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Research Article

Indoor Environmental Quality of Lecture-Halls at Cape Coast Technical University, Ghana

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Abstract

Global climate change and global warming has contributed to increase in air temperature, both outdoor and indoor environments. Educational buildings are to provide a comfortable environment for teaching and learning activities. The rise in air temperature, density of occupants and range of activities in lecture-halls have resulted in indoor air environment discomfort for students. The study sough to determine the air quality of lecture-halls at Cape Coast Technical University (CCTU), Ghana. The variables for building-related factors of thermal comfort in a naturally ventilated lecture-halls were measured, by examining the design of the ventilation system and window opening, and closing behaviours. The administering of the questionnaire was done through "reference by reference" technique or "snowball" sampling technique. The main classroom blocks/lecture-halls within the intuition (New block, old block, building auditorium, electrical auditorium and marketing block) were covered during the administration of the questionnaires. Exploratory factor analysis was used for the data collected, and further factor extraction and factor rotation were conducted on the variables to identify non-observable and non-measurable variables. Extracted factors were rotated to obtain common factors by rank analysis and calculating their coefficients and factor loadings. Findings show that the classroom blocks/lecture halls had less than sixty students. Most of the classroom blocks/lecture halls had two (2) doors with louver blade windows, and one-meter interval as sitting arrangements. Windows were often opened or using ceiling fans to regulate the indoor environment. Students mostly wore short sleeves shirts made of cotton as a means of maintaining thermal comfort. Lack of concentration of the students on their lessons, distraction of students' attention from their lecturers were attributed to poor quality of condition of classroom environment. Appropriate measures should be put in place by the Development Officer of CCTU to improve on classrooms/lecture halls environmental quality.

Keywords: ***Doors and windows openings, naturally ventilated classrooms, thermal comfort.***

1. Introduction

Here The performance of occupants in educational building has declined due to poor thermal comfort of indoor condition and this in critical in a natural ventilated building (Zamri et. al. (2019). Ventilation factor is a crucial factor that influences the indoor environment and thus influence the thermal comfort of the building as indicated by Zamri et. al. (2019) and the most common building-related factors are window design and window opening and closing behaviour. Indoor Environmental Quality (IEQ) is most simply described as the conditions inside the building. It includes air quality, but also access to daylight and views, pleasant acoustic conditions, and occupant control over lighting and thermal comfort (NIOSH, 2013). The increase in outdoor and indoor environments has been attributed to global climate change and global warming (Zamri et. al., 2019). The comfort temperature was reported by Rijal, Humphreys & Nicol (2017) to relate primarily to the indoor temperature, but suggested an adaptive relationship can be derived to estimate the indoor comfort temperature from the prevailing outdoor temperature. A transverse questionnaire study conducted on 30 university classrooms and 900 respondents during summer in India revealed that preferred temperature of 26.4 °C, high air speed for restoring thermal comfort by opening windows and doors as well as putting on fans. A prediction of more than 80% ceiling fan usage at indoor temperature of 29°C was estimated (Kumar et al., 2018). Several researchers (Mendell, 2005; Ameerudin, 2014 & Puteh, 2012) posited that unconducive environment within an educational setting will disrupt teaching and learning activities, reduce teachers' performance and cause lethargy to the students. They further indicated that it may lead to lack of concentration of the students on their lesson. Corgnati et al. (2007) argued that educational institutions with high level of environmental quality could improve students' attention, concentration, learning, hearing and performance. Toftum et al. (2015) on the other hand indicated that had resulted in the poor achievement of the students. Several factors, such as lighting, air quality and damp conditions of a building determines IEQ. Moreover, factors such as indoor temperatures, relative humidity and ventilation levels can also affect how individuals respond to the indoor environment (NIOSH, 2013). The study sought to determine the air quality of lecture-halls at Cape Coast Technical University.

