ASSESSMENT OF THERMAL COMFORT IN SOME SELECTED LECTURE ROOMS IN GIDAN-KWANO CAMPUS, FEDERAL UNIVERSITY OF TECHNOLOGY MINNA

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ABSTRACT

It is widely recognised that educational systems across the world involve different stages of learning where student spend different amounts of time in the class or lecture rooms. This study assessed the environmental factors in some selected Lecture rooms in Gidan-Kwano Campus of Federal University of Technology Minna, Niger State as they affect thermal comfort in the selected spaces, in relation to the recommended comfort zone by established standards. Fieldwork that involved the collection of data were conducted via the use of AirVisual Pro, wet and dry bulb thermometer device to monitor as well as measure the indoor environmental factors of thermal comfort (indoor air temperature and relative humidity) of the study area. The collected data were analysed using descriptive (mean) and inferential (Pearson's correlation) statistics. The results revealed that the temperature values in all the cases were slightly below 28°C, while the relative humidity values in the lecture rooms were well outside the comfort zone with average values of 88.8%, 86.1% and 85.3% for the studied indoor environment. It was concluded from the analyses of the results that the lecture rooms are not thermally comfortable enough. Therefore, it is recommended that a more conducive learning environment (lecture rooms) is needed to enable the students learn more and the lecturers to perform their duties productivity.

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CHAPTER ONE

1.0 INTRODUCTION

1.1 Background to the Study

People spend up to 90% of their time inside buildings, so the quality of their indoor thermal comfort has a significant impact on their quality of life (Arif *et al.,* 2016). *It is widely recognised that educational systems across the world involve different stages of learning where student spend different amounts of time in the class or lecture rooms (Wargocki & Wyon, 2013; De-Dear et al., 2013). Students between the ages of two to twenty-six years old spend a considerable amount of their waking hours in the classroom, (approximate ages from kindergarten to university) (De-Dear et al., 2013) and studies have shown the importance of thermal comfort in student achievement (*Mishra, *et al.,* 2017; Jing, *et al.,* 2019*).*

*Thermal comfort is established as a personal perception of the thermal environment and it is characterized as the neutral sensation experienced by the person in relation to a given thermal environment (Jara, 2015; American Society of Heating, Refrigeration and Air Conditioning Engineers ASHRAE, 2017). Expectations of thermal comfort depend on where the person is located, and the climatic conditions that exist inside and outside the enclosure (Djamila et al., 2013; Mirrahimi, et al., 2016). According to Jiang et al. (*2019*), the discomfort related to feeling hot or cold has a negative effect on the well-being of occupants.*

Studies have shown that good indoor thermal comfort has a significant role in affecting occupant wellbeing, health, and productivity (Yadeta *et al.,* 2019). According to Dovjak *et al*. (2015), the failure of humans to respond to the indoor environment through the thermo regulatory mechanism causes thermal discomfort. Thermal discomfort in buildings induces psychological stress, depression, and anxiety, as well as poor physical health, expressed as heart disease, insomnia, headache, and low arousal levels. Therefore, avoiding thermal discomfort within dwellings is not just about residents' satisfaction and comfort; it is also about protecting the health of the occupants (Hailu *et al*., 2021).

Research by Alikeju (2012) indicated severe cold or hot room temperatures affect pupils' learning because the brain will be constantly reminding the body to respond appropriately until the required temperature is achieved; these reminders are likely to affect learning and learning outcomes. This is because learning and memory require attention and so thermal stress on the individual may result in poor memory. A related experiment has established that temperature at 18°C and 28°C has significant negative effect on memory while temperature at 22°C showed no such effects (Abbasi *et al.*, 2019). This indicates that the latter temperature is ideal for learning since variances of temperature from 72ºF either way indicated reduction in ability to remember certain tasks. The United States Environmental Protection Agency (EPA) also maintains that within school settings poor management of indoor temperature and humidity have adverse effects on not only learners' performances but also those of teachers (Wargocki *et al.*, 2019). *The researcher also wants to investigate the* present state *of environmental factors as it affects thermal comfort in the lecture rooms of Gidan-Kwano campus of Federal University of Technology Minna.*

1.2 Statement of the Research Problems

Most of the learning occurs within indoor which implies that the thermal indoor environment has significance influence on learning efficiency. Meanwhile, learning requires high concentration and attention, which differs from general indoor activities, so it is necessary to create an appropriate indoor environment while considering learning behaviour, especially the indoor air temperature and relative humidity (Wolkoff *et al.*, 2021).

World Health Organisation (2010) postulated that high and low indoor relative humidity (RH) directly affects thermal comfort of school health which is an important concern. Previously, studies have investigated the relationship between school environment and poor academic performance, including problems with student-teacher ratio, school location, school population, classroom ventilation, poor lighting in classrooms, and inconsistent temperatures in the classroom with student health problems, student behaviour, and student achievement (Bakó-Biró, *et al.*,2007). A substantial amount of research exists on thermal comfort in offices but little research on lecture rooms (Teli *et al.*, 2013). Therefore, this emphasizes a need for assessment of indoor environmental factors that affects the thermal comfort of lecture rooms which is the focus of this research.

1.3 Aim and Objectives *of the Study*

The aim of this study is to assess the environmental thermal comfort in some selected Lecture rooms in Gidan-Kwano Campus of Federal University of Technology Minna, Niger State as they affect *thermal comfort in the selected spaces, in relation to the recommended comfort zone by established standards. The specific objectives of the study are to:*

i. *Identify the environmental parameter affecting thermal comfort conditions for lecture rooms*
ii. *Evaluate the selected lecture rooms on the environmental parameter variables at an interval of one hour during the day*
iii. *Compare the lecture rooms' indoor thermal environmental parameters and established standards.*

1.4 Justification of the Study

The lecture room is of greatest importance to students in any academic environment because it is the hub for access to physical or digital information. The relationship between thermal comfort and productivity is not far-fetched. That is why students are found to suffer from headaches, nausea, irritations of eyes, fatigue, rash, caused by improperly controlled relative humidity (Sookchaiya *et al.*, 2010). The students' attention, concentration, learning, hearing and performance can be greatly enhanced if the appropriate level of indoor thermal comfort is maintained in the lecture rooms. The lecturers will equally be able to deliver lectures in a conducive indoor environment if the recommendations from this research are duly implemented.

The outcome of the current assessment will assist in evaluating the kind and degree of thermal comfort corrections that must be introduced to the current university lecture rooms under study if they will fulfill their purpose.

To this end, the assessment of thermal comfort of the lecture rooms in Gidan-Kwano campus of the Federal University of Technology Minna is of importance to make the relevant information available for future design proposals of supporting environment that foster proper acquisition of knowledge in a climate that is constantly changing. This is the need this research seeks to address.

1.6 Scope and Delimitation of the Study

The scope of the research was limited to assessment of thermal comfort in the Lecture rooms within Gidan-Kwano campus of Federal University of Technology Minna. The readings were taken for only temperature and relative humidity using a high accuracy tool called Airvisual pro only.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Thermal Comfort

The specific ASHRAE definition of thermal comfort describes a person's psychological state of mind, and is used to describe a condition in which a person feels neither "too hot nor too cold". It is essentially a subjective response, or state of mind, where a person expresses satisfaction with his environment (Olesen & Brager, 2004). However, in deciding what people find thermally comfortable, one must take into account a range of environmental or climatic and personal factors (Shove, 2003)

Thermal comfort is one of the important characteristics of user satisfaction and energy consumption in buildings. It was defined as ''a state in which there are no driving impulses to correct the environment by the behaviour'' (Nagaraju & Remesh, 2019). A healthy indoor climate is not only important for occupant comfort & enhanced productivity, but also for minimizing building carbon footprint. A similar definition was given by Wargocki & Wyon (2013) that an indoor environment which people perceive as better than "just" comfortable or where people will be pleased with the indoor environment. Thermal comfort depends on objective parameters like air temperature and speed, relative humidity, the radiant temperature of the surrounding bodies and on subjective parameters like age, sex, health, and geographical conditions, (Modeste *et al.,* 2014). As per researchers like Humphreys and Nicol climate and culture plays a major role in affecting the thermal comfort which is interlinked (Humphreys & Nicol, 2002).

2.2 Thermal Comfort Standards and Specifications

Some international organizations set the minimum standards used to determine thermal conditions in a built environment. These main international bodies put in place regarding the determination of indoor environmental conditions are Chartered Institute of Building Services Engineers (CIBSE, 2007), American Society of Heating, Refrigerating and Air-conditioning Engineers (ASHRAE, 2017), International Standard Organisation (ISO) 7730:2005 and Comite´ Europe´en de Normalisation

(CEN) 1525.

2.2.1 Chartered institute of building services engineers (CIBSE)

The Chartered Institution of Building Services Engineers (CIBSE; pronounced ‘sib-see’) is an international professional engineering association based in London that represents building services engineers, also commonly known as mechanical and electrical engineers, architectural engineers, technical building services engineers, building engineers, or facilities and services planning engineers. It is a full member of the Construction Industry Council, and is consulted by government on matters relating to construction, engineering and sustainability. It is also licensed by the Engineering Council to assess candidates for inclusion on its Register of Professional Engineers (CIBSE, 2007). CIBSE Guide A (CIBSE, 2007) is intended to delineate the environments that building occupants will find comfortable.

This guide brings together information in all these aspects and tries to give the best and most up-to-date information on which building services engineers can base their designs. According to the CIBSE (2007), benchmarks for upper limits temperature in a non-air-conditioned school environment is 22^{o}C to 28^{o}C while the relative humidity is 40 – 60%.

2.2.2 American society of heating, refrigerating and air-conditioning engineers (ASHRAE Standard 55)

The comfort zone is defined as the range of climatic conditions within which a majority of persons would feel thermal comfort. ASHRAE 55 (2013) sets out an acceptable comfort zone on a psychrometric chart, specifying boundaries of operative temperature and humidity for sedentary activity (1 met-1.3 met) and defined clothing (0.5 clo -1 clo). While this psychrometric chart was constructed for designing the indoor environment of conditioned buildings (commercial and residential), it has gradually begun to be used in evaluating the indoor climate in naturally ventilated buildings as well (Givoni,1992). It has been investigated through literature study that some problems exist; when these comfort standards are used to evaluate the indoor conditions in naturally ventilated buildings especially in tropical countries (Lam *et al.,* 2006).

We are used to hearing about air temperature, relative humidity, and the dewpoint in discussions of weather conditions. All these properties and more are contained in a psychrometric chart as shown in Figure 2.1.

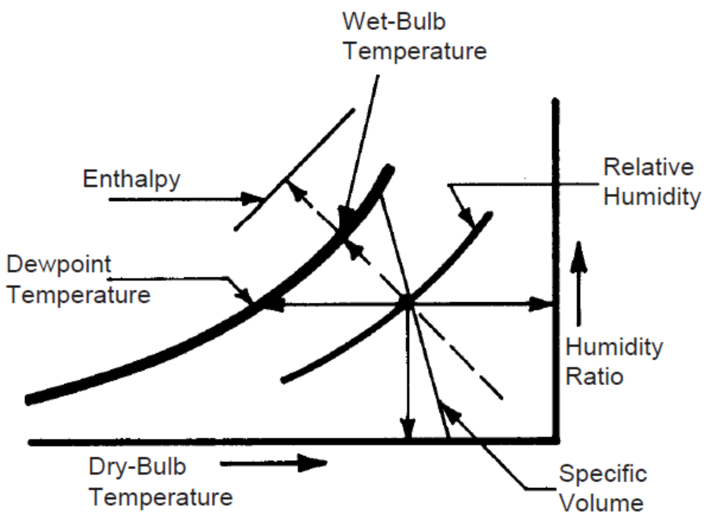

Figure 2.1: Properties of moist air on a Psychrometric chart
Source: https://extension.psu.edu

Figure 2.1 shows the psychrometric chart consisting of the following parameters;

i. Wet-bulb temperature: Temperature read with a thermometer whose bulb is encased in a wetted wick.
ii. Dry-bulb temperature: Temperature read with an ordinary thermometer.
iii. Relative humidity: The percentage of water vapor present in a given quantity of air compared to the amount it could hold at that temperature
iv. Enthalpy: This is the heat energy content of moist air.
v. Specific volume: This indicates the space occupied by air.
vi. Dew point temperature: It is an absolute measure of how much water vapor is in the air (how humid it is).
vii. Humidity ratio; Humidity ratio of moist air is the weight of the water contained in the air per unit of dry air.

