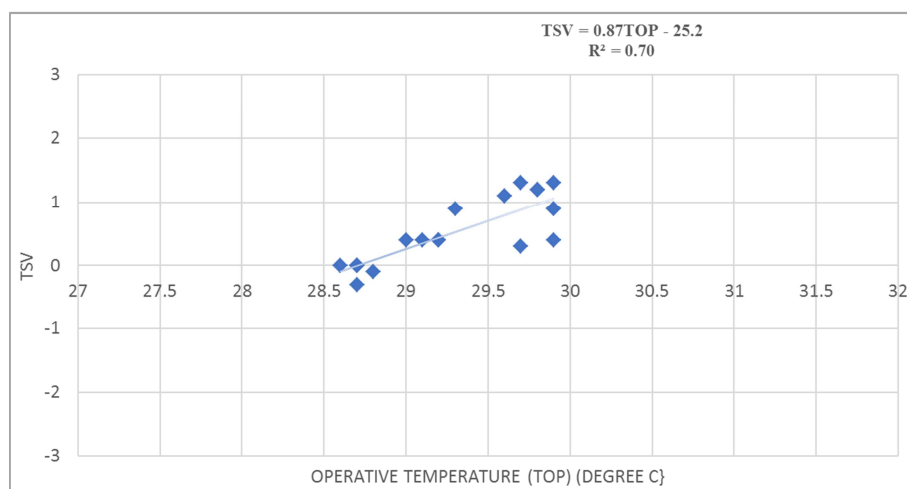


Figure 10. Mean thermal sensation votes of the teacher's vs TOP.

4.3.5. Thermal Acceptability of Teachers

The thermal acceptability question of the teachers in the surveyed classrooms was judged adopting the same questions

used on children's survey. As shown in Figure 11, only 35% of the teachers accepted the indoor thermal conditions while a good majority (65%) did not accept.

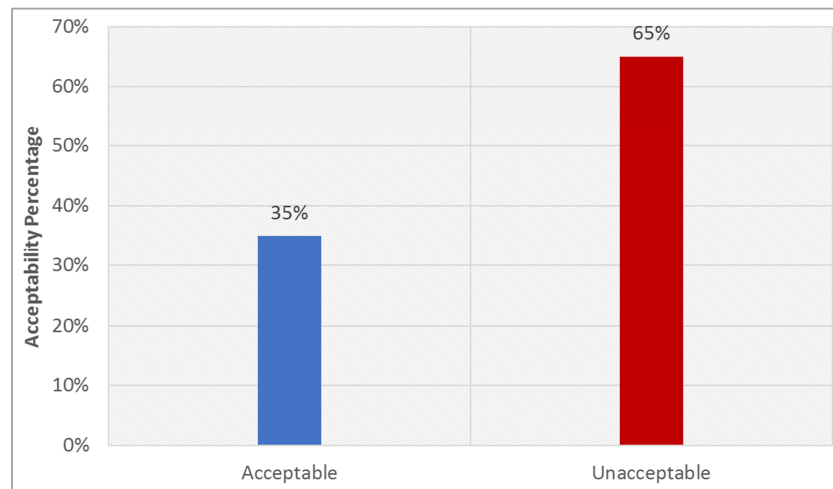


Figure 11. Thermal acceptability of the teachers.

4.4. Comparing Thermal Perception of the Children with That of Their Teachers

4.4.1. Thermal Sensation

A poor correlation was found between the thermal sensation of the schoolchildren and their teachers. While the mean thermal sensation of the teachers is +0.58 that of the children is +0.16. This suggested that the teachers perceived their indoor environment warmer than the children felt by 0.42 scale units. The implication is that, when the teachers are feeling warm, the pupils may not necessarily be feeling warm.

Another way of comparing the thermal sensation votes of these two age groups is to check the results of the voting on

the 7-point ASHRAE rating scale. As shown in Figure 12, 82% of the children voted on the three central categories of the ASHRAE scale (-1, 0, +1), while 73% of the teachers cast their votes on the same central category. Because voting on the 3-central categories of the ASHRAE scale is taken as 'comfortable', the result suggested that the teachers perceived the indoor environment less comfortable when compared to the young children. The histogram further highlights other differences in the voting of the children and their teachers. While half of the schoolchildren voted 'okay', only about a quarter of the teachers voted 'okay'. Furthermore, while 20% of the teachers voted on the warmer side of the scale (+3, +2), 15% of the children voted on the same side of the scale.