2. Thermal Comfort in Naturally Ventilated Buildings

This section presents review on thermal comfort in naturally ventilated building and building-related factors". Gou, Gamage, Lau (2018) conducted a pilot study (longitudinal survey) of thermal comfort and adaptive behaviours of respondents of naturally ventilated dormitories at the National University of Singapore. It was discovered that occupants in naturally ventilated building in tropics experienced higher temperature (acceptable however) than the comfort standard for naturally conditioned spaces in American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE). Controlling air velocity was found to be the preferred way of thermal adaptation. A thermal comfort study in 28 naturally ventilated (NV) and air-conditioned (AC) on 2787 individuals over fourteen months in Chennai and Hyderabad, India revealed a mean comfort temperature of 28.0 °C in NV mode and 26.4 °C in AC mode, which are above the Indian Standard limit (26.0°C). Air speeds of 1m/s improved the thermal comfort by 2.7 K in both modes. Logistic regression predicted 87% and 50% fan usage at 29 °C in NV and AC modes respectively (Indraganti, Ooka, Rijal & Brager, 2014). Zamri et. al. (2019) posited that "thermal comfort variables and building-related factors have a significant relationship with each other in order to determine thermal comfort in a building. The design of the ventilation system in a building (window and door opening design) have influence on thermal comfort of occupants Increasing the indoor air velocity by turning on mechanical fans and opening the door/windows for cross ventilation and putting on light clothes were the adaptive behaviours used to reduce heat stresses. The health and wellbeing of occupants within a given space of a building environment is termed as indoor environmental quality (IEQ) (National Institute for Occupational Safety and Health (NIOSH, 2013).

In a study by Kumar et al (2016) on 32 naturally ventilated building with 2610 respondents over four years and different seasons Sensations and preferences for air temperature, relative humidity and air velocity on ASHRAE seven point and five-point scales as well as methods of thermal adaptation such as adjusting clothing, window opening, and use of air circulation fans were examined. The comfort temperature for summer and winter was found to be 30.6°C and 25.2°C respectively. Lu et al. (2018) study on work environment (good ventilation) of 16 institutions comprising of 87 offices on 389 respondents showed to have risk reducing ability of Sick building syndrome (SBS) symptoms. SBS was defined by Lu et al. (2018) as a combination of symptoms that can be attributed to exposure to specific building conditions. Sun et al (2019 was of the view that dry air perception in SBS symptoms was as the result of influence on indoor air quality and ventilation. In a study by Jowkar et al. (2020) where 3000 participants were involved showed that students preferred to restore their thermal comfort through personal adaptive behaviour. However, environmental behaviour was shown to be preferred in the studios where the occupants have a greater freedom level. Jowkar et al (2020) posited that comfort temperature ranges in different classroom types. In a study by Rijal, Humphreys & Nicol (2017) a view to suggesting an adaptive model for seasonal adaptation to temperature in Japanes offices was done. Thermal comfort transverse surveys were conducted on 4660 samples from 1350 people in 11 office buildings in Tokyo and Yokohama, Japan. Respondents were satisfied with thermal environment even though the temperatures were lower than the recommended temperatures by the Japanese government. The cost of poor indoor environmental quality (IEQ) can be higher than cost of space conditioning and ventilation (Seppänen & Fisk, 2016). Therefore, there is the need to do a proper assessment of buildings as indicated by Mustapa et al. (2016) and further analysis of thermal comfort and occupant behaviour is very useful in energy saving programmes. Mustapa et al (2016) studied the thermal comfort and adaptive behaviour of respondents in university buildings with free running (FR) and cooling (CL) mode offices in Fukuoka, Japan and revealed that adaptive behaviours of occupants were more active in FR mode than in CL mode. Several researchers (Montazami, 2017; Samad, 2017 & Huang, 2015) have indicated that classroom condition of an environment has influence on teaching and learning process. Building-related factors have a significant influence in the study of thermal comfort as they affect the result of thermal comfort (Zamri et. al. 2019). The less common building-related factors that are measured by the researchers to determine thermal comfort are shading device and building envelope (Zamri et. al. 2019). Barbosa (2015), the application of shading devices is the most influential factor to determine building thermal performance. Kirimtat (2016), mentioned in their study that uses the proper type of shading devices is vital in a study of thermal comfort in a building.

