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Assessment of Temperature and Relative Humidity on Human Comfort at Enugu State University of Science and Technology (Esut) Campus, Nigeria

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ABSTRACT: *The paper examined the effect of temperature and relative humidity on the human comfort level in the ESUT campus. The five minutes daily minimum and maximum temperature and relative humidity were used for the study from January 2012 to December 2019 using the Automatic Weather Station in ESUT. The minimum and maximum temperature and relative humidity were summed up to obtain daily, weekly and monthly mean temperature and relative humidity. Five hundred questionnaires were administered to students to obtain their response on the condition of their lectures halls during lecture hours and to find out the comfortable temperature zone based on the weather of the ESUT campus. The result shows that the air temperature at the lecture hall range from 24°C to 31°C, relative humidity was between 54% to 62%, while the air velocity was 0.15m/s. It indicates that temperatures in the lectures are outside the comfort temperature zone specified in the National Standard according to ASHRAE; 22.2°C to 26.7°C for educational buildings. The questionnaire survey shows that 60.2% of the total students rated the thermal comfort level in the lecture halls as NOT ACCEPTABLE. The Time Series analysis established the pattern of Temperature and Relative Humidity with a positive trend line equation of yt = 27.747+0.0239*t for temperature, and yt = 58.0404+1.85490*t for relative humidity. It implies that temperature, and RH, are expected to increase with the respective trend line equation. Therefore, there is a need for sustainable environmental planning to adapt to climate variability and change.*

Keyword: *Temperature, humidity, climate change, environment, comfort,*

INTRODUCTION

Human Comfort by ASHARE (2017) is the condition of the mind that expresses satisfaction with the thermal environment. It is determined by personal factors such as metabolic rate and clothing and environmental factors: indoors (within a building) or outdoors (ambient conditions) like air temperature, mean radiant temperature, relative humidity, and air velocity (Prek and Butala, 2017). The combination of these factors creates an environment for humans. In the era of climate change, studies have predicted an increase in the number of hot days and nights, and extended periods of the hot season may lead to a high amount of heat waves in many areas (Ma *et al.,* 2016). Some of these impacts are experienced in African because of multiple existing stresses and low adaptive capacity (Sylla *et al.,* 2016). As the average surface earth temperature increases, the human body will adjust to maintain the thermal constant produced during metabolism and other environmental conditions (Protsiv *et al.,* 2020). The combination of high temperatures with relative humidity may lead to conditions beyond the human heat tolerance limit of 35–37ºC. At this temperature, the body cannot cool through sweating (USGCRP, 2016). High temperatures with high relative humidity place tremendous stress on the human body. Periods of high heat stress usually occur in January, February, October, March, and April (Chowdhury *et al.,* 2017) during these periods, as the body responds to thermoregulatory functions sweating is the primary mechanism. At a relative humidity of 40% and above and a temperature of 30ºC healthy individuals may begin to experience increasing tiredness and irritability in a prolonged activity (Kovats and Hajat, 2008). Therefore, this study seeks to examine the thermal comfort of ESUT during lecture hours using temperature and relative humidity.

MATERIAL AND METHOD

Study Area

ESUT is at Agbani, the headquarter of Nkanu West Local Government Area of Enugu State, Nigeria. ESUT lies in latitude 6°51’24” N and longitude 7°23’45” E. According to NiMet (2015), the monthly temperature of Agbani is 26.6 °C, and 32°C, mean monthly rainfall is about 140mm, the relative humidity ranges between 40% and 89%, while surface pressure is about 985.5hpa. The climate is tropical according to the Köppen-Geiger climate classification. ESUT is covered by a savanna forest with laterite soil.