2.2.3 Comite´ europe´en de normalisation (CEN)

The European Committee for Standardisation (Comite´ Europe´en de Normalisation – CEN– CEN/EN 15251 addresses indoor air quality, thermal environment, lighting, and acoustics. This standard apart from adopting PMV and PPD in its thermal comfort assessment also contains the adaptive comfort component. The standard considers the free-running buildings in its application (Nicol & Wilson, 2011).

2.3 Environmental Factors Affecting Thermal Comfort

Previous studies conducted by Haruna *et al*. (2018) have shown that environmental factors have significant influence on the occupants' comfort. A study by Ambler (1955) reported that air velocity lower than 0.1m/s had significant impact on the comfort of workers in office buildings in the hot/humid climatic sub-regions. Similarly, according to studies by Hayatu *et al.* (2015), during the hot and dry season theatre buildings in the semi-arid climatic regions of Kano city recorded a high indoor air temperature which causes discomfort to the occupants. However, similar studies by Ogbonna and Harris (2008) found that, the indoor conditions of residential and educational buildings were acceptable to the occupants in the temperate climates of Jos city.

According to De Waal (1993), the main climatic/environmental factors or parameters affecting human comfort and could be found in the lecture rooms are:

i. Air temperature

ii. Humidity and precipitation

iii. Air velocity

iv. Mean Radiant Temperature

2.3.1 Air temperature

It is the temperature of the air surrounding the body and it is used to determine how much indoor temperature would be in a space. It is usually given in degree Celsius (^oC) (ASHRAE, 2013). According to the Chartered Institution of Building Services Engineers (CIBSE), air temperature in a given space is often the most important environmental variable that affects thermal comfort (CIBSE, 2007). A thermometer that should not be affected by any radiant heat is usually the best instrument for measuring air temperature (CIBSE, 2007). Its conductivity depends on the materials used as different materials have different conductivity level and determines how much heat is dissipated in a space.

2.3.2 Relative humidity

Humidity is the water vapour or moisture content of the air. It can either be stated as relative humidity or absolute humidity (Havenith *et al*., 2015). Relative humidity is defined by ASHRAE as "the ratio of the partial pressure (or density) of the water vapour in the air to the saturation pressure (or density) of water vapour at the same temperature and the same total pressure". The ratio between the actual amount of water vapour in the air and the maximum amount of water vapour that the air can hold at that air temperature, expressed as a percentage (ASHRAE, 2013). The lower the relative humidity, the higher the evaporative cooling, hence a person will feel more comfortable under a warm temperature with low humidity than the same temperature with a higher level of relative humidity (Aronoff & Kaplan, 1995). Various researchers have indicated the relationship between relative humidity and thermal comfort of occupants of a space. Rajasekar and Ramachandraiah (2010) and Indraganti (2010) in their separate studies on apartment blocks posit that adding humidity in correlations between thermal sensation and indoor temperature changes their predictive power very little. Appah-Dankyi and Koranteng, (2012) argued further that a high relative humidity has no significant psychological or physiological influence in human response. According to Aljawabra (2014), under steady-state conditions and moderate air temperature (15-25°C) in temperate climates, the average relative humidity has little impact on thermal sensation. De-Dear *et al*. (1991) evaluated the preferred temperature of two subjects with different clothing values and reported that there are no significant differences when the RH was set at 70 and 55%. Mallick (1996) earlier posited that there are instances where people have reported to be comfortable in humidity above 95%. Junjie *et al.* (2011) suggested that people in locations that experience high humid conditions regularly are better acclimatized to such humidity levels. The various research results may have been the reason why less emphasis is paid on Relative humidity when determining occupants' comfort, as reported by Liang *et al*. (2012) that there is no limit in humidity required when the adaptive model developed in the ASHRAE Standard 55 is used.

However, Nicol (2004) reported that an elevated humidity of more than 75% has the tendency to reduce the comfort range and lowers temperature occupants feel comfortable. A higher relative humidity (RH) levels (more than 60%) can encourage the growth of mould and mildew. For some people, low relative humidity (RH) may aggravate allergies and can also lead to increased survival of some viruses and according to Indraganti (2010) low humidity can cause health-related issues. In EN ISO 7730, a humidity range of 30-70% is recommended for indoors (Olesen & Brager, 2004).

2.3.3 Air velocity

This is "an average of the instantaneous air velocity over an interval of time" (ASHRAE, 2013). While there is no specified limit to air velocity that is required in a given space to achieve thermal comfort, increased air flow across a space or body can alter the comfort sensation of the skin/body to feeling cooler in warm spaces (Nasrollahi, 2007). Air movement plays an important role in the comfort of a building occupant by causing the feeling of freshness. This is achieved by increasing the rate of evaporation in a human body, especially at high humidity where evaporative cooling is the main source of heat loss from the body. Wind, therefore, reduces the adverse effects of thermal discomfort caused by high temperature and humidity. However, high air movement in a cool or cold environment may be perceived as draught, if the air temperature is less than skin temperature, it will significantly increase convective heat loss. While in winter high air movement may be viewed as unwelcome by building occupants, the opposite is the case in summer especially when the indoor temperature becomes unbearable. Results from many researchers have indicated the importance of air movement in an indoor environment, especially in the tropics. According to Zhang *et al*. (2007), inadequate ventilation is probably the most important reason for occupant discomfort in naturally ventilated buildings. Mishra and Ramgopal (2013) reviewed field studies on thermal comfort and reported that in very few cases where a great number of occupants voted in the zone of discomfort in naturally ventilated buildings, this was attributed to low air pressure recorded. Both the field measurements and the subjective investigation showed that the indoor air velocity might be a big problem in naturally ventilated classrooms, especially where there are inadequate openings. Fieldwork by Zhang *et al.* (2007) indicated that while only 46.1% of the respondents in classrooms felt the air velocity was just okay, 53.5% perceived the air too steady. A very low percentage of 0.5% felt the velocity should be less indicating a large majority would prefer more air.

Various researchers argued from their field works the need to increase airspeed above the one recommended by ASHRAE 55 and ISO 7730. Humphreys and Nicol (2002) argued that subjects could be comfortable at temperatures up to or even exceeding 30ºC, in hot climates, especially if fans are used to increase indoor air. In separate studies carried out by Zhai *et al*. (2017) and Cândido *et al.* (2011) both observed that more people view air movement as positive in offices and in classrooms. Children requested slightly more air movement in the study conducted by Wigö (2013) in a school in Sweden during the spring and autumn when they were subjected to air velocity at irregular intervals. Schiavon *et al.* (2017) assessed the thermal comfort conditions of Singaporean office workers in a tropical setting and observed that the occupants felt more thermally comfortable at the temperature of 26ºC with the aid of fan than at 23ºC when fan was not used. Some other researchers also supported the extension of the width of the comfort zone with increased air movement (Zhang *et al*., 2007). Arens *et al.* (2009) supports an increase in air velocity for thermal sensations from 0.7-1.5. Cândido *et al.* (2010) is of the opinion that the limit for a neutral to warm conditions be relaxed when the temperature is above 26ºC. Zhai *et al.* (2015) confirmed that the air movement highly improves thermal comfort at 30ºC.

Furthermore, fieldwork carried out on naturally ventilated residential buildings in Jos Nigeria by Ogbonna and Harris (2008) gave a low coefficient between air velocity and actual votes by occupants. The researcher attributed the likely cause to the low sensitivity of occupants to air velocity. McIntyre (1978) suggests that overall comfort deteriorates when the temperature reaches 30^{o}C even when airspeed is as high as 2m/s. However, Zhai *et al*. (2015) argue that at that temperature (30^{o}C) subjective thermal sensation remains in the neutral zone and with a fan it could be comparable to the thermal conditions of the subjects without fans at 26^{o}C. Building bioclimatic chart adopted by Givoni (1998) reports that, the upper- temperature boundary could be up to 3K more in a little breeze condition with air speed of 2m/s compared with the still air condition with an air speed less than 0.25m/s. This means that the rising of air velocity can extend people's comfort zone.

Having observed the importance of increased air velocities to thermal comfort especially at high temperatures, researchers, such as (Zhang *et al*., 2007), went further to suggest recognizing an increase in air velocity as one of the actions to enhance thermal comfort. The airspeed limit was extended to 0.8m/s (160fps) by ASHRAE for operative above 25.5^{o}C (77.9^{o}F) in all types of buildings (Cândido *et al.,* 2011). Further research based on numerous reports from fieldwork, convinced ASHRAE to vary the airspeed from 0.2m/s to 1.2m/s, and for higher activity levels over 1.3met there is no limit (Nicol *et al.,* 2012). Elevations allowed in comfort limits are 1.2^{o}C, 1.8^{o}C, and 2.2^{o}C for airspeeds of 0.6m/s, 0.9m/s, 1.2m /s respectively (Mishra & Ramgopal, 2015). This limit for airspeed level is based on the operative temperature and also on the difference between the mean radiant temperature and air temperature, and this limit of air speed level is based on the operative temperature (Toftum *et al.,* 2000). With the building occupant not having control over their environment, the limit goes back to Fanger's laboratory-based limits for draft in which the air velocity value must not exceed 0.2m/s.

Also, some thermal comfort researchers have advocated for the allowance of higher air movement in buildings that have no individual control. For example, Cândido *et al.* (2010) posited that it is important to investigate other sources of effects of air movement in actual buildings, with or without individual control. Candido argued that air movement limits imposed by current standards come out with inherent energy penalties and may not be providing occupants with the indoor environment they prefer. However, the low range of air movement specified was recently removed from ANSI/ASHRAE 55 (Schiavon *et al.,* 2017). The new ASHRAE comfort standard 55-2017 specifies an extension of summer comfort zone with elevated air movement up to 0.8m/s (without personal control) and 1.2m/s (with personal control) (Zhai *et al*., 2015). However, when the air movement in a room is so slight, it will be unnecessary to include air speed in thermal comfort assessment since natural convention prevails at the clothed surface of the body (Humphreys *et al.,* 2007).

Clearly, a specific airspeed has many possible physiological and subjective effects that range from a pleasant sense of coolness to an unpleasant sense of draft, depending on the condition of the indoor climate variables and the occupants' individual factors (Candido & De-Dear, 2012). However, designers of buildings located in the tropics should take advantage of the recent suggestion in ASHRAE standard, for higher air velocity consideration in the warmer climates, to produce sustainable designs that rely on the infiltration of more air into naturally ventilated buildings. Apart from the ultimate benefit of providing buildings that contribute a reduction of greenhouse gas emission and cheaper to maintain, it could also provide what Toftum (2004) refers to as indoor environments that are stimulating and pleasurable to the occupants.

Apart from the evidence of the benefit of increased air velocity to enhance thermal comfort, there are also reports that link it to better health and academic performance. The study conducted by Bakó-Biró *et al*. (2007) found a positive relationship between increased ventilation rates and higher alertness, better work mood, the tendency for less tiredness and increased attention among pupils in schools.