3. Methodology

This section presents the various methods used to collect data and type of analysis used for the study. Window design and window opening and closing behaviours were considered for the study because they were found to be the most common building related factors (Zamri et. al., 2019) and these variables were measured by several researchers on Indoor Environmental Quality (Zamri et. al. 2019). The questionnaire was designed, taking into consideration building-related factors of thermal comfort in a naturally ventilated classroom blocks/lecture-halls and the design of the ventilation system, and window opening and closing behaviours. The designed questionnaires were administered among students in different classes and at various sections of the lecture-halls within Cape Coast Technical University. Due to the large number of students in the institution, the "reference by reference" technique or "snowball" sampling technique was used to search for the students in their various classroom blocks/lecture-halls to answer the questionnaires (Wang et al., 2018). Besides, the technique of "reference by reference" or "snowball" sampling technique, students within campus or those who were out of their classrooms/lecture-halls or have completed their lectures were also contacted to obtain relevant information (Wang et al., 2018). Five research assistants from the department of building technology were involved in the data collection. Each research assistant was stationed at each of the five blocks (New block, old block, building auditorium, electrical auditorium and marketing block). These blocks serve as the main classroom blocks/lecture-halls within the institution. The exercise was carried out throughout the week to ensure that each lecture-hall was covered and most of the students on campus were captured during the data collection. At the end of the week's exercise, the researchers and their assistants converged to examine the classroom blocks/lecture-halls covered from various departments to ensure that no class was left out of the study. The entire exercise was carried out for a period of four weeks. All the information collected based on the various classroom blocks/lecture-halls were put together to determine those departments which were covered twice in the study and deleted before the data were captured for analysis. Exploratory factor analysis was used for the data collected, and further factor extraction and factor rotation were conducted on the variables to identify non-observable and non-measurable variables. Extracted factors were rotated to obtain common factors by rank analysis and calculating their coefficients and factor loadings. All the variables under poor quality of condition for classroom environment, high level of environmental quality that improves students' performance, and other factors that could affect thermal comfort were subjected to principal component with varimax rotation. The factors were extracted based on the content of the items with factor loadings exceeding 0.40. The greater the loading, the higher the variable's status as a pure measure of the factor. The exercise led to the use of the Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy and Bartlett's test of sphericity. The KMO of higher than 0.040 and a Bartlett's test of sphericity being statistically significant at 0.05 support the factorability of the data set. The preceding section presents the findings.

4. Findings

This section presents the findings form the survey conducted on indoor environmental quality of classroom blocks/lecture halls at Cape Coast Technical University.

Information about the classroom blocks/lecture halls

There were five different blocks (New block, old block, building auditorium, electrical auditorium and marketing block) at Cape Coast Technical University (CCTU) used as lecture halls. Majority (29.3) of the respondents were found at the electrical block. Followed by 'old block' and 'new block' with 24.4% and 23.4% respectively. The least respondents were found at the 'marketing auditorium.

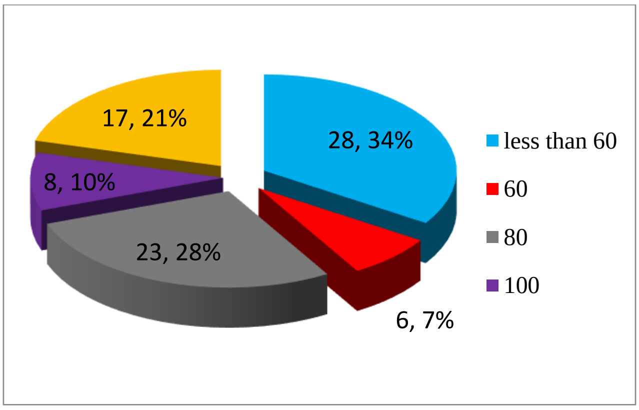

Figure 1: Number of seats in a classroom

Figure 1 shows that majority (28.34%) of the respondents were found in a classroom block with less than sixty (60) students. This is followed by a classroom with eighty (80) students and classroom with more than one hundred (100) students. The least number of respondents were found in a classroom with sixty (60) students.