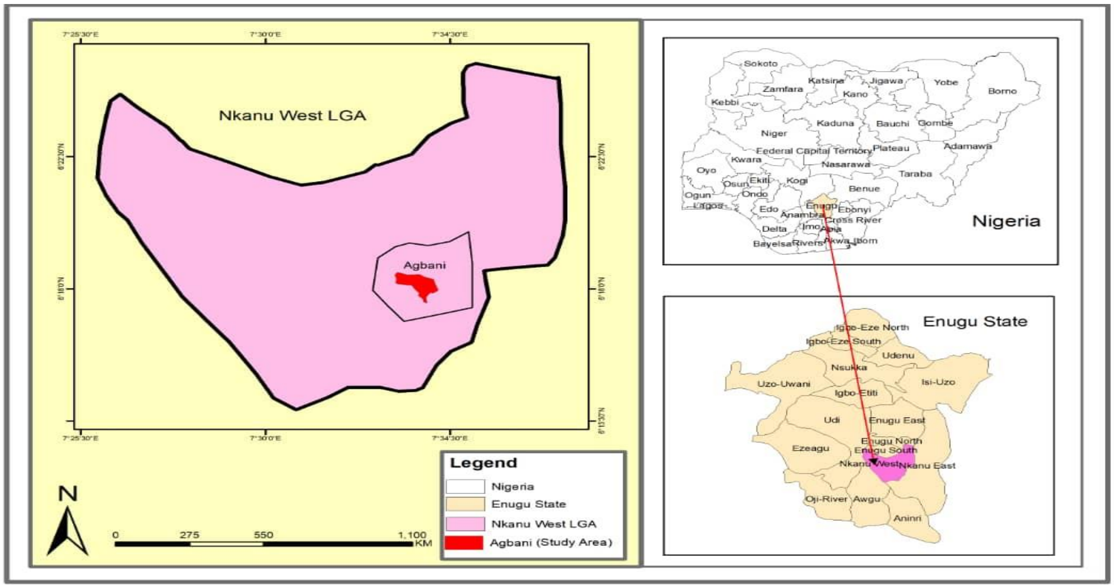

Figure 1: Map of Nigeria showing Enugu State
Map of Enugu state showing location of study area (Agbani, Nkanu West).
Source: Okoro *et al.,* 2019

Thirty lecture halls were randomly selected from all the faculties at ESUT for the study. The study used field measurement and surveyed questionnaires to gather information from the students. The questions reflect the type of clothing, student activities, thermal sensation, thermal comfort, thermal preference, and thermal acceptance. The questionnaire was administered from March 11th to 15th 2019 at noon. A digital thermo-hygrometer and anemometer were also used to measure the air temperature and the relative humidity of the lecture halls. Temperature and relative humidity data were also obtained from ESUT Meteorology Station. The data were in five (5) minutes intervals from January 2012 till December 2019. The data were summed up to obtain a daily temperature and relative humidity. The daily temperature and relative humidity were summed and divided by the number of days in the month to derive the mean monthly temperature and relative humidity using an Excel package:

$$Mean = \frac{S}{C}$$

Where S = Sum of the total T or RH per month
C = Count per five minutes

The result of the temperature, relative humidity, and questionnaire was tabulated. Trend regression analysis was used to predict a trend in the annual mean temperature and relative humidity.

RESULT

Table 3.1: Observed mean meteorological parameters at the lecture halls

Meteorological Parameters	*Min*	*Max*	*Mean*
Temperature	24^0C	31^0C	27.5^0C
Relative humidity	54%	62%	58%
Air velocity	0.15m/s	0.15m/s	0.15m/s

The mean air temperature conditions of the surveyed classrooms are 27.5°C, relative humidity was 58%, while the air velocity was 0.15m/s. These show that the lecture halls have high temperatures during the day.

Table 3.2: Distribution of questionnaire

SEX	*LEVEL*						
	UGY1	*UGY2*	*UGY3*	*UGY4*	*UGY5*	*PGS*	*TOTAL*
Male	35	44	37	29	41	58	244
Female	40	48	35	58	41	26	248
TOTAL	71	90	88	87	79	77	492

Note: UGY1 = Undergraduate Year 1, UGY2 = Undergraduate Year 2,
UGY3 = Undergraduate Year 3, UGY4 = Undergraduate Year 4,
UYG5 = Undergraduate Year 5, PGS = Postgraduate Students

Five hundred (500) questionnaire was administered to the student and Four hundred and Ninety Two was returned.

