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A THERMAL COMFORT EVALUATION OF A JUNIOR HIGH SCHOOL BUILDING IN ACCRA, GHANA

Appah, D.J[1] and Koranteng, C.[2]

[1,2]Department of Architecture, Kwame Nkrumah University of Science and Technology, Kumasi, Ghana
Email: rcbpd.ghana@yahoo.com

Abstract
A field study of students' and teachers' thermal comfort in a school building (St. Andrews Junior High School) was carried out at Madina, Accra. The building was chosen due to the sustainable design principles (e.g. form, orientation and ventilation) employed in the design and construction of the school. The aim of the study was to investigate peoples' perception of comfort as well as examine the prevailing thermal conditions in the classrooms. Moreover, a comparative analysis of the results with the worldwide accepted ASHRAE recommendations was carried-out. The study employed the use of subjective assessments through questionnaires and physical measurements. The measured environmental parameters required the use of Hobo data sensors, these measured temperature and relative humidity values. The subjective responses concerned the occupants' judgement about their thermal environment. One significant conclusion drawn was that the classroom spaces on the ground floor experienced lower temperatures, whilst those on the first floor had a higher temperature (difference of 2°C). The first floor classrooms experienced higher thermal conditions as a result of the absence of a ceiling. In addition, though a large majority of the respondents accepted their overall thermal conditions, a number of them still voted below the standard set by ASHRAE of 80% positive votes by occupants for thermal comfort. The study also showed that respondents in tropical countries such as Ghana may have a higher heat tolerance, since most of the interviewees accepted the existing thermal conditions which exceeded the standard of between 26°C and 28°C (summer comfort range) by 1°C to 5°C.

Keywords: Thermal comfort, occupants, school buildings, tropics.

INTRODUCTION

The American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) (2004) define thermal comfort as that condition of mind which expresses satisfaction with the thermal environment. A definition most people can agree on, but also a definition that is not easily converted into physical parameters (Hussein and Rahman, 2009).

Thermal comfort is a key component for quality of indoor environments. Environmental elements such as heat from electrical lighting, lack of adequate ventilation, high humidity levels, and poorly performing building envelopes can contribute to health problems at workplaces. Thermal discomfort in school buildings can create unsatisfactory conditions for both teachers and students. This can be distracting for the occupants and is likely to reduce their productivity and performance. The challenge is to come out with self-sustaining buildings which will facilitate learning and overcome the state of discomfort with minimum energy utilization.

It is worth noting that generally, most of the research conducted revealed that building occupants ascertained indoor thermal condition to be acceptable even though the thermal sensation votes (TSV) exceeded those specified by the highly recognised American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) standard 55. This standard specifies conditions in which majority of the occupants will find their environment thermally acceptable. The standard suggests that there might be other contributory factors (psychological, health state of occupants, adaptation, etc.) which are responsible for this occurrence. In addition, the negative effects of heat on student's learning capacity can be alarming and has therefore necessitated the research study.

A lot of research has been carried out in the field of thermal comfort regarding educational buildings in temperate climates. However, very few studies have been published on the comfort of building occupants in Ghana. For the purpose of this study, attempts will be made in relating various factors (shape, orientation, absorption of solar heat by exterior surfaces, etc.) that affect indoor thermal conditions to school buildings in Ghana (Madina, Accra). This will in effect ascertain how well passive design techniques have contributed to providing an acceptable indoor climate and if not, what possible mechanisms could be put in place to enhance the thermal comfort of junior high school buildings.

Research suggests that school children (humans) are susceptible to heat stress (Szokolay, 2004 and Prescott et al, 2001).