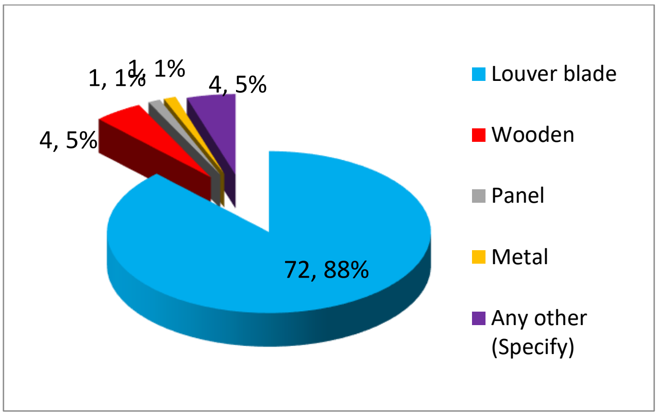

Figure 2: Type of window

Figure 2 shows that most (72.39%) of the lecture halls had louver blade windows and followed by wooden, and different specifications. Very few had metal and panel windows. Most (41.5%) of the windows had ten (10) blades and few had more than ten (10) blades.

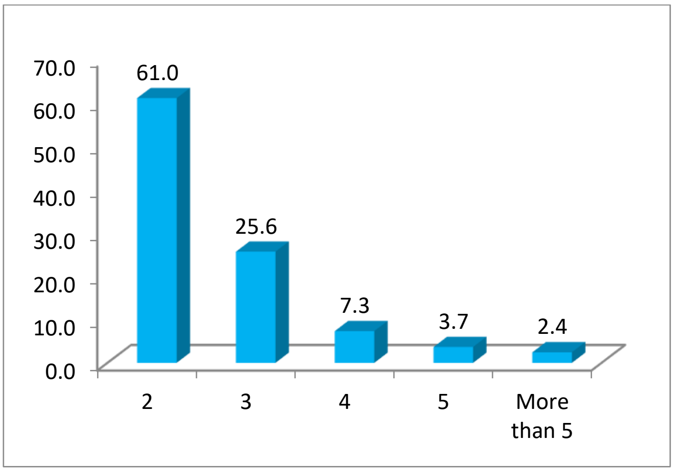

Figure 3: Number of doors

Figure 3 shows that most (61.0%) of the lecture halls had two (2) doors. This is followed by lecture halls with three (3) doors. Very few classroom blocks/lecture halls had five (5) or more doors. Most (44.54%) of the lecture halls had their doors made of wood. This is followed by doors made of panel (32.39%) and the least were made of glass.

Table 1: Distance between two seats in a classroom / lecture hall

	Frequency	Percent (%)
One-meter interval	19	23.2
Two meters interval	27	32.9
Three meters interval	20	24.4
Four meters interval	15	18.3
Any other	1	1.2
Total	82	100.0

Table 1 shows that majority (32.9%) of the respondents indicated that the distance between two seats had two-meters interval. This is followed by 24.4% of the respondents who indicated that the distance between two seats was three-meters interval. These are very common in architectural studios/ drawing rooms. Normal classrooms/lecture halls had one-meter interval seating arrangements with 23.2% of the respondents. Most (38.46%) of the respondents indicated that indoor temperature can be regulated by opening the windows. This is followed by 28.34% of the respondents who indicated that indoor temperature can be regulated by turning on the fan. Only 16.20% of the respondents indicated that indoor temperature can be regulated by opening the doors. Majority (50.61%) of respondents indicated that the regulator of the fan in the classroom/ lecture hall was normally on medium. This is followed by 20.24% of the respondents who indicated that the regulator was on fastest. The least (12.15%) indicated that it was on the lowest.

Information about means of adaptation, types of clothing and fabric

Table 2: Means of adaptation to maintain thermal comfort

	Frequency	Percent (%)
Putting on appropriate cloth	62	75.6
Taking in drinks	14	17.1
Using pomade	2	2.4
Any other	4	4.9
Total	82	100.0

Table 2 shows that majority (75.6%) of the respondents put on appropriate clothing in order to maintain thermal comfort. This is followed by those respondents who take in drinks on regular basis to maintain thermal comfort. Very few respondents use pomade as a means of maintaining thermal comfort.