Analysis of the questionnaire results

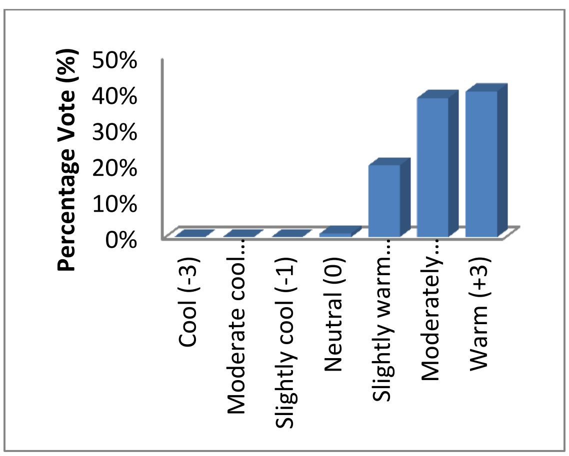

Figure 3.1: Students vote on thermal sensation

The results were obtained using a 7-point thermal sensation subjective scale (-3 cool, -2 moderate cool, -1 slightly cool, 0 neutral, +1 slightly warm, +2 moderate warm, +3 warm). The result shows that 1.01% of the students voted for neutral, 19.92% voted for slightly warm, 38.62% voted for moderately warm, while 40.45% voted for warm sensation. The ASHRAE standard 55 specified that an acceptable thermal environment should have 80% of the respondents vote for the central categories that are -1 (slightly cool), 0 (neutral), and +1 (slightly warm). In this research, only 20.93% voted within the central three categories, showing that the students were not comfortable in the lecture halls.

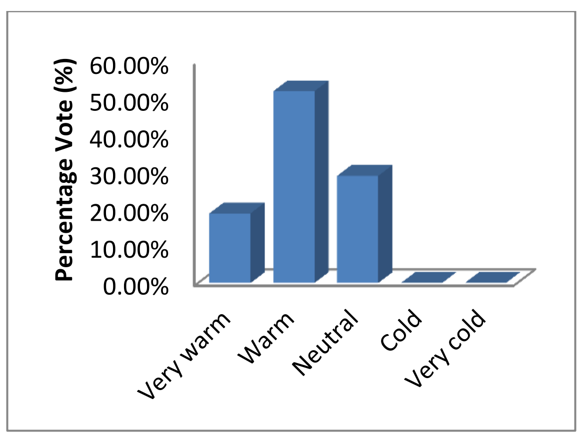

Figure 3.2: Students vote on air temperature

The majority of the students voted for neutral sensation, warm sensation, and very warm sensation. The ASHRAE standard specified that an acceptable thermal environment should have 80% of occupants vote for the central categories (-1, 0, +1). In this research, students vote for the central category which is within the ASHRAE standard. It shows that the students were in thermal acceptable conditions within the lecture halls.

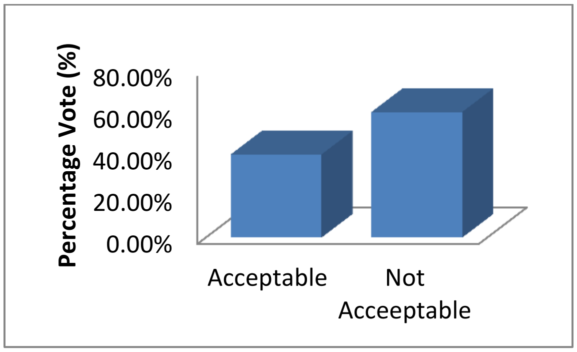

Figure 3.3: Students vote on thermal acceptability

The responses on thermal acceptability are presented in figure 3.3. The majority (60.16%) of the students voted not acceptable, while 39.84% voted acceptable. The result is attributed to many factors that were not considered in the design of the lecture halls.