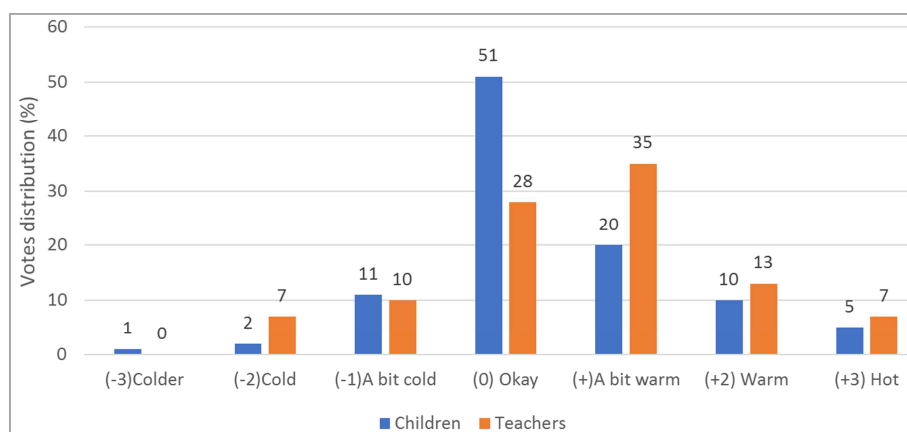


Figure 12. Comparing thermal sensation votes of teachers and schoolchildren.

The results further suggested that the thermal sensation votes of the children were more spread compared to that of their teachers in the same indoor environment. The diverse activity of the children which produced different metabolic rates and the

inability of some of them to adapt as they wished because of some restricted adaptive opportunities likely influenced the diverse result in their thermal sensation. The teachers' activities were similar to one another and resulted in a similar metabolic

rate. Equally, all the teachers had the freedom to use adaptive opportunities available in the classrooms. These influenced the clustering of the result of their thermal sensation.

4.4.2. Thermal Preference

Poor correlation was also observed in the thermal preference of the students and the teachers, especially on the wanting to be warmer side of the 3-point McIntyre preference scale. While 13% of the students would prefer to be warmer, 28% of the teachers would prefer warmer conditions, indicating a significant difference in preferring to be warmer by 15%. 37% of the school children would prefer to remain in the thermal state they found themselves, while 32% of the teachers would rather prefer to remain in the thermal state, they found it. Using the thermal sensation scale, alongside the thermal preference scale, reveals further

differences between these two age groups. Relating the votes in Figures 12 and 13, 14% of the children who voted neutral on the thermal sensation scale would rather prefer to be cooler or warmer. While 4% of the teachers who voted neutral on the thermal sensation scale would rather prefer to be 'okay' on the preference scale. The reason for this higher shift in these two scales by the children may be linked to their higher metabolism when compared to that of their teachers. The higher activity of the children, when compared to that of their teachers, results in high fluctuations (unsteady) in their body temperature.

However, both groups of people shared a commonality by casting more votes on preference to be 'cooler' than on preference for 'no change' and on preference to be 'warmer'; 40% for the teachers and 50% for the schoolchildren.

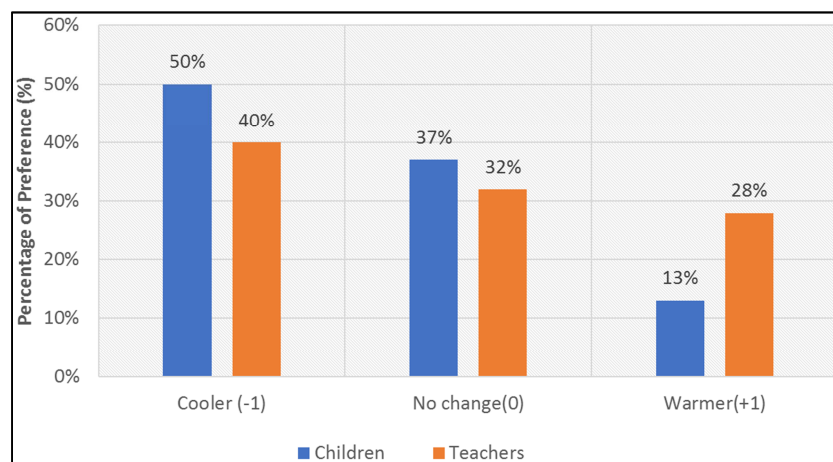


Figure 13. Comparing thermal preferences of teachers and schoolchildren.