Table 3: Type of clothing normally worn to school

	Frequency	Percent (%)
Double (inner and outer)	20	24.4
Short sleeves shirts	41	50.0
Long sleeves shirts	17	20.7
Any other	4	4.9
Total	82	100.0

Table 3 shows that majority (50.0%) of the respondents wore short sleeves shirts to school in order to maintain thermal comfort. This is followed by respondents who wore double (inner and other) clothing, and long sleeves shirts respectively in order to maintain thermal comfort.

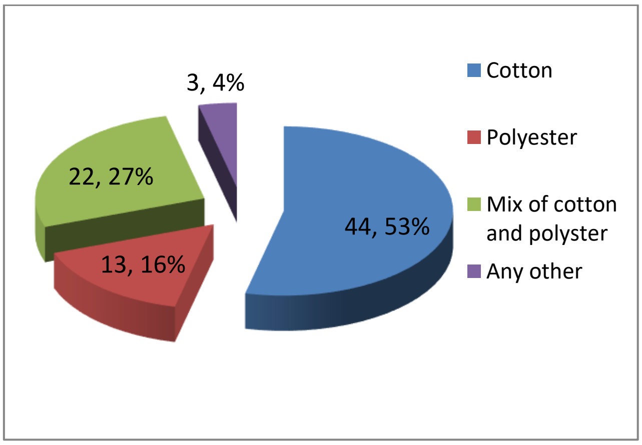

Figure 4: Type of fabric used to sew the clothes

Figure 4 shows that majority (44.5%) of the respondents wore cotton to school. This is followed by respondents who wore polyester, and mix of cotton and polyester respectively to school.

Table 4 shows a recorded mean ranged of 2.70 to 3.28 and a standard deviation range of 1.133 to 1.527. The nineth (9th) variable was ranked as the highest among the nine (9) variables with a mean of 3.28 and a standard deviation of 1.381. Followed by the sixth (6th) variable with a mean of 3.15 and a standard deviation of 1.248. The least among the nine (9) variables was the second (2nd) variable with a mean of 2.48 and a standard deviation of 1.199.

Table 4: Poor Quality Condition of Classroom Environment

	Mean	Std. Dev.	Mean Rank
Impact on teaching and learning process	3.04	1.527	5
Contribute to students' poor achievements	2.48	1.199	9
Good quality condition of classroom environment will lead to Improvement in students' performance	3.10	1.428	4
Discomfort environments in a classroom	2.70	1.411	8
Cause lethargy to the students	2.78	1.286	7
Disrupt students' attention from a lecturer	3.15	1.248	2
Disrupt teaching and learning activities	3.11	1.133	3
Reduce lecturers' performance	2.94	1.417	6
Contribute to lack of concentration of the students on their lessons	3.28	1.381	1

Table 5 shows a recorded mean ranged of 3.392 to 3.72 and a standard deviation range of 1.252 to 1.526. The fifth (5th) variable was ranked as the highest among the seven (7) variables with a mean of 3.72 and a standard deviation of 1.501. Followed by the seventh (7th) variable with a mean of 3.63 and a standard deviation of 1.252. The least among the seven (7) variables was the fourth (4th) variable with a mean of 3.39 and a standard deviation of 1.412.

Table 5: High Level of Environmental Quality Improves Students' Performance

	Mean	Std. Dev.	Mean Rank
Attention	3.50	1.526	**4**
Concentration	3.48	1.525	**5**
Learning	3.59	1.342	**3**
Performance	3.39	1.412	**7**
Comfortable indoor environment	3.72	1.501	**1**
Contribute to high performance	3.44	1.389	**6**
Excellent work quality of the students	3.63	1.252	**2**

Table 6 shows a recorded mean ranged of 3.05 to 3.56 and a standard deviation range of 1.147 to 1.774. The nineth (9^{th}) variable was ranked as the highest among the nine (9) variables with a mean of 3.56 and a standard deviation of 1.334. Followed by the tenth (10^{th}) variable with a mean of 3.54 and a standard deviation of 1.509. The last five (5) variables among the fourteen (14) variables have a mean range of 3.05 to 3.29 and standard deviation of 1.147 to 1.774.