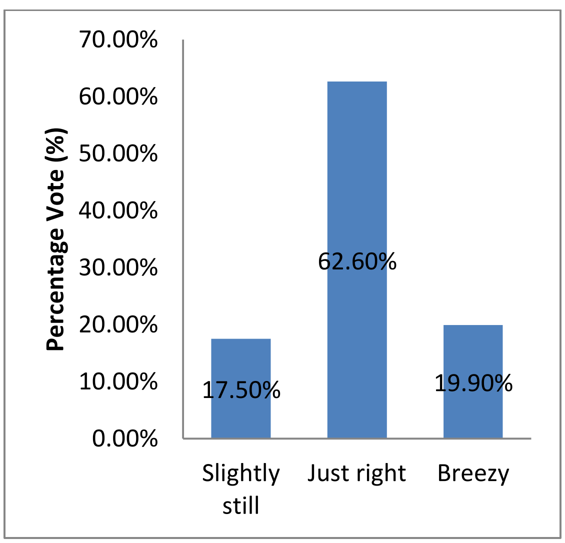

Figure 3.4: Students vote on air movement

The result shows that with 17.5% of the students are saying that the air movement is slightly still, 62.69%% are saying that the air movement is just right, while 19.90% said that the air is breezy.

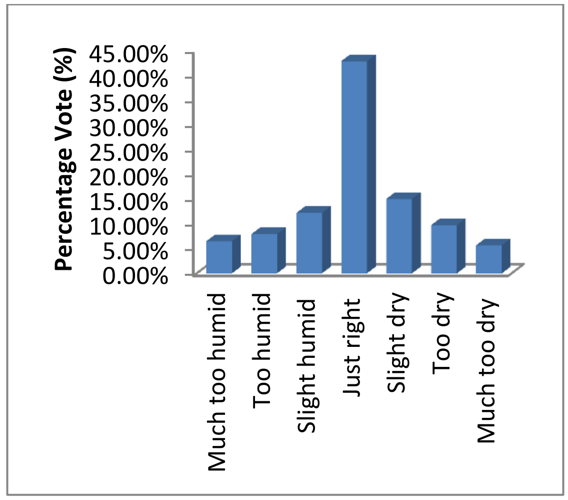

Figure 3.5: Students vote on humidity sensation

The humidity assessment uses the subjective scale of -3 (much too dry), -2 (too dry), -1 (slightly dry), 0 (just right), +1 (slightly humid), +2 (too humid), and +3 (much too humid). The result shows that 70.13% of the students voted within the categories (-1, 0, +1). Therefore, the relative humidity was comfortable for most of the students in their lecture halls.

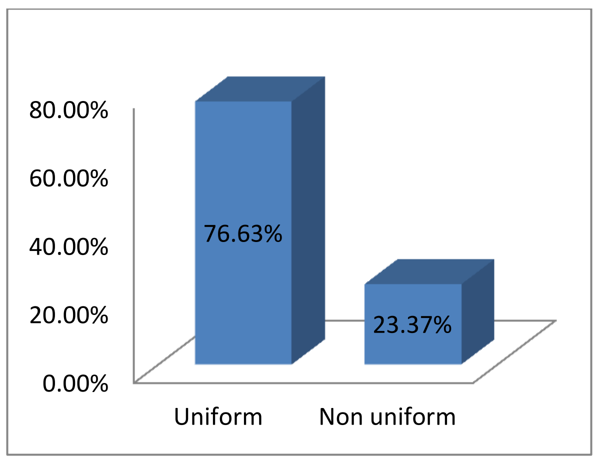

Figure 3.6: Students dressing type

The result shows that 76.63% of the students identified to wear a uniform, while 23.37% don't wear school uniforms.