4.4.3. Comparing Comfort Range

According to table 6, the 80% acceptability (± 0.85), the comfort bandwidths were 5.8K and 1.9K for the children and the teachers, respectively which indicated a significant comfort band difference of 3.9K. This suggests that the comfort range of children is wider than that of the adults as confirmed in the work of [24]. In order words, the students were adaptable to the indoor thermal conditions compared to their teachers.

The observation in this work about the difference in comfort perception of children and adults was also highlighted in the previous works of some thermal comfort researchers. For example, the levels of responses between children were found to have a lot of variance, and classroom activities were more diverse than adult activities over a typical day [25]. Also, in a review paper on field studies on thermal comfort, children were observed to have different levels of thermal sensation, different metabolic rates, different clothing restrictions, and

different sensitivities to temperature changes [26].

Furthermore, a check on the summary Table 6 shows that differences also existed in thermal perception between these two age groups, considering the upper limits and the lower limits of the comfort temperature. For instance, while the upper limit of the children was 31.6°C that of their teachers was 29.9°C, a difference in comfort temperature of 1.7K considering the 80% acceptability (± 0.85). This suggested that the children accepted higher indoor temperature in the classrooms by up to 1.7K more (higher temperature) compared with the teachers who shared the same classroom environment with them. Also, the children were able to accept lower indoor temperature by 2.2K more (lower temperature) compared to their teachers, considering the 80% acceptability (± 0.85). The result is in agreement with the findings from previous works that children likely prefer a cooler temperature than adults [14, 28, 6, 24].

Table 6. Comparing thermal perception of students and teachers.

Group	Neutral Temp (°C)	TSV mean	Comfort Bandwidth		Comfort limits				Sensitivity	Correlation Coefficient (R ²)
			± 0.85 (80%)	± 0.5 (90%)	Upper ± 0.85 (80%)	Lower ± 0.85 (80%)	Upper ± 0.5 (90%)	Lower ± 0.5 (90%)		
Children	28.8	+16	5.8	1.7	31.6	25.8	30.4	28.7	0.29	0.51
Teachers	28.9	+55	1.9	1.1	29.9	28.0	29.5	28.4	0.87	0.70

4.4.4. Comparing Coefficient of Determination (r^2)

The coefficient of determination (r^2) is another way of checking how sensitive building occupants are to variations in indoor temperatures. As shown in Table 6, the regression results from the regression of mean thermal sensation votes and the indoor operative temperatures produced r^2 with a value of 0.51 for the children and 0.70 for the teachers. The value from the children is low, while that from the teachers is high. However, for surveys involving human behaviors, an r^2 value as low as 0.40 is often considered a strong correlation [26]. Lower r^2 indicates better adaptation to indoor thermal conditions. The lower value reported by the children suggested that the studied children were more tolerant of the changes in the indoor thermal conditions compared to their teachers. This means that a change of 1.9K in the room temperature changed the children's thermal sensation by 1 scale unit, while a change of 1.4K in the room temperature changed the teacher's thermal sensation by 1 scale unit. The same finding was also reported in the works of [19, 15, 18].

5. Conclusion

This study is part of the wider fieldwork undertaken to investigate the comfort temperature in a primary school setting in the warm and humid environment. Generally, occupants of buildings located in the tropical climates perceive thermal comfort as the indoor environmental component that gives them most concern [27]. In this paper, the need to focus on comparison of the comfort temperature of schoolchildren and their teachers became imperative. This is because, both age groups stay in the same indoor environment where they are exposed to the same indoor thermal conditions. As observed in the literature review, the research on thermal comfort of building occupants championed by Professor Fanger did not include children in the sample of occupants for the investigation of thermal comfort. It is of recent that research is being focused on young children to determine their thermal comfort. This comparative analysis produced the following results.

- 1) The children perceived different thermal comfort from what their teachers perceived.
- 2) The mean thermal sensation of the children was +0.16, while that of their teachers was +0.58.
- 3) While the preferred temperature of the children was 27.4°C, that of their teachers was 29.4°C.
- 4) The comfort range of the children was 25.8 - 31.6°C, while that of their teachers was 28.0 -29.9°C.

The findings from this work will guide professionals in the built environment, especially architects when designing primary school buildings in warm and humid climates. However, further research work is recommended to furnish more information about the comfort temperature of schoolchildren and their teachers, not only from the warm and humid climates but also from other climatic regions in Nigeria.

Conflict of Interest

The authors declare that they have no competing interests.

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