2.3.4 Mean radiant temperature

ASHRAE defines mean radiant temperature (MRT) as the uniform surface temperatures of an imaginary blacken closure, in which an occupant would exchange the same amount of radiant heat as the actual non-uniform space (ASHRAE, 2013). CIBSE also describe it as the relative effect of all the radiant heat transfers from the surfaces and object in space, such as walls, ceiling, windows heaters, lights, equipment (CIBSE, 2007). MRT can be measured using a globe thermometer. The value of MRT can be estimated from Air Temperature (TA) using Equation 1, based on the experiment conducted by Nagano and Mochida (2004).

$$MRT = 0.99TA - 0.01 \ (R^2 = 0.99) \quad \text{Equation 1}$$

Where,

MRT is mean radiant temperature

TA is air temperature

2.4 Thermal Comfort in Schools

Research in schools has been widely developed in several countries to evaluate the thermal comfort of pupils from 7 years old. In the hot humid climate of the southern region of Malaysia, Hussein and Rahman (2009) conducted studies in two schools with fans. Although 80% of respondents found the thermal environment acceptable, the actual sensation vote (ASV) exceeded the one specified by ASHRAE 55, showing that people of this region have a higher tolerance and adaptability to the heat. Hwang *et al.* (2009) studied the applicability of an adaptive model in naturally ventilated schools in Taiwan. The results show that the comfort zone for 80% acceptability has a wider band and the comfort zone for 90% acceptability has a narrower range than ASHRAE 55 adaptive model. Ter Mors *et al.* (2011) studied the parameters of thermal comfort with children between 9 and 11 years of age in unconditioned environments in the Netherlands during winter, spring and summer. Through the PMV model, the mean thermal sensation was underestimated at 1.5 points, an inaccurate result. When the thermal sensation was compared to the comfort zone of the adaptive model, authors found that children prefer lower temperatures. Teli *et al.* (2012) studied the applicability of the adaptive model of EN 15251 with children between 7 and 11 years old in naturally ventilated classrooms in England. Results indicated that the temperature of comfort achieved through the PMV was 4°C lower than that obtained by questionnaires and the one obtained by the adaptive model was 2°C lower, indicating that children are more sensitive to high temperatures. In another study, Teli *et al.* (2013) show the adjustments that should be made in the current comfort criteria to evaluate the thermal perception of children in various climates. The current thermal comfort criteria lead to an underestimation of the thermal sensation of children during the summer. The study of De Giuli *et al.* (2014) held in a school in Padova (Italy), found no match between the Predicted Mean Vote/Predicted Percentage Dissatisfied and the children's Actual Sensation Vote (ASV) neither between the adaptive model nor the ASV.

Corgnati *et al.* (2007) studied the thermal preferences of students in schools and in a university in the city of Torino, Italy. The mean of subjective votes was compared with the perception of the thermal environment and the results showed that people accept those environments judged as neutral or warm. In the research of Teli *et al*. (2013), held during the end of summer in Southampton (UK), children tended toward warm a thermal sensation which was not complemented in the same way by strong preference for cooler spaces.

Another study by Corgnati *et al*. (2009) performed during the mid-season in schools under free running conditions in Turin (Northwest Italy) compared the subjective responses with those obtained in another study conducted during the heating season. Results show a gradual change in thermal preference starting in the heating period until the mid-season. During the mid-season the preference was for neutral environments, while during the heating season the preference was for slightly warm or warm environments.

A study conducted by Dias Pereira *et al.* (2014) in naturally ventilated classrooms in Beja (Portugal), in a Mediterranean climate, found that students preferred slightly warm environments in the mid-season, with an acceptable temperature range beyond the comfort zone.

In Sweden, Wigo *et al*. (2013) presented the evaluations of students who were subjected to intermittent air velocity in a school, during the spring and autumn. Results indicate that variations in air velocity cause people to perceive the air as being cooler and more refreshing than when the air velocity is constant. Pupils in the study also requested slightly more air movement.

A study conducted by Montazami and Nicol (2013) in 18 naturally ventilated schools in the UK analyzed the new version of overheating guidelines for schools with the old version, both published by the British government. Despite the new guidelines are more stringent, further developments are needed.

In Taiwan, Liang *et al.* (2012) found that the building envelope energy regulation has great impact on the thermal comfort sensation in naturally ventilated buildings. Katafygiotou and Serghides (2014) showed that there is a relation between poor indoor quality conditions and the low-energy efficiency of buildings.

Zeiler *et al.* (2009) evaluated the performance of thermo active building systems for heating schools during the winter in the Netherlands. According to the results of the questionnaires, these systems generate a slight improvement in the perception of thermal environment and greater user satisfaction with respect to the indoor temperature, when compared with traditional heating systems.

2.5 Thermal Comfort in Educational Buildings

Hwang *et al.* (2006) conducted field studies in 10 naturally ventilated and 26 air-conditioned classrooms in seven universities in Taiwan. The analysis found that relative humidity had no significant influence on the assessment of students' thermal sensation. Student responses point to wider ranges of thermal acceptability in Taiwan. In a later study carried out by Cheng *et al.* (2008) in university dormitories in Taiwan the neutral and preferred temperatures of students were similar in both classrooms and dormitories.

Zhang *et al*. (2007) conducted a study in naturally ventilated classrooms with ceiling fans in Hunan University in China. Results showed that most students were satisfied with the thermal environment during the experiments (March–April). Authors analyzed a modified model of PMV, but the discrepancy between predicted and actual thermal sensations did not reduce noticeably.

In another study, Zhang *et al.* (2010) evaluated the adaptive behaviours of students during a year in free-running buildings in a hot-humid area of China. A close match between the physical variables of the indoor environment and the clothing with outdoor climate was found. People in the analyzed climate are more tolerant of heat and humidity and less tolerant of cold environments when compared to studies conducted in temperate climates. In a study performed in buildings with split air-conditioners in a hot humid area of China, Zhang *et al*. (2013) conclude that occupants of buildings with split air-conditioners keep their environment cooler, use adaptive opportunities early on and perceive their environment more sensitively and rigidly than users of naturally ventilated environments.

In the study by Yao *et al*. (2010) carried out for a year in university classrooms in China, the comfort range found was broader than that recommended by the ASHRAE 55, with the exception of the hottest and coldest months, in which the range was narrower. In the oceanic temperate climate of Korea, a field study conducted in university classrooms during the spring and fall showed that the thermal acceptability range diverged from that recommended by ASHRAE 55.

Wang *et al.* (2014) conducted a study during the winter in Harbin (China) in university classrooms and offices, and concluded that the neutral temperatures were different in winter and spring (the neutral temperature was higher in spring than in winter), demonstrating the influence of the prevailing weather conditions in adaptation.

A study conducted Mishra and Ramgopal (2014) in the laboratories of a university in India showed high acceptance of the indoor thermal environment and adaptability by the students to high levels of humidity. The answers from the questionnaires showed a strong correlation between indoor comfort conditions and the outdoor temperature.

Based on the results of two field studies conducted in two cities, Karyono (2008) evaluated the applicability of the adaptive model in Indonesia. Results showed that user's comfort temperatures were in line with mean outdoor temperatures, as stated by the adaptive model.

A post-occupancy evaluation by Lenoir *et al.* (2012) assessed the perception of students and staff of a zero-energy building, located in a French island in the Indian Ocean (tropical climate). The building was designed to be mixed-mode in some areas and uses passive strategies. Results indicate that during most of the year, users are in thermal comfort without using air-conditioning. Serghides *et al*. (2014) identified the inappropriate use of cooling and heating systems (very low temperatures in summer and very high temperatures in winter) in a university building in Cyprus. In the field study carried out in buildings of a university in

During the fall, winter and spring, Buratti and Ricciardi (2009) performed a field study in classrooms of three universities located in three cities in Italy. The correlation of the responses from questionnaires and PMV showed significant differences between them. The results of the study by Memon *et al.* (2008), at a university in the subtropical region of Pakistan, indicated that people in this area felt in thermal comfort with effective temperatures of 29.85 ºC (operative temperature of 29.3 ºC). Such a result was compared with the neutral effective temperature determined by the adaptive model, demonstrating that this model predicted it very well. PMV was compared with the actual sensation vote (ASV) and significant discrepancies were found, for example, an ASV = 0 was predicted by PMV as +1.34.

The effect of ventilation was studied by Norback and Nordström (2008) in computer classrooms (university students) with different air exchange rates. Higher air exchange was associated with a perception of lower temperature, higher air movement and better air quality.

The results of the study by Cândido *et al.* (2010), performed in the hot and humid climate of the city of Maceió, Brazil, demonstrate the importance of the occupants' thermal history and their preference for higher air movement. According to the authors, people who are under steady conditions in their thermal environment (air-conditioned – AC – environments) have less tolerance and are less able to adapt to the dynamic conditions of naturally ventilated spaces. People who were constantly exposed to AC preferred this type of conditioning while people accustomed to free-running buildings preferred not to have AC. The minimum air velocities required to achieve 80% and 90% of acceptability were closer or above the maximum velocity (0.8 m/s) recommended by ASHRAE 55.

2.6 Thermal Comfort in Educational Buildings in Nigeria

In the educational buildings category in Nigeria, Wahab (2015) studied the influence of bricks as walling materials on the adaptive behaviour of secondary school students in Ibadan city. The study pointed out that, brick had significant influence on the thermal performance of buildings. The result showed that, comfort temperature range was between 27.90C to 31.40C. Additionally, building orientation, shading devices, surrounding vegetation and landscape were also identified as contributing factors. A similar study on comparative analysis of thermal performance of public-school classrooms in the mainland and island locations of Lagos metropolis was conducted by Oginni (2018). The study found that classrooms on the mainland had better thermal performance than those on the island. That may be due to the effect of warm air blowing over the sea in daytime.

Furthermore, a field study conducted by Munonye and Ji (2018) evaluated and compared the thermal sensation of pupils in two classrooms having different plans, in Imo state, Nigeria. The results revealed that, the operative temperature of the open-plan classroom was 28.8^{o}C while that of the enclosed space classroom was 29.1^{o}C. This result indicated that, the open-plan offers better comfortable conditions than the enclosed space, due to improved air circulation. Other studies were conducted in some university buildings. A field study was conducted by Hayatu *et al.* (2015) to assess the thermal comfort conditions in lecture theatres at the Bayero University, Kano. The result showed that during the hot season, the comfort temperature ranges from 31.8^{o}C to 36.2^{o}C, relative humidity from 36.5% to 50.6% and the air velocity was from 0.05m /s to 0.29m/s. It indicated that, the indoor air temperatures which causes discomfort to the occupants. However, similar studies by Ogbonna and Harris (2008) found that, the indoor conditions of residential and educational buildings were acceptable to the occupants in the temperate climates of Jos city.

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Research Design

Research design refers to the understanding of the research and the strategy chosen to answer the research question (Kabir, 2016). It also refers to a system of explicit rules and procedures upon which research is based and against which claims for knowledge are evaluated.

3.2 Study Area

The study was done in the lecture rooms of Federal University of Technology (FUT) Minna, Gidan-Kwano main campus sited on 10,650 hectares of land located along Minna-Kataeregi-Bida express road. The institution lies within the latitudes 9.5º38’55.8”N – 9.0º31’15”N and longitude 6.4º33’16”E – 6.0º36’22”E .

3.3 Population of Study

The study comprised of lecture rooms located in Gidan-kwano campus of Federal University of Technology Minna, Niger State. This was either a lecture room or a lecture theater.

3.4 Sample Size

Gidan-Kwano campus of Federal University of Technology Minna comprises of five operational schools as at the time this research was conducted. These schools include;

i. School of Environmental Technology (SET)

ii. School of Engineering and Engineering Technology (SEET)

iii. School of Innovative Technology (SIT)

iv. School of Agriculture and Agricultural Technology (SAAT)

v. School of Information and Communication Technology (SICT)

The lecture rooms in each school were categorised into three (3) according to their seat capacity. The categories were;

i. Category A: Lecture theaters with capacity to accommodate above five hundred persons.

ii. Category B: Lecture theaters with capacity to accommodate between one hundred to five hundred persons.

iii. Category C: Lecture theaters with capacity to contain below one hundred persons.

Table 3.1: Categories of lecture rooms in Gidan-Kwano campus and the available quantities under each category

School	Category		
	A	B	C
	Above 500	100-500	Less than 100
SET		2	8
SEET	2	1	11
SIT		1	6
SAAT	1	2	7
SICT	1	1	
Total	4	7	32

Summation of all lecture rooms = 43

3.5 Sampling Techniques

The study utilized stratified random sampling which started off by dividing the lecture rooms into groups with similar attributes. Then a random sample is taken from each group. Four lecture theatres were selected for category A while five lecture rooms were selected for categories B and C respectively.