Table 6: Other Factors that could Affect Thermal Comfort

	Mean	Std. Dev.	Mean Rank
Building orientation	3.05	1.515	14
Doors and windows closing and opening behaviour	3.24	1.402	12
Window to wall ratio	3.28	1.147	11
Wall and roof materials	3.10	1.496	13
Shading device	3.29	1.774	10
Design of doors and windows have an influence on heat gain/heat loss of the building	3.46	1.199	4
Heat gain and heat loss result in increase and decrease of the temperature inside the room	3.38	1.411	7
Control of the opening is a vital factor in achieving thermal comfort in a building	3.38	1.339	7
Opening of windows increase the air movement in the room	3.56	1.334	1
Students prefer high air movement by opening windows and doors to restore their comfort	3.54	1.509	2
Design of ventilation system is critical to provide adequate ventilation in a room	3.49	1.459	3
A proper opening design of a building determines a good ventilation system for the building	3.33	1.611	9
Opening design also influences air movement in the room	3.46	1.549	4
Air movement in a building has an influence on human comfort	3.46	1.467	4

Kaiser-Meyer-Olkin Measure of Sampling Adequacy, Bartlett's Test of Sphericity, and Component Matrix

Table 7 shows that the p-value of the KMO = 0.869 is greater than the 0.05 significance level of 0.05 for the measure of sampling adequacy; thus, for quality of condition for classroom environment. The Bartlett's test of sphericity will be rejected at the significance level of 0.05. Thus, the correlation matrix is not an identity matrix since the p-value is less than 0.05.

Table 7: KMO and Bartlett's Test

Kaiser-Meyer-Olkin Measure of Sampling Adequacy		0.869
Bartlett's Test of Sphericity	Approx. Chi-Square	515.130
	Df	36
	Sig.	0.000

All the variables under consideration as shown in Table 8 have stronger factor loadings ranging from 0.664 to 0.910, which is higher than the minimum requirement of 0.40. Thus, the status of the variables serves as a pure measure of poor quality of condition for classroom environment.

Table 8: Component Matrix for Poor Quality of Condition for Classroom Environment

	Component 1
Impact on teaching and learning process.	
Contribute to students' poor achievements.	0.664
Good quality of condition of classroom environment will lead to Improvement in students' performance.	0.809
Discomfort environments in a classroom	0.856
Cause lethargic to the students.	0.856
Disrupt students' attention from a lecturer.	0.812
Disrupt teaching and learning activities.	0.745
Reduce lecturers' performance.	0.827
Contribute to lack of concentration of the students on their lessons.	0.910

Table 9 shows that the p-value of the KMO = 0.895 is greater than the 0.05 significance level of 0.05 for the measure of sampling adequacy; thus, for high level of environmental quality improves students' performance. The Bartlett's test of sphericity will be rejected at the significance level of 0.05. Thus, the correlation matrix is not an identity matrix since the p-value is less than 0.05.

Table 9: KMO and Bartlett's Test

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		0.895
Bartlett's Test of Sphericity	Approx. Chi-Square	602.602
	Df	21
	Sig.	.000

All the variables under consideration as shown in Table 10 have stronger factor loadings ranging from 0.674 to 0.925, which is higher than the minimum requirement of 0.40. Thus, the status of the variables serves as a pure measure of high level of environmental quality that improves students' performance.

Table 10: Component Matrix for High Level of Environmental Quality that Improves Students' Performance

	Component 1
Attention	0.924
Concentration	0.924
Learning	0.899
Performance	0.893
Comfortable indoor environment	0.917
Contribute to high performance	0.925
Excellent work quality of the students	0.674

Table 11 shows that the p-value of the KMO = 0.850 is greater than the 0.05 significance level of 0.05 for the measure of sampling adequacy; thus, for other factors that could affect thermal comfort. The Bartlett's test of sphericity will be rejected at the significance level of 0.05. Thus, the correlation matrix is not an identity matrix since the p-value is less than 0.05.