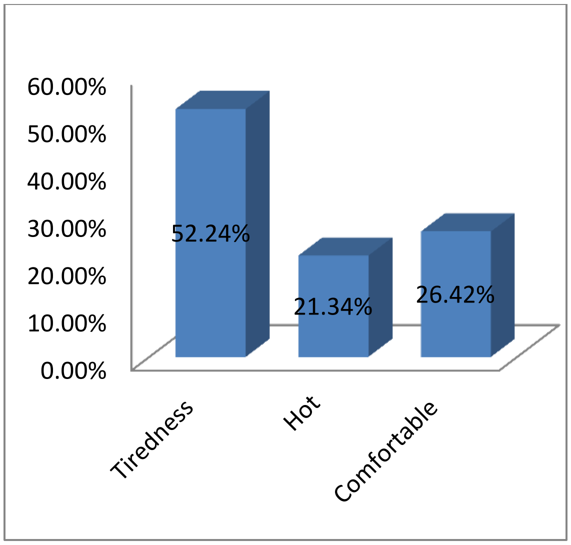

Figure 3.7: Students response after lecture activities

Figure 3.7 shows the responses of the students after lectures. 52.24% complained of tiredness after lectures, 21.34% feel hot, while 26.42% feels comfortable after lectures.

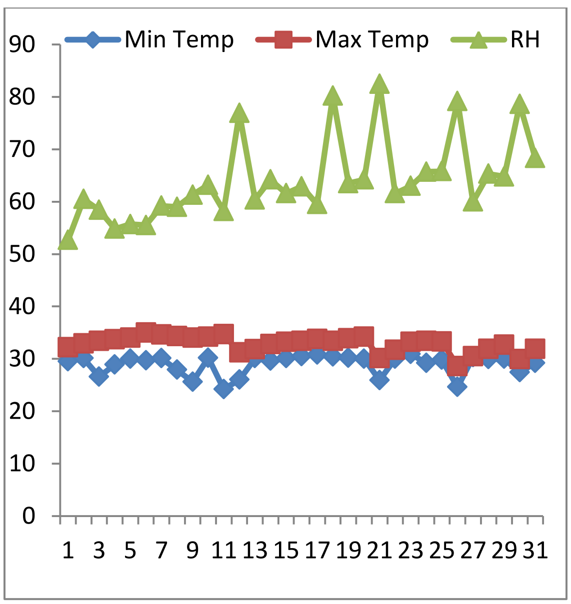

Figure 3.8: Min. and Max. Temperature and Relative humidity for March, 2019.

In March 2019, the 6th of March recorded the highest mean temperature (32.3°C). The RH was highest on 21st March (82.5%).

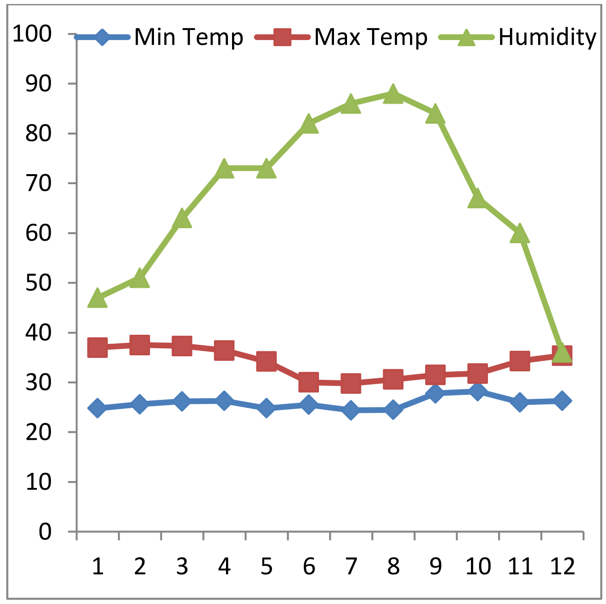

Figure 3.9: Min. and Max. Temperature and Relative humidity from January to December, 2019.

In 2019, the annual mean temperature is 29.8°C, the month of March recorded the highest temperature of 31.8°C. The annual mean of RH is 68%, the highest RH was in August (88%).