Heat stress is defined as that combination of air temperature, radiation, moisture content of the air, air movement, clothing and behaviour that induces a physiological inability of the body to maintain its temperature within limits that permit normal physiological performance (Aynsley et al., 1996). Heat stress can have a negative impact on the learning capacity of people. For instance, at high temperatures, people are less able to concentrate and may exhibit irritable or aggressive behaviour, and operate building systems for comfort (Rijal et al., 2008; Mahdavi et al, 2007; Sutter et al., 2006; Nicol and Roaf, 2005; Herkel et al., 2005; and Nicol, 2001). In order to restore thermal comfort, air-condition may be the answer to this problem of uncomfortable conditions. Tough reassuring, air conditioning in the tropics (developing countries) has its consequences. Precisely, mechanical air conditioning requires high amounts of energy which presently, Ghana cannot afford. Therefore, there is the need to provide a comfortable indoor climate with minimum energy utilization. It is worth noting that a comfortable thermal environment makes people healthy, both physically and psychologically and this will positively influence productivity.

According to Hussein and Rahman (2009), actual thermal comfort standards are based upon laboratory studies carried out in climatic chambers, ignoring the complex interaction between occupants and their environments that could affect their comfort. In reality, occupants are comfortable in a wider range of conditions. This is because people are able to adapt to the environment that they are used to. The tropical climate in Ghana is warm and humid with mean outdoor temperatures of about 26°C but relative humidity values are rather high (above 80%). However, Accra's daily average temperature is 30°C. The prevailing climate may have an adverse impact on indoor occupant comfort.

ASHRAE (2004) stipulates that for a building or a space to be comfortable, 80% of the occupants should be satisfied with the thermal conditions (summer comfort is given as 26°C to 28°C with relative humidity being less than 70%). Thermal comfort is complex and partly subjective. It depends on environmental and personal factors, namely, air temperature, humidity, air movement, thermal radiation, the metabolic rate and the level of clothing (Chenvidyakarn, 2007).

Humans require energy to perform work and produce heat to maintain an internal body temperature of around 37°C.

If the core body temperature is reduced by more than about 1°C hypothermia sets in; if it increases by more than about 1°C the person may suffer a heat stroke (Alder, 1999). The higher the activity level, the more heat is produced. If too much heat is produced, then the body will sweat, which causes discomfort. If too little heat is produced blood will be withdrawn from the hands and feet, skin temperature will fall and the person feels cold and uncomfortable (Havenith et al., 2002). Besides, clothing interferes with our ability to lose heat to the environment. Thermal comfort is very much dependent on the insulating effect of clothing on the wearer.

The insulation of clothing is measured in units of CLO (1 CLO = 0.155 m2 K/W; the units are those of internal resistance) (Szokolay, 2004). Relative humidity (RH) of a space will affect the rate of evaporation from the skin. The RH is 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 (Stein and Reynolds, 2000). At high air temperatures (approaching average skin temperature of 34 °C) evaporation heat loss is important to maintain comfort. Human occupants are sensitive to the variation of temperature rather than relative humidity (Hussein et al., 2002) and there is little conclusive evidence to show that either high or low humidity is detrimental to the health of normal people. However, some studies (e.g. Klein and Schlenger, 2008) indicate that people, when exposed to low relative humidity conditions, may develop dry and irritated skin, mainly due to the increase in evaporation rate from the skin. A study conducted by Arens et al. (2002) on thermal comfort at high relative humidity shows that there are no significant psychological or physiological differences in human response to exposure of between 60% to 90% relative humidity for the temperature range of 20ºC to 26ºC while sedentary.

Air temperature is often taken as the main design parameter for thermal comfort. Hence, it is essential for occupants' well-being, productivity and efficiency (Adebamowo and Akande, 2010). Nyuk and Shan (2003) concluded from their field study conducted in Singapore for classrooms (mechanically ventilated by fans) that the acceptable temperature range is from 27.1ºC to 29.3ºC, implying that the ASHRAE Standard 55 is not wholly applicable in the free running buildings in the tropical climate. Kwok (1998) studied the thermal comfort conditions in classrooms in Hawaii (naturally ventilated and air conditioned types).