3.6 Method of Data Collection

This study involves the evaluation of thermal comfort at the intermediate level, using objective (monitoring of indoor comfort parameters) method. A stage-by-stage schedule was carefully planned to ensure safety and standard data collection through the various research instrument that are explained in the following heading:

3.6.1 Data collection instrument

The instrument used for data collection in the study is mainly direct measurement. Installation/reading (thermal comfort measuring equipment) was adopted to obtain thermal comfort measurement values in the direct measurement phase of the study.

Physical measurements of environment variables were recorded using high accuracy hand held tools called AirVisual Pro. AirVisual Pro is a portable multi meter tester (Plate IV) with the general specifications shown in Table 3.2.

Table 3.2: General specifications of AirVisual Pro

General specifications	
Dimensions	H 8.2 x W 18.4 x D 10 cm
Screen Size	12.7 cm LED screen
Battery Information	Rechargeable Lithium Ion - 2500 mAH capacity
Battery Life	Approximately 4 hours on a single charge
Wireless Technology	802.11 b/g/n - 2.4 GHz
Operating Temperature	0 to 40 °C
Sensor Specifications	
PM2.5 (Particulate Matter)	0.3 - 2.5 µm
CO_2 (Carbon Dioxide)	400 - 10,000 ppm (parts per million)
Temperature	-10 to 40 °C
Humidity	0 - 95%
Features	
Unit Selection	Metric (°C) or Imperial (°F)

Air Quality Indices	American & Chinese AQI
Display Languages	3 user-selectable languages: English, Chinese, French
Supplied Accessories	Micro USB to USB cord, USB power adapter

Source: https://www.iqair.com

Plate I: AirVisual Pro

3.7 Procedures for Data Collection

The methodology of measurement employed in the study was similar to those used in previous works of Ricciardi and Buratti (2018) and Nematchoua *et al.* (2014), and prescriptions of existing standards such as ISO 7730 (2005) and ASHRAE standard 55 (2017). In every lecture room assessed, the air temperature and relative humidity at three different points were measured. The first point was at the occupancy area near the outer wall, the second point was in the occupancy area near the wall adjacent to another room and the third point was between the first and the second points.

The Airvisual Pro instrument uses the Pro's internal data storage to store the measurement carried out at each point. The data was then downloaded through the AirVisual's website dashboard. It measures and calculates temperature (in Fahrenheit and Celsius) and relative humidity (in Percentage directly).

3.8 Method of Data Analysis

The data collected (temperature and relative humidity) from the case study lecture rooms were subjected to descriptive and inferential statistics. The descriptive statistics made use of graphs and charts with the aid of Microsoft Excel Software and Psychrometric charts. The Pearson Correlation was used to determine whether there is any linear relationship between the established standards and the measured environmental factors in the case study lecture rooms.

CHAPTER FOUR

4.0 RESULTS AND DISCUSSION

4.1 Presentation of Result

The aim of this study was to assess the thermal comfort in some selected Lecture rooms in Gidan-Kwano Campus of Federal University of Technology Minna, Niger State as they affect thermal comfort in the selected spaces, in relation to the recommended comfort zone by established standards. As at the time this study was conducted the research student carried out measurement in the fourteen (14) selected lecture rooms to represent the three categories of lecture theatres and lecture rooms in Gidan-Kwano campus of the Federal University of Technology Minna. This was achieved via the use of the AirVisual Pro thermal comfort monitor device.

4.2 Mean Temperature Hourly Pattern for Category A Lecture Theater

This is the hourly pattern of mean temperature readings within Category A lecture theaters (lecture theaters with above 500 seat capacity) over the course of a day for a period of a month.

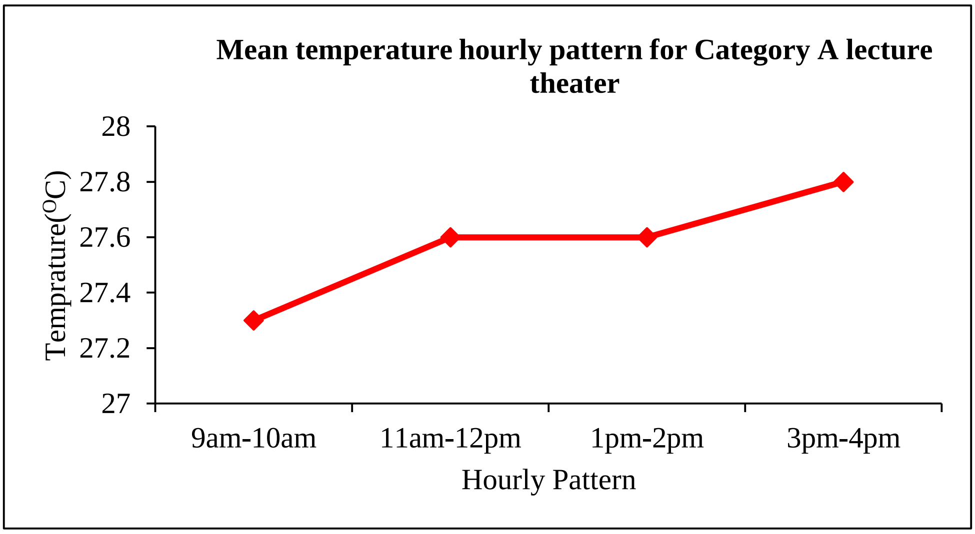

Figure 4.1: Mean temperature hourly pattern for category A lecture theater

As shown in Figure 4.1, there was a stable trend variation in the mean temperature readings for the period the research was conducted. The temperature was higher at 3pm to 4pm. The mean temperature values were as followed 27.3^{0}C, 27.6^{0}C, 27.6^{0}C and 27.8^{0}C. The values obtained are slightly within the comfort zone as specified by the psychrometric chart since they are between 22^{0}C to 28^{0}C

4.3 Mean Temperature Hourly Pattern for Category B Lecture Theater

This is the hourly pattern of mean temperature readings within Category B lecture theaters (lecture theaters with between 100 to 250 seat capacity) over the course of a day.

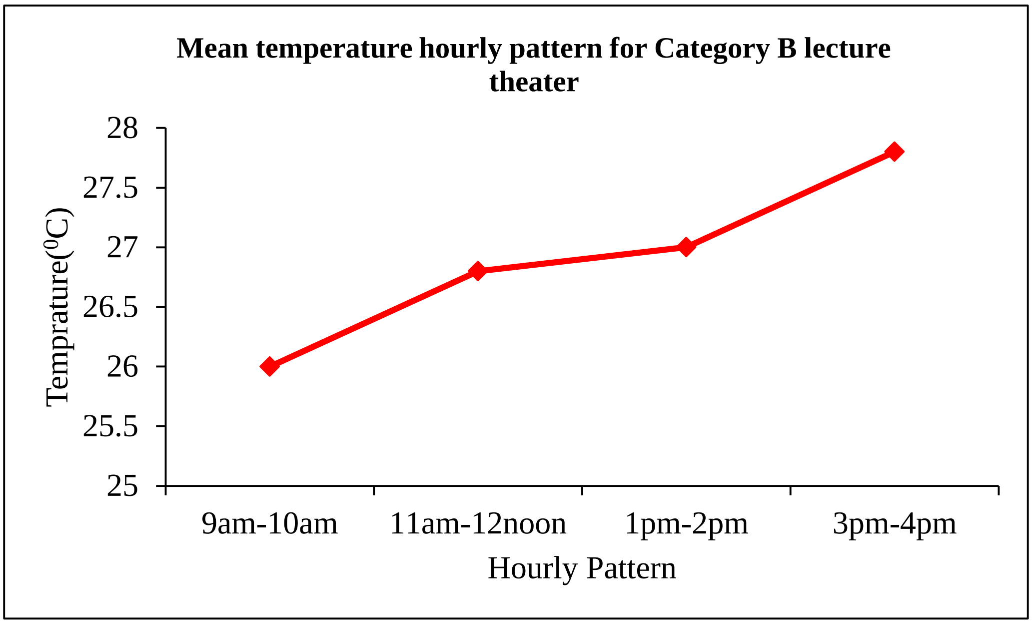

Figure 4.2: Mean temperature hourly pattern for category B lecture theater

As shown in Figure 4.2, there was a slight variation in the mean temperature readings for the period the research was conducted. The temperature was higher at 3pm to 4pm. The mean temperature values obtained were as follows; 26^0C, 27.8^0C, 27^0C and 27.8^0C. The values obtained are slightly within the comfort zone as specified by the psychrometric chart since they are between 22^0C to 28^0C.

4.4 Mean Temperature Hourly Pattern for Category C Lecture Rooms

This is the hourly pattern of mean temperature readings within Category C lecture rooms (lecture rooms below 100 seat capacity) over the course of a day.

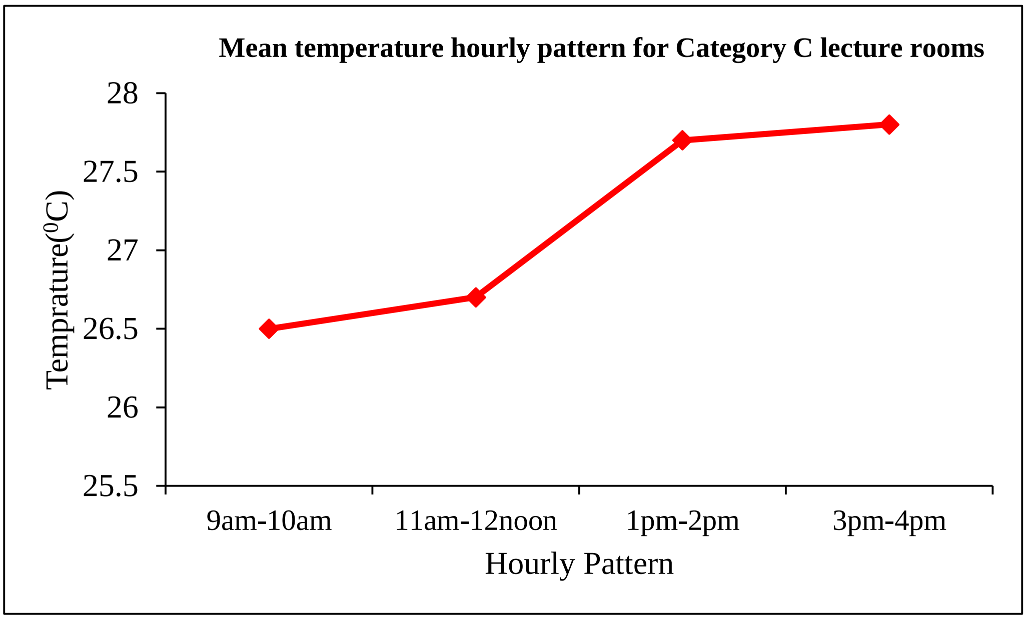

Figure 4.3: Mean temperature hourly

pattern for category C lecture rooms

As shown in Figure 4.3, there was a slight variation in the mean temperature readings for the period the research was conducted. The temperature was higher at 3pm to 4pm. The mean temperature values obtained were as follows; 26.5^{0}C, 26.7^{0}C, 27.7^{0}C and 27.8^{0}C. The values obtained are slightly within the comfort zone as specified by the psychrometric chart since they are between 22^{0}C to 28^{0}C.