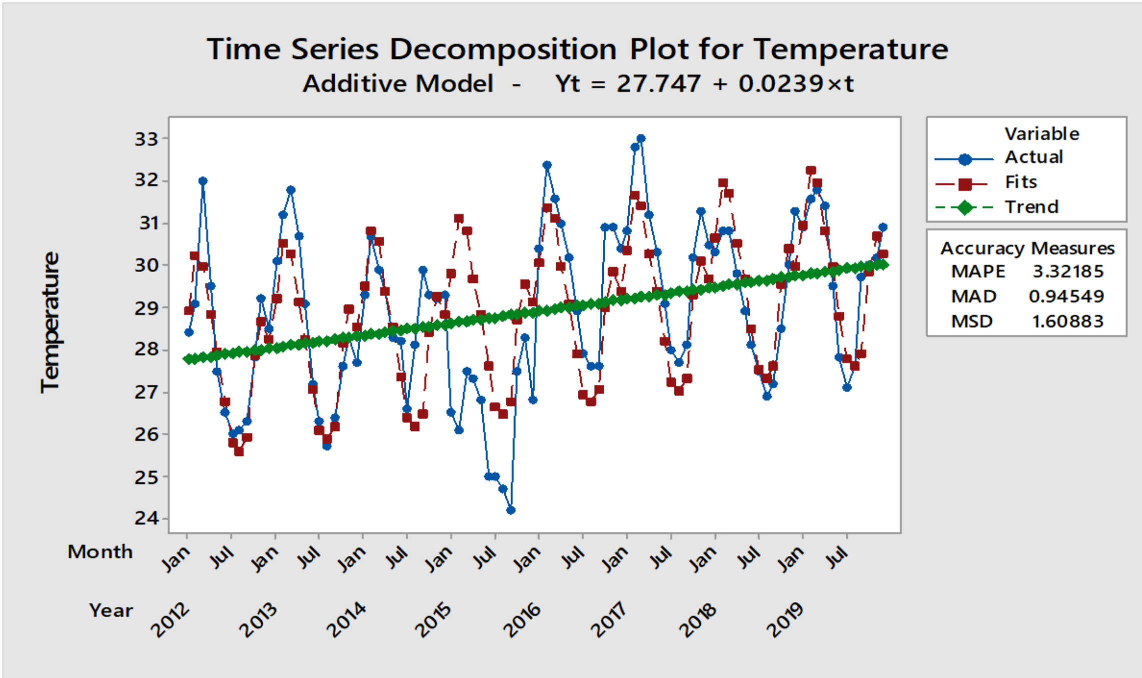

Figure 3.10: Temperature trend from 2012 to 2019

The seasonal trend of temperature shows an increasing pattern with a trend line of yt=27.747+0.0239*t on average. It means that the temperature is increasing monthly from 2012 to 2019.