Neutral temperatures (temperature at which majority of people felt neither too warm nor too cold) for the two types of classrooms were 26.8ºC and 27.4ºC. As important as these studies are, their findings have not yet emerged into comprehensive and widely accepted guidelines for tropical naturally ventilated buildings (Adebamowo, 2007). In reality, occupants are comfortable in a wider range of conditions.

The effects of the other environmental parameters on thermal comfort have also been studied. Auliciens and Szokolay (2007) reported on comfort perception at different air velocities. Heat radiation on comfort has been outlined by HSE (2011). The thermal performance of a building is the degree at which the building modifies the prevailing outdoor climate to create a unique indoor environment. Many factors (shape, orientation, absorption of solar radiation, window to wall ratio, materials, etc.) contribute to the way buildings are able to respond to their external environment.

AL-Najem (2010) reported that heat gain through the exterior window accounts for 25-28% of the total heat gain. As a result of this, window placement has a strong influence on the productivity and comfort of the people who occupy the building. Moreover, the thermal capacities (a measure of the ability to store heat from the surrounding air and surfaces) of various materials respond differently on incident solar radiation (Stein and Reynolds, 2000). A high-density material such as concrete solid block will store more heat than a low-density material (concrete hollow block). The extent of landscaping also has an influence on the amount of radiation reflected onto building envelopes. Moreover, orientation and spatial organisation affect the ability of a building to ventilate and receive solar radiation. To minimise solar gain and maximise ventilation, buildings should be orientated in such a way that the longer sides of the buildings intercept prevailing winds and the shorter sides face the direction of the strongest solar radiation. The result is the achievement of effective ventilation while thermal impact from solar radiation is minimised (Koranteng and Abaitey, 2010). The positive effects of shading on comfort and energy performance of buildings have been stated by Chenvidyakarn (2007), Sumanon (2004), Lechner (2001), Hyde (2000), Chukiatman (1998), and U-Sanno (1997).

As far as thermal comfort is concerned, there have been immense contributions to this field of study. Research has shown that occupants can accept a thermal range beyond the stipulated ASHRAE comfort zone. This, more often than not, can be attributed to the natural tendency of people to adapt to changing conditions in their environment as well as acclimatization. In Ghana, very few studies have been conducted (Korantaeng and Mahdavi, 2010 and, Koranteng et al., 2011) In view of this, there is the need to add up to the growing knowledge of thermal comfort in buildings. Under the present circumstances, this research on comfort in school buildings is to investigate the occupants' perception of the accepted level of indoor thermal comfort and to validate the level of acceptability of the findings with ASHRAE Standard 55.

METHODOLOGY

In view of the objective to analyse peoples' subjective feelings about prevailing indoor conditions, a philosophy for the study needed to be established. Therefore, the research philosophy adopted was positivism. Positivism recognizes working with an observable social reality and that the end product of such research can be law-like generalisations similar to those produced by the physical and natural scientists (Remenyi et al., 1998, cited in Saunders et al., 2003). Moreover, the researcher is convinced that truth is not dependent on belief alone but on statements that can be verified through examination and observation of external occurrences.

The method applied for the study was a combination of descriptive and explanatory research. These were based on a case study object as a means to gain insight into how school buildings and the environment modify the prevailing weather conditions to provide acceptable indoor climates conducive for learning.

The monitored building is located at Madina (Accra, Greater Accra Region) and it houses the St. Andrews Junior High School. This particular school was chosen based on the fact that sustainable design principles (which are often neglected in the design of buildings) have been employed. Some of the employed design principles include the orientation of form, ventilation and shading.

Furthermore, the structure is not different from most educational buildings situated in the area and therefore lessons drawn could be applied to school buildings in general.

The facility consists of a crèche, primary and Junior High School (J.H.S). The primary and the crèche are made up of single storey, multiple buildings. The selected J.H.S. structure is a two storey, multiple building. However, due to financial constraints, only two classes were selected for the study. These classes (1A and 2A) are located on each of the floors of the school building (see Fig. 1). The overall floor area of each classroom is 54 m². The building is oriented in such a way that openings are exposed to the north and south direction. Trees are shading the southern sides, as well as a verandah which is used to assess the classrooms. The school building is naturally ventilated and each classroom has two ceiling fans to aid in comfort ventilation.