4.5 Mean Relative Humidity Hourly Pattern for Category A Lecture Theater

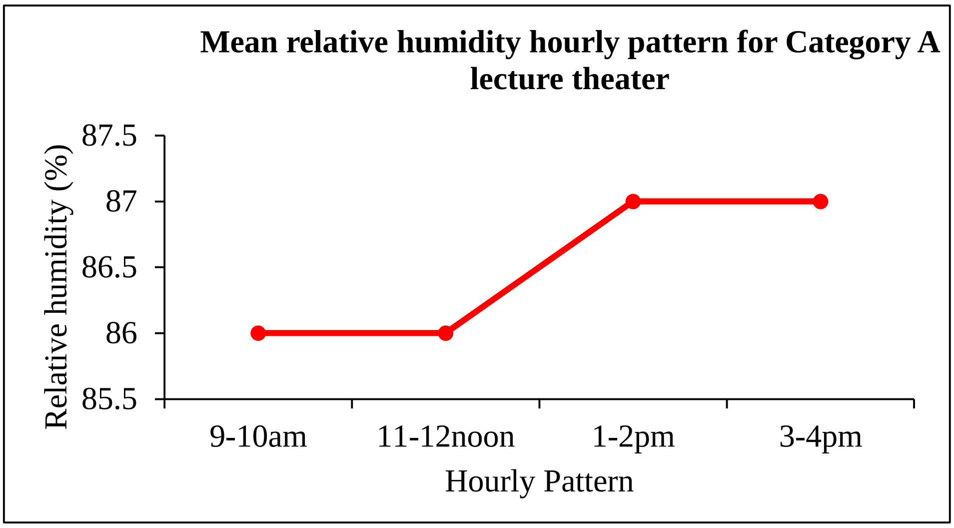

Figure 4.4: Mean relative humidity hourly pattern for category A lecture theater

Figure 4.4 showed the hourly pattern of mean relative humidity readings within Category A lecture theaters over the course of a day. The mean readings obtained are; 86%, 86%, 87% and 87%. All the readings obtained within this category are well above the standard as specified by ASHRAE standard depicted in the psychrometric chart.

4.6 Mean Relative Humidity Hourly Pattern for Category B Lecture Theater

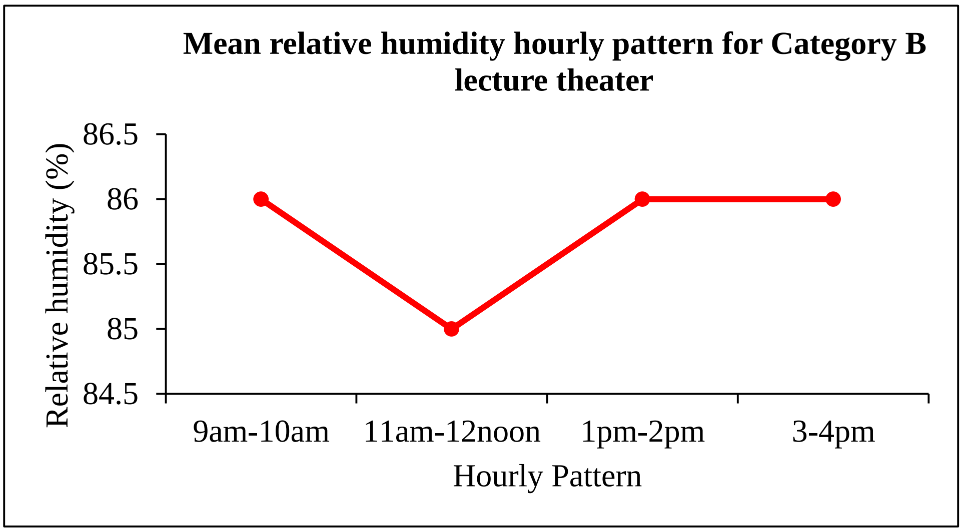

Figure 4.5: Mean relative humidity hourly pattern for category B lecture theater

As shown in Figure 4.5, there was a slight variation in the mean relative humidity readings for the period the research was conducted. The values obtained are 86%, 85%, 86% and 86%. The upper limit for comfort zone relative humidity as specified by ASHRAE standard is 70%, none of the obtained values within this category falls below the standard.

4.7 Mean Relative Humidity Hourly Pattern for Category C Lecture Rooms

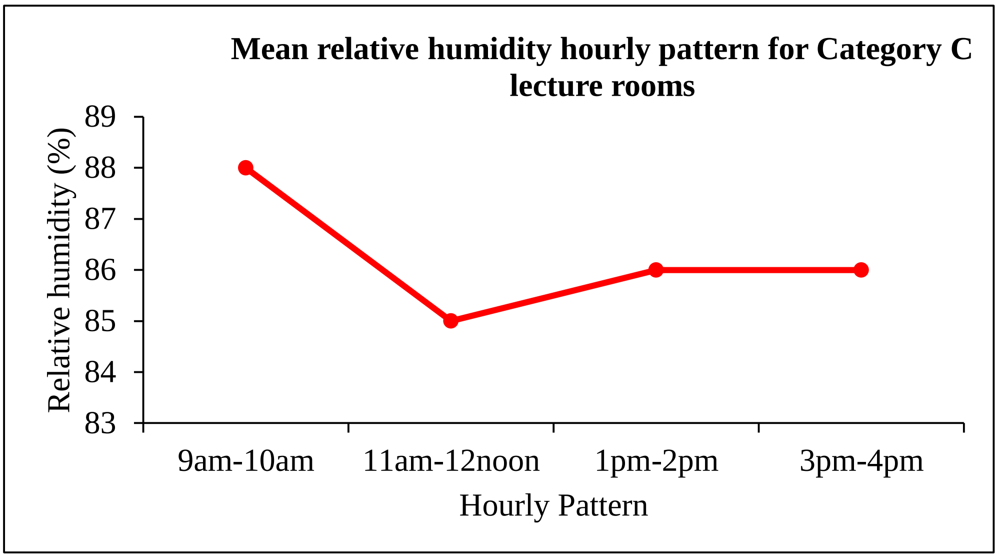

Figure 4.6: Mean relative humidity hourly pattern for category C lecture rooms

Figure 4.6 showed the hourly pattern of mean relative humidity readings within Category C lecture rooms over the course of a day. The mean readings obtained are; 88%, 85%, 86% and 86%. All the readings obtained within this category are well above the standard as specified by ASHRAE standard depicted in the psychrometric chart.

4.8 Psychrometric Chart Analyses

The recorded indoor air temperature and relative humidity average values have been plotted on psychrometric charts to analyse the thermal conditions of the lecture rooms (Category A, Category B and Category C) in relation to the comfort zone.

4.8.1 Category a lecture theaters

From the psychrometric chart shown in Figure 4.3 the blue shaded portion on 22ºC to 28ºC and 40% to 60% (for temperature and relative humidity respectively) represents the thermal comfort zone parameters as stipulated by thermal comfort standards (ASHRAE Standard and CIBSE Guide A). While the red line around the comfort zone plotted on 22ºC to 27.4ºC and 40% to 86.1% (for temperature and relative humidity respectively) depicts the average values of the comfort parameters measured in the Category A lecture theaters. The relative humidity did not comply with the thermal comfort standards and could be seen to be well outside the comfort zone as delineated on the psychrometric chart.

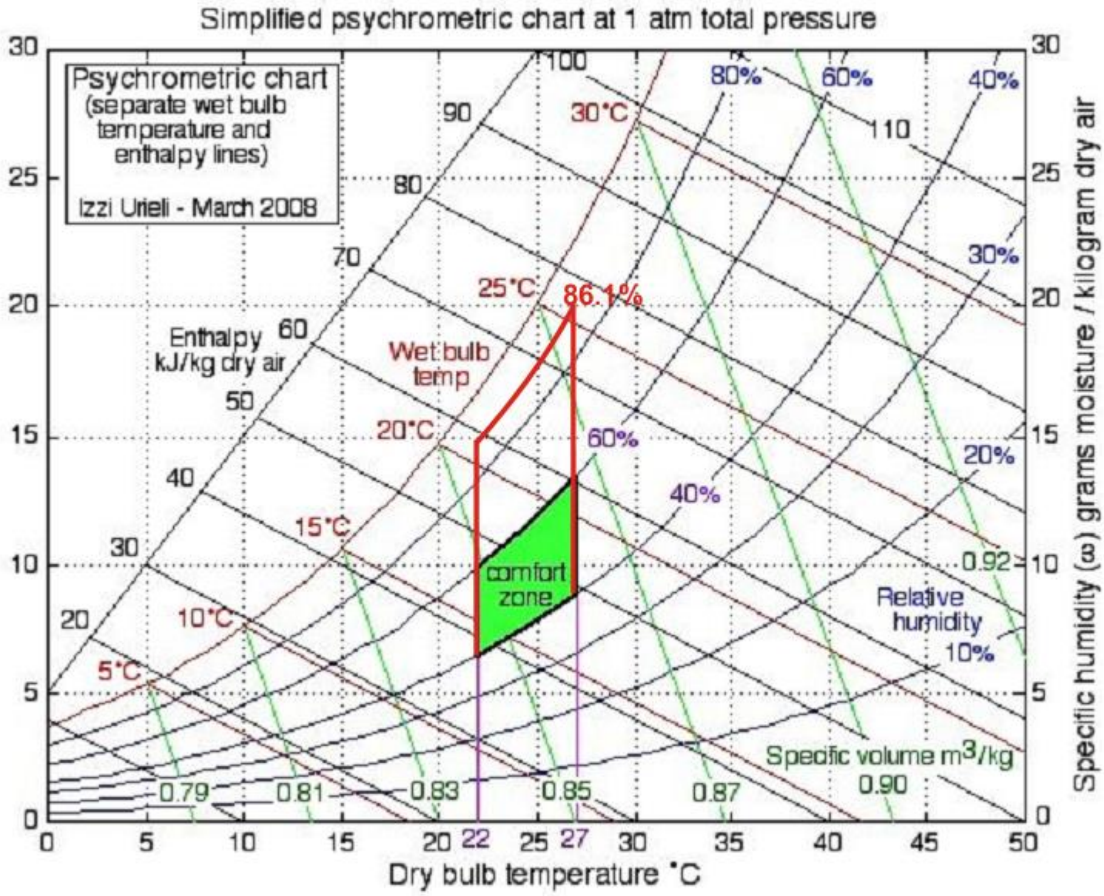

Figure 4.7: Psychrometric chart showing comfort zone and the comfort parameters of Category A Lecture Theaters

4.8.2 Category b lecture theaters

From the psychrometric chart shown in Figure 4.4, the blue shaded portion on 22ºC to 28ºC and 40% to 60% (for temperature and relative humidity respectively) represents the thermal comfort parameters as stipulated by thermal comfort standards (ASHRAE Standard and CIBSE Guide A). While the red line around the comfort zone plotted on 22ºC to 26.8ºC and 40% to 88.8% (for average temperature and relative humidity respectively) depicts the average values of the comfort zone parameters measured in the Category B theaters. The average temperature is within the comfort zone while the relative humidity could be seen to be well outside the comfort zone as delineated on the psychrometric chart.

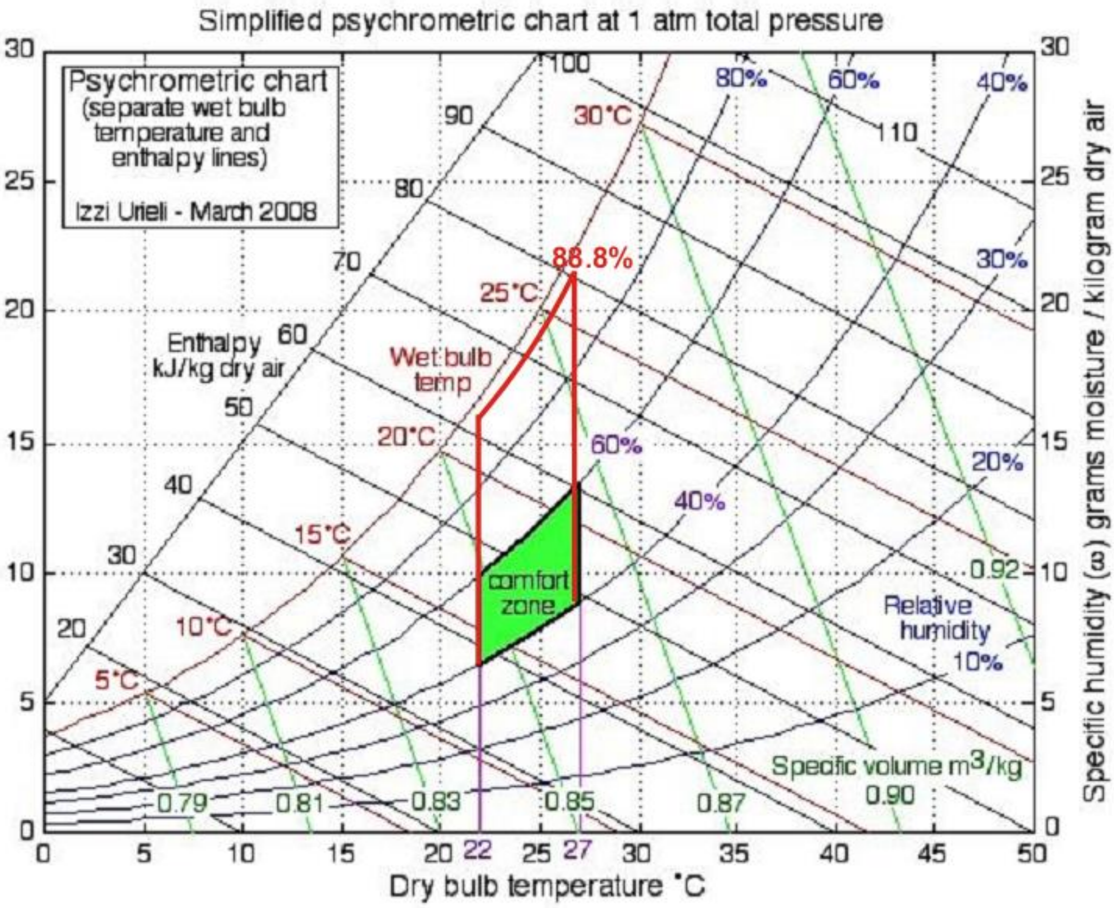

Figure 4.8: Psychrometric chart showing comfort zone and the average comfort parameters of Category B Lecture Theaters.