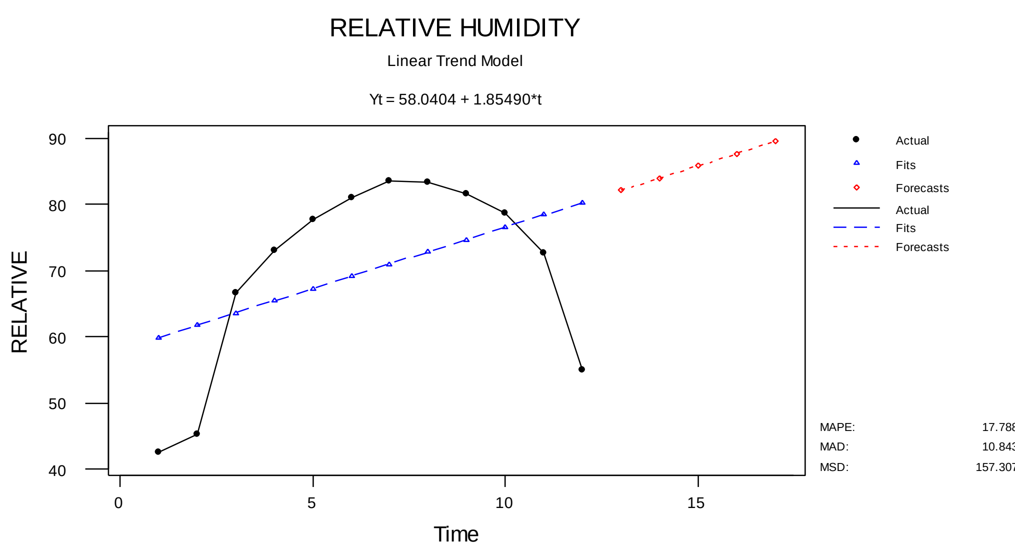

Figure 3.10: Humidity trend from 2012 to 2019

The seasonal trend of humidity shows an increasing pattern with a trend line of yt=58.040+1.85490*t on average. It means that the humidity is increasing monthly from 2012 to 2019.

DISCUSSION

The condition of the surveyed lecture halls shows the hot thermal environments. The air temperature in the lecture halls ranges from 24°C to 31°C, with an average of 27.5°C, which already is beyond the thermal comfort specified in the National Standard by to ASHRAE (2015); 22.2°C to 26.7°C for educational buildings. This condition could have a problem for students (Puteh *et al.,* 2012). However, the student's responses on the thermal sensation give similar figures, where more than 95% voted within the (+1 to +3) option. This thermal environment is quite different from the one recorded in the secondary school in the tropics (Baharuddin *et al.,* 2018) and similar to the result recorded by Hayatu *et al.,* 2015) in Nigeria. These indicate that naturally ventilated buildings in the tropic area in Nigeria experience hot temperatures during the daytime.

A high percentage of students (more than 90%) voted for options (+1 to +3). It shows that students are not comfortable in the lecture halls because of the hot temperature. The student's responses indicate that they value both thermal sensation and comfort perception. A similar result was recorded in Hayatu *et al.,* (2015) the students opined that the lecture halls are unacceptable at high temperatures. Different results were also observed in Hamzah *et al.,* (2018) and Abba *et al.* (2019) explaining that many students still feel comfortable (−1 to +1) based on thermal sensation and thermal comfort. Though, the comfort zone is outside the ASHRAE standard. The students expressed satisfaction with the thermal environment. Bridger (2008) emphasized that whether an individual feels thermally comfortable or not varies from one individual to another. Both can be in the same teaching/learning space but have different thermal comfort even when exposed to the same indoor environmental conditions. State of health, age, physical activities, type of clothing, the physique of the individual, and the degree of acclimatization determine the thermal comfort.

ESUT as a learning environment, more than 60% of the students voted for the unacceptable thermal condition while 39.84% voted for the accepted thermal condition of the ESUT campus. We observed that the temperature range of ESUT is above the standard thermal condition zone. Therefore, 52.24% of the students complained that they are tired after lecture periods, 26.42% feel comfortable, while 21.34% feel hot. This result is similar to Alvouy *et al.* (2016) that increased temperature impacts student learning by altering human physiology and cognition. When students experience thermal discomfit, it causes stress and affects learning (Tamaraukuro and Japo, 2016).

The result shows that the students voted within the category of (-1, 0, +1). It means that the humidity of ESUT is comfortable for the student at their lecture halls. Baharuddin *et al.,* (2018) recorded a similar result. According to Indraganti *et al.,* (2012), low humidity helps to reduce or moderate human comfort. A period of low humidity encourages the evaporation of sweat from the human body and allows rapid cooling of the skin. The temperature and relative humidity show a positive increasing trend. The report of Akinbile *et al.,* (2019) agrees with the findings of this study.

CONCLUSION

The study revealed that the air temperature in the lecture halls of ESUT campus range from 24°C to 31°C, with an average of 27.5°C, which already is beyond the thermal comfort specified in the National Standard by to ASHRAE (2015) 22.2°C to 26.7°C for educational buildings. The result of thermal discomfort in the lecture hall affected students learning in terms of concentration, as students complain of tiredness after lectures. To improve effective teaching-learning in the ESUT campus, we recommend that the teaching-learning indoor environment should be assessed for thermal comfort by providing the lecture halls with adequate ventilation and installation of air conditioners in the lecture halls.

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