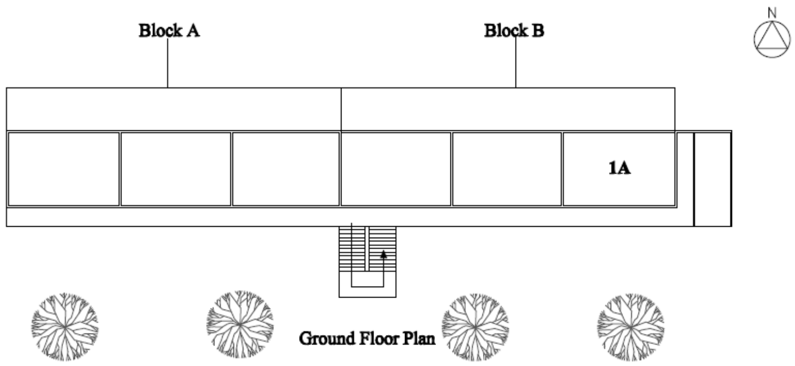

Fig. 1: A schematic plan of St. Andrews J.H.S showing the class 1A and the position of trees

Fig. 2: St. Andrews J.H.S. building and surrounding

The study made use of an instrument called HOBO data logger as well as surveyors tape measure. The HOBO data logger was used for measuring temperature and relative humidity (see Table 1). These sensors were placed in the respective classes (Fig. 2) for four weeks (November 1 to 30, 2011). In addition, the outdoor temperature was recorded.

The measuring tape was used to obtain wall lengths and floor areas, which were used to draw the schematic plans of the building.

Table 1: Accuracy of the hobo sensors

Sensor	Range	Error
Air Temperature	-20 to70 °C	± 0.4°C
Relative Humidity	5 to 95%	± 3%

Fig. 3: Location of sensors in the classrooms
(The design, dimension and seating arrangement are the same for both classrooms)

Interviews and questionnaire surveys were conducted at the end of the study period (Figs. 4 and 5). The subjective assessments were based on the occupants' vote on thermal sensation, thermal preference, thermal acceptance, air velocity and humidity in the occupied zone. The scales used were the worldwide accepted ASHRAE scale, preference scale, air flow scale and humidity scale (ASHRAE, 2004).

Fig. 4: Students answering questions at the end of the study period

The first part of the questionnaire dealt with general issues (demographics) and the second part required the 116 students to ascertain how comfortable their classrooms were. This was in relation to the temperature they considered optimum for them as well as their humidity preference. This was based on ASHRAE 7-point scale (ASHRAE, 2004). The students also accessed the rate of air flow and how they wanted it if otherwise.

The study took into consideration the kind of clothing the students wore as this affects the rate of heat dissipation from the body (Szokolay, 2004). The clothing that the occupants wore could be categorized as light summer clothing (tropics), and the clothing insulation was 0.5 clo (Aucliciens and Szokolav, 2007). The metabolic rate was estimated to be 1.2 met ($70W/m^2$) which corresponds to sedentary activity in all locations (Aucliciens and Szokolav, 2007). The activities of the students were writing and listening to lessons at seated positions.
Two sets of parameters were investigated into (physical and subjective). Data obtained from the sensors (Physical Parameter) were analysed with the aid of Microsoft Excel. Different line graphs were subsequently generated. These graphs related different indoor temperature and humidity from the outside ones. In addition, the average temperature and humidity of the classrooms monitored were related to their corresponding outdoor values. The subjective parameter also made use of Microsoft Excel. Each response was keyed into the Excel spread sheet under different areas of the study. However, the bar graphs generated highlighted areas of key interest and this included thermal preference, thermal sensation vote, humidity levels, air movement and the overall thermal acceptability.