4.8.3 Category c lecture rooms

From the psychrometric chart shown in Figure 4.4, the blue shaded portion on 22ºC to 28ºC and 40% to 60% (for temperature and relative humidity respectively) represents the thermal comfort parameters as stipulated by thermal comfort standards (ASHRAE Standard and CIBSE Guide A). While the red line around the comfort zone plotted on 22ºC to 27.6ºC and 40% to 85.3% (for the average temperature and relative humidity respectively) depicts the average values of the comfort parameters measured in Category C lecture rooms. The average temperature is within the comfort zone while the relative humidity could be seen to be well outside the comfort zone as delineated on the psychrometric chart.

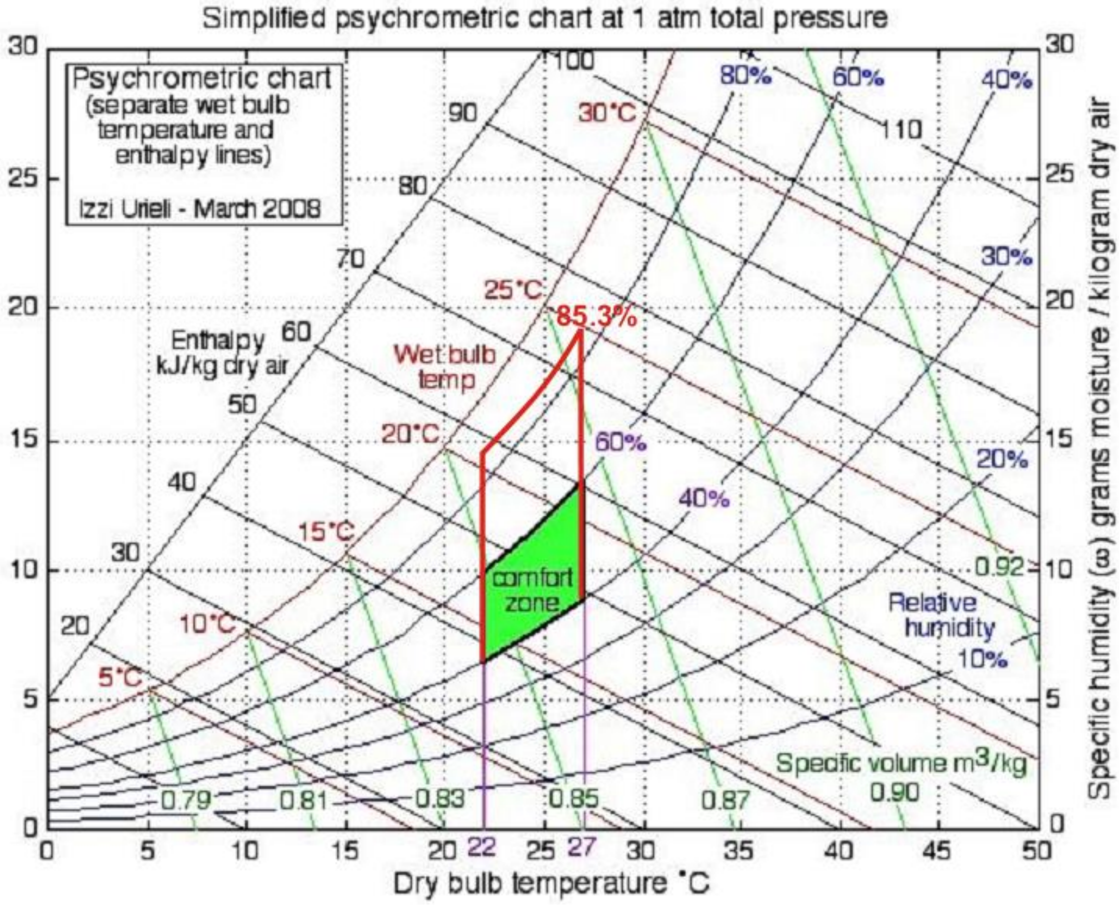

Figure 4.9: Psychrometric chart showing comfort zone and the comfort parameters of Category C lecture rooms

4.9 *Relationship between the Lecture Rooms' Indoor Thermal Environmental Parameters and Established Standards*

Table 4.1: ***Relationship between the Lecture Rooms' Indoor Thermal Environmental Parameters and Established Standards.***

		Established Standard Temperature value	**Measured value**
Standard thermal comfort value	Pearson correlation	1	0.994"
	Sig (2 tailed)		.000
	N	9	24
Measured value	Pearson correlation	0.994"	1
	Sig (2 tailed)	.000	
	N	24	9

The result of the correlation relationship between the established standard temperature values and the measured temperature values is positive where the Pearson's correlation coefficient, r, is equal to 0.994 (p-value < .001) which means the results were highly significant. The result showed that, the measured temperature complied with the temperature range of comfort zone.

CHAPTER FIVE

5.0 CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

The aim of this study is to assess the comfort zone in some selected Lecture rooms in Gidan-Kwano Campus of Federal University of Technology Minna, Niger State with a view to establishing compliance to established standards. The measured parameters were plotted on the traditional ASHRAE 55 psychrometric comfort zone, it was revealed that the measured values were represented outside the comfort zone in terms of relative humidity. The reasons were the high relative humidity values, even though the temperature values in all the cases being slightly below 28°C.

5.2 Summary of Findings

The study revealed that the average temperatures values in all the cases were slightly below 28°C, while the relative humidity values in the lecture rooms were well outside the comfort zone as shown in the psychrometric charts with average values of 88.8%, 86.1% and 85.3% for Category B, Category A and Category C respectively.

5.3 Recommendations

Based on the summary of findings in section 5.2 above, the following recommendations have been made:

i. There is the need for a more conducive learning environment (lecture rooms) to enable the students learn more and the lecturers to perform their duties conveniently. Since the relative humidity is high, as well as temperature, the skin remains clammy or damp as a result of oversaturation of the air. Further assistance is therefore required through mechanical ventilation.

ii. Lecturers should not spend time beyond the allocated scheduled time for each course so that students will not get exhausted as a result of thermal discomfort which is capable of causing tiredness, non-vigilance, restlessness and irritation during lectures.

iii. Appropriate lecture room seat capacity should be adhered to in order to avoid overcrowding of the teaching-learning room space.

5.3.1 Recommendations for further research

There is need for other researchers to carryout research on both subjective and objective thermal comfort of lecture rooms in Gidan-Kwano Campus of Federal University of Technology Minna to enable the establishment of comfort zone for the campus.

5.4 Contribution to Knowledge

The study identified that while the temperature values were slightly below the recommended level, the relative humidity values were well outside the comfort zone.

The study also highlights the need for a more conducive learning environment to enable students to learn effectively and lecturers to perform their duties conveniently. The study recommends the use of mechanical ventilation to reduce the high relative humidity values in the lecture rooms.

Furthermore, the study recommends that lecturers should not spend time beyond the allocated scheduled time for each course to avoid thermal discomfort, which can cause tiredness, non-vigilance, restlessness, and irritation during lectures. The study also recommends that appropriate lecture room seat capacity should be adhered to in order to avoid overcrowding of the teaching-learning room space.

Overall, this study contributes to the existing body of knowledge on thermal comfort in lecture rooms, and provides useful information for policymakers, architects, engineers, and facility managers who are responsible for creating and maintaining comfortable and conducive learning environments in tertiary institutions.

REFERENCES

Abbasi, A. M., Motamedzade, M., Aliabadi, M., Golmohammadi, R., & Tapak, L. (2019). The impact of indoor air temperature on the executive functions of human brain and the physiological responses of body. *Health promotion perspectives*, 9(1), 55.

Alikeju, E. H. (2012). The Impact of Climate Change in Nigeria: Implications for Schooling. *Mediterranean Journal of Social Sciences, 3*(16), 137-13.

Aljawabra, F. (2014). *Thermal comfort in outdoor urban spaces: the hot arid climate*, Doctoral dissertation, University of Bath.

Appah-Dankyi, J., & Koranteng, C. (2012). An assessment of thermal comfort in a warm and humid school building at Accra, Ghana.

Arens, E., Turner, S., Zhang, H., & Paliaga, G. (2009). Moving air for comfort. *Center for the Built Environment*, 18-28.

Arif, M., Katafygiotou, M., Mazroei, A., Kaushik, A., & Elsarrag, E. (2016). Impact of indoor environmental quality on occupant well-being and comfort: A review of the literature. *International Journal of Sustainable Built Environment, 5*(1), 1-11.

Aronoff, S., & Kaplan, A. G. (1995). *Total workplace performance: Rethinking the office environment*. Wdl Publications.

ASHRAE (2013). Standard 55-2013: Thermal Environmental Conditions for Human Occupancy. *American Society of Heating, Refrigerating, and Air-Conditioning Engineers, Inc. Atlanta*.

ASHRAE (2017). Thermal environmental conditions for human occupancy. ANSI/ASHRAE Standard 55-2004. *American Society of Heating, Refrigerating and Air conditioning Engineers*, *145*.

Bakó-Biró, Z., Kochhar, N., Clements-Croome, D. J., Awbi, H. B., & Williams, M. (2007). Ventilation rates in schools and learning performance. *Proceedings of CLIMA*, 1434-1440.

Buratti, C., & Ricciardi, P. (2009). Adaptive analysis of thermal comfort in university classrooms: correlation between experimental data and mathematical models. *Building and Environment*, 44, 674–687.

Candido, C., & Dear, R. D. (2012). From thermal boredom to thermal pleasure: a brief literature review. *Ambiente Construído*, 12, 81-90.

Cândido, C., De-Dear, R. J., Lamberts, R., & Bittencourt, L. (2010). Air movement acceptability limits and thermal comfort in Brazil's hot humid climate zone. *Building and environment*, 45(1), 222-229.

Cândido, C., De-Dear, R., & Lamberts, R. (2011). Combined thermal acceptability and air movement assessments in a hot humid climate. *Building and Environment*, 46(2), 379-385.

Cheng, M. J., Hwang, R. L., & Lin, T. P. (2008). Field experiments on thermal comfort requirements for campus dormitories in Taiwan. *Indoor and Built Environment*, 17(3), 191-202.

CIBSE (2007). Refurbishment for improved energy efficiency: an overview. *CIBSE (ed.), Knowledge Series12*, 48.

Corgnati, S.P., Ansaldi, R., & Filippi, M. (2009). Thermal comfort in Italian classrooms under free running conditions during mid seasons: assessment through objective and subjective approaches. *Building and Environment*, 44, 785–792.

Corgnati, S.P., Filippi, M., & Viazzo, S. (2007). Perception of the thermal environment in high school and university classrooms: Subjective preferences and thermal comfort. *Building and Environment,* 42, 951–959.