Table 11: KMO and Bartlett's Test

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		**0.850**
Bartlett's Test of Sphericity	Approx. Chi-Square	1328.230
	Df	91
	Sig.	.000

All the variables under consideration (components 1 and 2) as shown in Table 12 have stronger factor loadings ranging from 0.578 to 0.926, which is higher than the minimum requirement of 0.40. Component 1 had factor loadings ranging from 0.578 to 0.910 and component 2 had its factor loadings ranging from 0.717 to 0.926. Thus, the status of the variables serves as a pure measure of other factors that could affect thermal comfort.

Table 12: Rotated Component Matrix for Other Factors that could Affect Thermal Comfort

	Component	
	1	2
Window to wall ratio	0.578	
Shading device	0.910	
Heat gain and heat loss result in increase and decrease of the temperature inside the room	0.668	
Control of the opening is a vital factor in achieving thermal comfort in a building	0.735	
Students prefer high air movement by opening windows and doors to restore their comfort	0.825	
Design of ventilation system is critical to provide adequate ventilation in a room	0.818	
A proper opening design of a building determines a good ventilation system for the building	0.861	
Opening design also influences air movement in the room.	0.778	
Building orientation		0.908
Door and windows closing and opening behaviour.		0.718
Wall and roof materials		0.926
Design of doors and windows have an influence on heat gain/heat loss of the building		0.717
Opening of windows increase the air movement in the room.		0.592
Air movement in a building has an influence on human comfort		0.837

Extraction Method: Principal Component Analysis. Rotation Method: Varimax with Kaiser Normalization.

5. Discussion of findings

Most of the respondents were found in a classroom block/lecture hall with less than sixty (60) students. The classroom blocks/lecture hall had two (2) doors with louver blade windows. The classroom block/lecture hall had one-meter interval and the architectural studio/ drawing room had between two (2) and three (3) meters intervals. The indoor temperature can be regulated by opening the windows or using the ceiling fan and the findings concur with the findings of Kumar et al. (2018). Putting on appropriate clothes were found to be common among the students to maintain thermal comfort. Most of the students wore short sleeves shirts made of cotton to school as a means of maintaining thermal comfort. Poor quality of condition of classroom environment were found to reduce concentration of the students on their lessons, disrupt students' attention from a lecturer, disrupt teaching and learning activities. The findings concur with the findings of Montazami (2017), Samad (2017) and Hua,ng (2015). Whiles, high level of environmental quality that improves students' performance was attributed mostly to comfortable indoor environment, excellent work quality of the students, learning habit of the students and attention paid during classes. The findings concur with the findings of Mendell (2005), Ameerudin (2014) and Puteh (2012). Other factors that could affect thermal comfort were mostly found to be attributed to opening of windows and doors, design of ventilation system in the rooms, design of doors and windows of the buildings. The p-value of the KMO was found to be 0.869 at 0.000 significance for quality of condition for classroom environment. Their factor loadings range from 0.664 to 0.910, thus, the status of the variables serves as a pure measure of the factor. The p-value of the KMO was found to be 0.895 at 0.000 significance for high level of environmental quality that improves students' performance. Their factor loadings range from 0.674 to 0.925, thus, the status of the variables serves as a pure measure of the factor. The p-value of the KMO was found to be 0.850 at 0.000 significance. Their factor loadings range from 0.578 to 0.926, thus, the status of the variables serves as a pure measure of the factor.

6. Conclusion and Recommendations

The study sough to determine the air quality of classroom blocks/lecture-halls at Cape Coast Technical University (CCTU). The classroom blocks/lecture halls at CCTU are within the stipulated measure for indoor environmental quality. The doors and windows openings of the classroom blocks/lecture halls fall within the thermal comfort of naturally ventilated buildings. The management of CCTU under the supervision of the Development Officer should ensure that classroom blocks/lecture halls which are under poor conditions are put in good shape to improve on teaching and learning activities of students, their 'concentration on lessons, and draw their attention to their lecturers.

Declarations

Data availability

The datasets used for this study are available from the corresponding author on reasonable request.

Funding statement

Not applicable

Conflict of interest

The authors declare no conflict of interest

Acknowledgments

Not applicable

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