RESULTS AND DISCUSSIONS

A total of 116 respondents participated in the survey. 70 of them were male and 46 female. A 100% attendance was recorded for the classes during the questionnaire period. The environmental parameters are illustrated. The indoor air temperatures in the occupied zones were between 29.4°C and 32.3°C with indoor relative humidity between 60.8% and 74.2%. From the data obtained, it can be seen that most of the temperature and relative humidity values exceeded the standard for sedentary activity during summer conditions. The temperature specified by the standard should be between 26°C and 28°C and relative humidity should be between 30% and 70% (ASHRAE, 2004). The statistical results of the environmental parameters data is shown in Table 2.

Table 2: Statistical results of environmental parameters

Parameter	Average	Maximum	Minimum
Ground floor-Indoor Air temperature (°C)	30.3	30.9	29.4
First Floor- Indoor Air Temperature (°C)	31.4	32.3	29.9
Ground floor- Relative Humidity (%)	72.4	77.4	60.8
First Floor- Relative Humidity (%)	68.4	74.2	65.0
Outdoor Air Temperature (°C)	31.7	32.3	30.5
Outdoor Relative Humidity (%)	67.7	73.2	64.8

Fig. 5 shows the ground floor classroom (1A) and outdoor temperature pattern whereas Fig. 6 demonstrates the situation at the first floor during the school hours (9-15 hours).

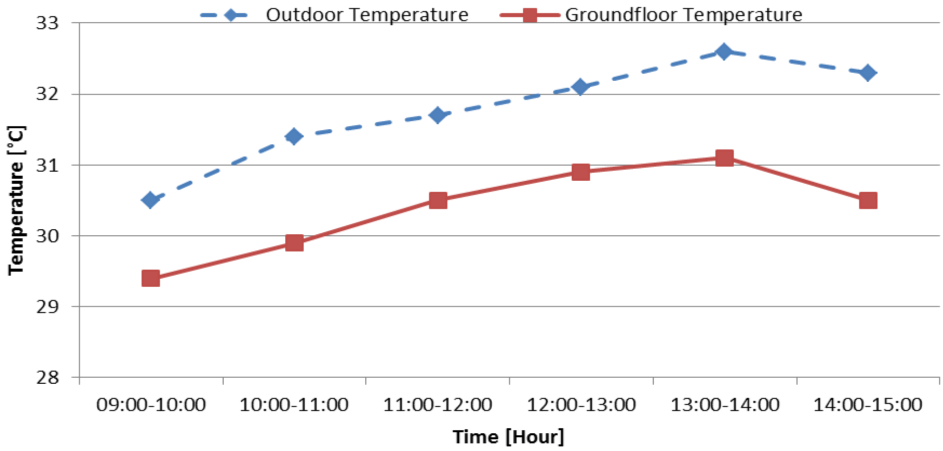

Fig. 5: Ground floor (1A) as related to outdoor in terms of temperature

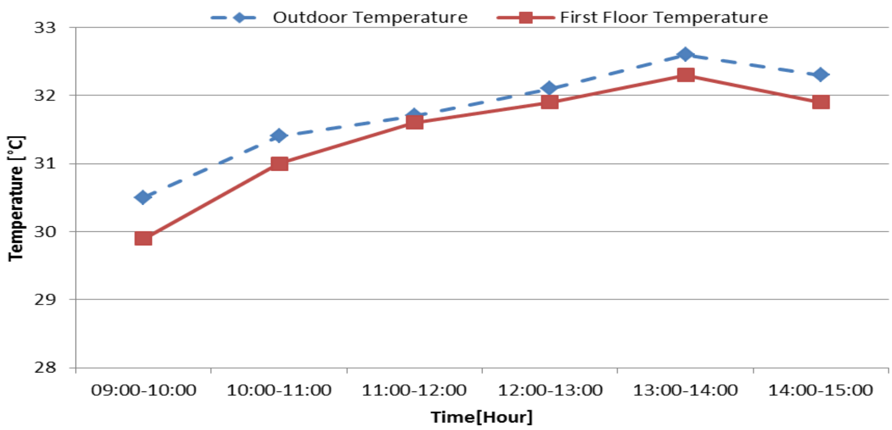

Fig. 6: First floor space (2A) as related to outdoor in terms of temperature

Moreover, Fig. 7 gives the performance of both classrooms in relation to indoor temperature.