De-Dear, R. J., Akimoto, T., Arens, E. A., Brager, G., Candido, C., Cheong, K. W. D. & Zhu, Y. (2013). Progress in thermal comfort research over the last twenty years. *Indoor air*, 23(6), 442-461.

De-Dear, R. J., Leow, K. G., & Foo, S. C. (1991). Thermal comfort in the humid tropics: Field experiments in air conditioned and naturally ventilated buildings in Singapore. *International Journal of Biometeorology*, 34(4), 259-265.

De Giuli, V., Zecchin, R., Corain, L., & Salmaso, L. (2014). Measured and perceived environmental comfort: Field monitoring in an Italian school. *Applied Ergonomics*, 45(4), 1035-1047.

De Waal, H. B. (1993). New recommendations for building in tropical climates. *Building and environment*, 28(3), 271-285.

Dias Pereira, L., Raimondo, D., Corgnati, S.P., & Gameiro da Silva, M. (2014). Assessment of indoor air quality and thermal comfort in Portuguese secondary classrooms: methodology and results. *Building and Environment* 81, 69–80.

Djamila, H., Chu, C. M., & Kumaresan, S. (2013). Field study of thermal comfort in residential buildings in the equatorial hot-humid climate of Malaysia. *Building and Environment*, 62, 133-142.

Dovjak, M., Shukuya, M., & Krainer, A. (2015). Exergetic issues of thermoregulation physiology in different climates. *International Journal of Exergy*, 17(4), 412-432.

Givoni, B. (1992). Comfort, climate analysis and building design guidelines. *Energy and buildings*, 18(1), 11-23.

Givoni, B. (1998). *Climate considerations in building and urban design*. John Wiley & Sons.

Hailu, H., Gelan, E., & Girma, Y. (2021). Indoor Thermal Comfort Analysis: A Case Study of Modern and Traditional Buildings in Hot-Arid Climatic Region of Ethiopia. *Urban Science*, 5(3), 53.

Haruna, A. C., Muhammad, U. D., & Oraegbune, O. M. (2018). Analysis of indoor thermal comfort perception of building occupants in Jimeta, Nigeria. *Civil and environmental research*, 10(4), 11-20.

Havenith, G., Kuklane, K., Fan, J., Hodder, S., Ouzzahra, Y., Lundgren, K., & Loveday, D. (2015). A database of static clothing thermal insulation and vapor permeability values of non-western ensembles for use in ASHRAE standard 55, ISO 7730, and ISO 9920. *Ashrae Trans*, *121*(1), 197-215.

Hayatu, I., Mukhtar, I., Mu'az, N., & Enaburekhan, J. (2015). An assessment of thermal comfort in hot and dry season (a case study of 4 theaters at Bayero University Kano). *International Journal of Multidisciplinary and Current Research*, 3, 1117-1121.

Humphreys, M. A., & Nicol, J. F. (2002). The validity of ISO-PMV for predicting comfort votes in every-day thermal environments. *Energy and buildings*, 34(6), 667-684.

Humphreys, M. A., Nicol, J. F., & Raja, I. A. (2007). Field studies of indoor thermal comfort and the progress of the adaptive approach. *Advances in building energy research*, 1(1), 55-88.

Hussein, I., & Rahman, M. H. A. (2009). Field study on thermal comfort in Malaysia. *European Journal of Scientific Research*, 37, 134-152.

Hwang, R. L., Lin, T. P., & Kuo, N. J. (2006). Field experiments on thermal comfort in campus classrooms in Taiwan. *Energy and Buildings*, 38(1), 53-62.

Hwang, R.L., Lin, T.P., Chen, C.P., Kuo, N.J. (2009). Investigating the adaptive model of thermal comfort for naturally ventilated school buildings in Taiwan. *International Journal of Biometeorology*, 53, 189–200.

Indraganti, M. (2010). Adaptive use of natural ventilation for thermal comfort in Indian apartments. *Building and environment*, 45(6), 1490-1507.

Jara, P. (2015). Thermal comfort and its importance for the architectural design and environmental quality of indoors space. *Arquitectura y cultura*, 7, 106-121.

Jing, S., Lei, Y., Wang, H., Song, C., & Yan, X. (2019). Thermal comfort and energy-saving potential in university classrooms during the heating season. *Energy and Buildings*, 202, 109390.

Junjie, Z., Ling, J., Cunen, C., & Qinglin, M. (2011). Thermal comfort of naturally ventilated houses in countryside of subtropical region. In *2011 International Conference on Electric Technology and Civil Engineering (ICETCE)*, 6371-6375.

Kabir, S. M. S. (2016). Basic Guidelines for Research. *An Introductory Approach for All Disciplines*, 168-180.

Karyono, T. H. (2008). Bandung thermal comfort study: assessing the applicability of an adaptive model in Indonesia. *Architectural Science Review*, 51(1), 60-65.

Katafygiotou, M. C., & Serghides, D. K. (2014). Indoor comfort and energy performance of buildings in relation to occupants' satisfaction: investigation in secondary schools of Cyprus. *Advances in Building Energy Research*, 8(2), 216-240.

Lam, J. C., Yang, L., & Liu, J. (2006). Development of passive design zones in China using bioclimatic approach. *Energy Conversion and Management*, 47(6), 746-762.

Lenoir, A., Baird, G., & Garde, F. (2012). Post-occupancy evaluation and experimental feedback of a net zero-energy building in a tropical climate. *Architectural Science Review*, 55, 156–168.

Liang, H. H., Lin, T. P., & Hwang, R. L. (2012). Linking occupants' thermal perception and building thermal performance in naturally ventilated school buildings. *Applied Energy*, 94, 355-363.

Mallick, F. H. (1996). Thermal comfort and building design in the tropical climates. *Energy and buildings*, 23(3), 161-167.

McIntyre, D. A. (1978). Preferred air speeds for comfort in warm conditions. *ASHRAE Transaction*, 84(1), 264-277.

Memon, R. A., Chirarattananon, S., & Vangtook, P. (2008). Thermal comfort assessment and application of radiant cooling: a case study. *Building and environment*, 43(7), 1185-1196.

Mirrahimi, S., Mohamed, M. F., Haw, L. C., Ibrahim, N. L. N., Yusoff, W. F. M., & Aflaki, A. (2016). The effect of building envelope on the thermal comfort and energy saving for high-rise buildings in hot–humid climate. *Renewable and Sustainable Energy Reviews*, 53, 1508-

1519.

Mishra, A. K., & Ramgopal, M. (2013). Field studies on human thermal comfort—an overview. *Building and Environment*, 64, 94-106.

Mishra, A. K., & Ramgopal, M. (2014). Thermal comfort in undergraduate laboratories—A field study in Kharagpur, India. *Building and environment*, 71, 223-232.

Mishra, A. K., & Ramgopal, M. (2015). A thermal comfort field study of naturally ventilated classrooms in Kharagpur, India. *Building and Environment*, 92, 396-406.

Mishra, A. K., Derks, M. T. H., Kooi, L., Loomans, M. G. L. C., & Kort, H. S. M. (2017). Analysing thermal comfort perception of students through the class hour, during heating season, in a university classroom. *Building and Environment*, 125, 464-474.

Modeste, K. N., Tchinda, R., & Ricciardi, P. (2014). Thermal comfort and air movement preference in some classrooms in Cameroun. *Journal of Renewable Energies*, 17(2), 263-278.

Montazami, A., & Nicol, F. (2013). Overheating in schools: comparing existing and new guidelines. *Building Research & Information*, 41(3), 317-329.

Munonye, C., & Ji Y. (2018). Rating the Components of Indoor Environmental Quality in Students Classrooms in Warm Humid Climate of Uli, Nigeria. *Coou African Journal of Environmental Research*, 1(2), 118-29.

Nagano, K., & Mochida, T. (2004). Experiments on thermal environmental design of ceiling radiant cooling for supine human subjects. *Building and environment*, 39(3), 267-275.

Nagaraju, K., & Ramesh, S. (2019). Thermal Comfort Studies In Classrooms Of Higher Education Institutions; A Review. IMPACT: *International Journal of Research in Humanities, Arts and Literature*, 7(5), 175-188.

Nasrollahi, N. (2007). *Thermal environments and occupant thermal comfort in Iranian office buildings*. Doctoral dissertation, University of Wales, Cardiff.

Nematchoua, M. K., Tchinda, R., Ricciardi, P., & Djongyang, N. (2014). A field study on thermal comfort in naturally-ventilated buildings located in the equatorial climatic region of Cameroon. *Renewable and Sustainable Energy Reviews*, 39, 381-393.

Nicol, F. (2004). Adaptive thermal comfort standards in the hot–humid tropics. *Energy and buildings*, 36(7), 628-637.

Nicol, F., Humphreys, M., & Roaf, S. (2012). *Adaptive thermal comfort: principles and practice*. Routledge, 1, 208.

Nicol, J. F., & Wilson, M. (2011). A critique of European Standard EN 15251: strengths, weaknesses and lessons for future standards. *Building Research & Information*, 39(2), 183-193 Khaliq.

Norbäck, D., & Nordström, K. (2008). An experimental study on effects of increased ventilation flow on students' perception of indoor environment in computer classrooms. *Indoor air*, 18(4), 293-300.

Ogbonna, A. C., & Harris, D. J. (2008). Thermal comfort in sub-Saharan Africa: field study report in Jos-Nigeria. *Applied Energy*, *85*(1), 1-11.

Oginni, A. (2018). Comparative Analysis of the Thermal Performance of Selected Public School Classroom Buildings in Lagos, Nigeria. *In Proceedings of the 8th International RAIS*

Conference on Social Sciences, 139-157.

Olesen, B. W., & Brager, G. S. (2004). A better way to predict comfort: The new ASHRAE standard 55-2004. *ASHRAE Journal*, 46(8), 20–28.

Rajasekar, E., & Ramachandraiah, A. (2010). Adaptive comfort and thermal expectations–a subjective evaluation in hot humid climate. *Proceedings of the adapting to change: new thinking on comfort. Windsor, London, UK*, 9-11.

Ricciardi, P., & Buratti, C. (2018). Environmental quality of university classrooms: Subjective and objective evaluation of the thermal, acoustic and lighting comfort conditions. *Building and Environment*, 127, 23-36.

Schiavon, S., Yang, B., Donner, Y., Chang, V. C., & Nazaroff, W. W. (2017). Thermal comfort, perceived air quality, and cognitive performance when personally controlled air movement is used by tropically acclimatized persons. *Indoor air*, 27(3), 690-702.

Serghides et al. (2014) Serghides, D. K., Chatzinikola, C. K., & Katafygiotou, M. C. (2015). Comparative studies of the occupants' behaviour in a university building during winter and summer time. *International Journal of Sustainable Energy*, 34(8), 528-551.

Shove, E. A. (2003). *Comfort, Cleanliness and Convenience: The Social Organization of Normality*. Berg.

Sookchaiya, T., Monyakul, V., &Thepa, S. (2010). Assessment of the thermal environment effects on human comfort and health for the development of novel air conditioning system in tropical regions. *Energy and Buildings*. 42, 1692-1702.

Teli, D., James, P. A., & Jentsch, M. F. (2013). Thermal comfort in naturally ventilated primary school classrooms. *Building Research and Information*, 41(3), 301-316.

Teli, D., Jentsch, M.F., James, P.A.B. (2012). Naturally ventilated classrooms: an assessment of existing comfort models for predicting the thermal sensation and preference of primary school children. *Energy and Building*, 53, 166–182.

Ter Mors, S., Hensen, J. L., Loomans, M. G., & Boerstra, A. C. (2011). Adaptive thermal comfort in primary school classrooms: Creating and validating PMV-based comfort charts. *Building and Environment*, 46(12), 2454-2461.

Toftum, J., Zhou, G., & Melikov, A. (2000). Effect of airflow direction on human perception of draught. *Proceedings of CLIMA*, 2000.

Wahab, A. B. (2015). Effect of physical characteristics and thermal performance of secondary school built with bricks on adaptive behaviour of its occupants. *Civil and Environmental Research*, 7(1), 55-63.

Wang, Z., Li, A., Ren, J., & He, Y. (2014). Thermal adaptation and thermal environment in university classrooms and offices in Harbin. *Energy and Buildings*, 77, 192-196.

Wargocki, P., & Wyon, D. P. (2013). Providing better thermal and air quality conditions in school classrooms would be cost-effective. *Building and Environment*, 59, 581-589.

Wargocki, P., Porras-Salazar, J. A., & Contreras-Espinoza, S. (2019). The relationship between classroom temperature and children's performance in school. *Building and Environment*, 157, 197-204.

Wigö, H. (2013). Effects of intermittent air velocity on thermal and draught perception–a field study in a school environment. *International Journal of Ventilation*, 12(3), 249-256.

Wolkoff, P., Azuma, K., & Carrer, P. (2021). Health, work performance, and risk of infection in office-like environments: The role of indoor temperature, air humidity, and ventilation. *International Journal of Hygiene and Environmental Health*, 233, 113709.

World Health Organization. (2010). *WHO guidelines for indoor air quality: selected pollutants*. World Health Organization. Regional Office for Europe.

Yadeta, C., Tucho, G. T., Tadesse, E., & Alemayehu, E. (2019). Human Thermal Comfort and Its Analysis by Computational Fluid Dynamics for Naturally Ventilated Residential Buildings of Jimma Town, South West Ethiopia. *Ethiopian Journal of Education and Sciences*, 15(1), 102-115.

Yao, R., Liu, J., & Li, B. (2010). Occupants' adaptive responses and perception of thermal environment in naturally conditioned university classrooms. *Applied Energy*, 87, 1015–1022.

Zeiler, W., & Boxem, G. (2009). Effects of thermal activated building systems in schools on thermal comfort in winter. *Building and Environment*, *44*(11), 2308-2317.

Zhai, Y., Arens, E., Elsworth, K., & Zhang, H. (2017). Selecting air speeds for cooling at sedentary and non-sedentary office activity levels. *Building and Environment*, 122, 247-257.

Zhai, Y., Zhang, Y., Zhang, H., Pasut, W., Arens, E., & Meng, Q. (2015). Human comfort and perceived air quality in warm and humid environments with ceiling fans. *Building and Environment*, 90, 178-185.

Zhang, G., Zheng, C., Yang, W., Zhang, Q., & Moschandreas, D. J. (2007). Thermal comfort investigation of naturally ventilated classrooms in a subtropical region. *Indoor and Built Environment*, 16(2), 148-158.

Zhang, H., Arens, E., Fard, S. A., Huizenga, C., Paliaga, G., Brager, G., & Zagreus, L. (2007). Air movement preferences observed in office buildings. *International journal of Biometeorology*, 51(5), 349-360.

Zhang, Y., Chen, H., & Meng, Q. (2013). Thermal comfort in buildings with split air-conditioners in hot-humid area of China. *Building and Environment*, *64*, 213-224.

Zhang, Y., Wang, J., Chen, H., Zhang, J., Meng, Q. (2010). Thermal comfort in naturally ventilated buildings in hot-humid area of China. *Building and Environment*, 45, 2562–2570.

APPENDICES

APPENDIX A

Field Measurements of Thermal Parameter for Category A Lecture Theaters

Date;Time;Timestamp;PM2_5(ug/m3);AQI(US);AQI(CN);PM10(ug/m3);Outdoor AQI(US);OutdoorQI(CN);Temperature(C);Temperature(F);Humidity(%RH);CO2(ppm);VOC(ppb)
2021/09/06;14:11:29;1630937489;11.0;46;16;13.0;0;0;27.7;81.8;88;460;-1
2021/09/06;14:11:39;1630937499;14.0;55;20;16.0;0;0;27.7;81.8;87;435;-1
2021/09/06;14:11:49;1630937509;15.0;57;21;16.0;0;0;27.7;81.8;87;433;-1
2021/09/06;14:11:59;1630937519;17.0;61;24;18.0;0;0;27.7;81.8;87;439;-1
2021/09/06;14:12:09;1630937529;15.0;57;21;16.0;0;0;27.6;81.8;86;437;-1
2021/09/06;14:12:19;1630937539;15.0;57;21;16.0;0;0;27.6;81.8;86;436;-1
2021/09/06;14:12:29;1630937549;11.0;46;16;12.0;0;0;27.6;81.8;86;436;-1
2021/09/06;14:12:39;1630937559;12.0;50;17;12.0;0;0;27.6;81.7;86;435;-1
2021/09/06;14:12:49;1630937569;14.0;55;20;15.0;0;0;27.6;81.7;86;436;-1
2021/09/06;14:12:59;1630937579;16.0;59;23;18.0;0;0;27.6;81.7;86;435;-1
2021/09/06;14:13:09;1630937589;15.0;57;21;17.0;0;0;27.6;81.6;86;434;-1
2021/09/06;14:13:19;1630937599;13.0;53;19;14.0;0;0;27.6;81.6;86;433;-1
2021/09/06;14:13:29;1630937609;12.0;50;17;12.0;0;0;27.6;81.6;86;433;-1
2021/09/06;14:13:39;1630937619;12.0;50;17;12.0;0;0;27.5;81.5;86;432;-1
2021/09/06;14:13:49;1630937629;13.0;53;19;13.0;0;0;27.5;81.5;86;432;-1
2021/09/06;14:13:59;1630937639;14.0;55;20;15.0;0;0;27.5;81.5;86;432;-1
2021/09/06;14:14:09;1630937649;15.0;57;21;16.0;0;0;27.5;81.5;86;432;-1
2021/09/06;14:14:19;1630937659;14.0;55;20;15.0;0;0;27.5;81.5;86;432;-1
2021/09/06;14:14:29;1630937669;13.0;53;19;14.0;0;0;27.5;81.5;86;432;-1
2021/09/06;14:14:39;1630937679;11.0;46;16;12.0;0;0;27.4;81.4;86;432;-1
2021/09/06;14:14:49;1630937689;13.0;53;19;15.0;0;0;27.4;81.4;86;432;-1
2021/09/06;14:14:59;1630937699;12.0;50;17;15.0;0;0;27.4;81.4;86;432;-1
2021/09/06;14:15:09;1630937709;13.0;53;19;15.0;0;0;27.4;81.3;86;433;-1
2021/09/06;14:15:19;1630937719;12.0;50;17;13.0;0;0;27.4;81.3;86;433;-1
2021/09/06;14:15:29;1630937729;13.0;53;19;14.0;0;0;27.4;81.3;86;434;-1
2021/09/06;14:15:39;1630937739;12.0;50;17;13.0;0;0;27.3;81.2;86;434;-1
2021/09/06;14:15:49;1630937749;12.0;50;17;15.0;0;0;27.3;81.2;86;434;-1
2021/09/06;14:15:59;1630937759;12.0;50;17;16.0;0;0;27.3;81.2;86;434;-1
2021/09/06;14:16:09;1630937769;14.0;55;20;18.0;0;0;27.3;81.2;87;435;-1
2021/09/06;14:16:19;1630937779;14.0;55;20;16.0;0;0;27.3;81.2;87;438;-1
2021/09/06;14:16:29;1630937789;14.0;55;20;15.0;0;0;27.3;81.2;87;447;-1
2021/09/06;14:16:39;1630937799;12.0;50;17;13.0;0;0;27.3;81.2;87;467;-1
2021/09/06;14:16:49;1630937809;12.0;50;17;13.0;0;0;27.3;81.2;87;476;-1
2021/09/06;14:16:59;1630937819;11.0;46;16;12.0;0;0;27.3;81.2;87;484;-1
2021/09/06;14:17:09;1630937829;12.0;50;17;13.0;0;0;27.3;81.2;87;485;-1
2021/09/06;14:17:19;1630937839;11.0;46;16;12.0;0;0;27.3;81.2;87;481;-1
2021/09/06;14:17:29;1630937849;12.0;50;17;13.0;0;0;27.3;81.2;87;478;-1
2021/09/06;14:17:39;1630937859;13.0;53;19;14.0;0;0;27.3;81.1;87;473;-1
2021/09/06;14:17:49;1630937869;13.0;53;19;14.0;0;0;27.3;81.1;87;467;-1
2021/09/06;14:17:59;1630937879;13.0;53;19;14.0;0;0;27.3;81.1;87;461;-1
2021/09/06;14:18:09;1630937889;13.0;53;19;14.0;0;0;27.3;81.1;87;458;-1
2021/09/06;14:18:19;1630937899;14.0;55;20;15.0;0;0;27.3;81.1;87;453;-1
2021/09/06;14:18:29;1630937909;14.0;55;20;16.0;0;0;27.3;81.1;87;449;-1
2021/09/06;14:18:39;1630937919;14.0;55;20;16.0;0;0;27.3;81.1;87;446;-1
2021/09/06;14:18:49;1630937929;14.0;55;20;17.0;0;0;27.3;81.1;87;444;-1
2021/09/06;14:18:59;1630937939;14.0;55;20;16.0;0;0;27.3;81.1;87;441;-1
2021/09/06;14:19:09;1630937949;14.0;55;20;16.0;0;0;27.3;81.1;87;439;-1
2021/09/06;14:19:19;1630937959;12.0;50;17;15.0;0;0;27.3;81.1;87;437;-1

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2021/09/06;14:19:49;1630937989;12.0;50;17;15.0;0;0;27.3;81.1;87;434;-1
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2021/09/06;14:20:09;1630938009;13.0;53;19;14.0;0;0;27.2;81.0;87;432;-1
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2021/09/06;14:20:59;1630938059;11.0;46;16;13.0;0;0;27.2;81.0;87;432;-1
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2021/09/06;14:23:19;1630938199;13.0;53;19;14.0;0;0;27.2;81.0;86;443;-1
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2021/09/06;14:27:39;1630938459;10.0;42;14;11.0;0;0;27.3;81.1;86;440;-1
2021/09/06;14:27:49;1630938469;11.0;46;16;12.0;0;0;27.3;81.1;86;439;-1
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2021/09/06;14:28:09;1630938489;15.0;57;21;17.0;0;0;27.3;81.1;86;439;-1
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2021/09/06;14:28:29;1630938509;12.0;50;17;15.0;0;0;27.3;81.1;86;442;-1
2021/09/06;14:28:39;1630938519;13.0;53;19;16.0;0;0;27.3;81.1;86;446;-1

2021/09/06;14:28:49;1630938529;13.0;53;19;16.0;0;0;27.3;81.1;86;448;-1
2021/09/06;14:28:59;1630938539;13.0;53;19;15.0;0;0;27.3;81.1;86;450;-1
2021/09/06;14:29:09;1630938549;12.0;50;17;14.0;0;0;27.3;81.2;86;457;-1
2021/09/06;14:29:19;1630938559;10.0;42;14;11.0;0;0;27.3;81.2;86;462;-1
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APPENDIX B

Field Measurements of Thermal Parameter for Category B **Lecture Theaters**

Date;Time;Timestamp;PM2_5(ug/m3);AQI(US);AQI(CN);PM10(ug/m3);Outdoor AQI(US);OutdoorQI(CN);Temperature(C);Temperature(F);Humidity(%RH);CO2(ppm);VOC(ppb)
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APPENDIX C

Field Measurements of Thermal Parameter for Category C Lecture Rooms

Date;Time;Timestamp;PM2_5(ug/m3);AQI(US);AQI(CN);PM10(ug/m3);Outdoor AQI(US);OutdoorQI(CN);Temperature(C);Temperature(F);Humidity(%RH);CO2(ppm);VOC(ppb)
2021/09/06;14:45:49;1630939549;11.0;46;16;11.0;0;0;27.5;81.6;86;434;-1
2021/09/06;14:45:59;1630939559;11.0;46;16;12.0;0;0;27.5;81.6;86;433;-1
2021/09/06;14:46:09;1630939569;13.0;53;19;14.0;0;0;27.5;81.5;86;433;-1
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2021/09/06;14:46:29;1630939589;13.0;53;19;14.0;0;0;27.5;81.5;86;429;-1
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