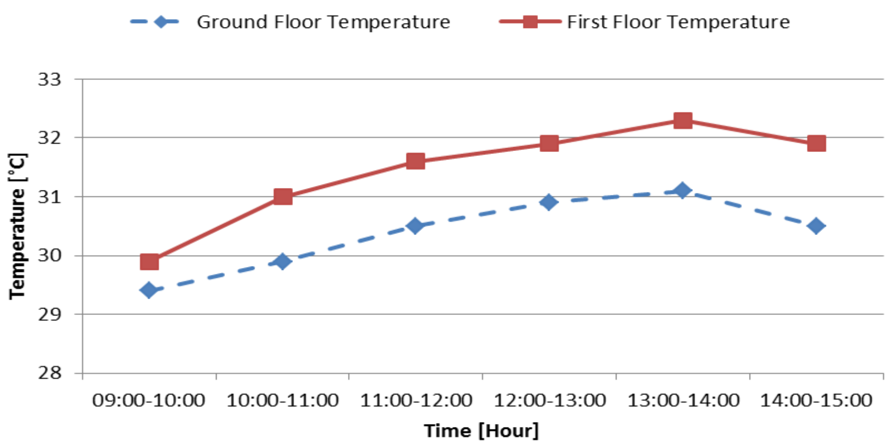

Fig. 7: Ground floor as related to first floor in terms of temperature

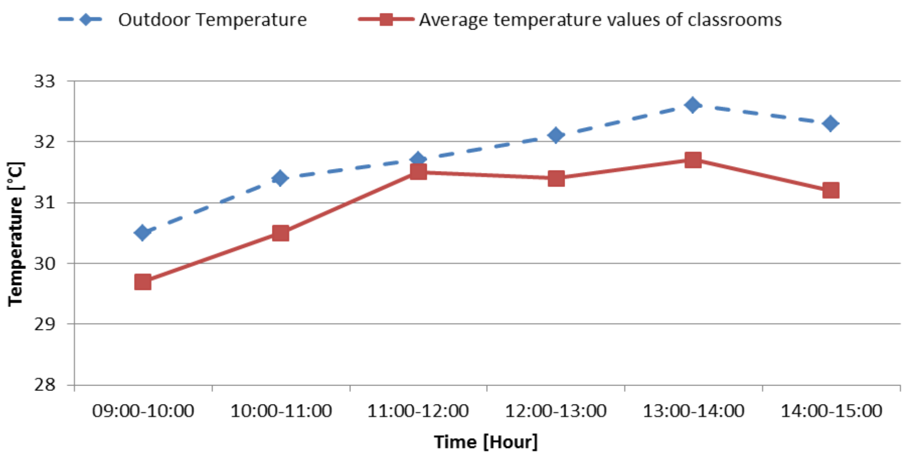

Fig. 8: Average Values of classrooms related to outdoor in terms of temperature

From Fig. 5, the outdoor temperature value rises from 30.5°C in the morning to a peak of about 32.6°C during school hours. However, in the morning, all the temperatures in the respective classrooms happen to be the same (29.7°C). As the outdoor temperature rises with increasing solar radiation, the indoor temperature also increases (Figs. 5, 6 and 8). The indoor temperature of the classroom on the ground floor rises steadily from 29.0°C in the morning and reaches a peak of about 30.9°C and this happens between the hours of 13:00 to 14:00 (Fig. 7). The temperature behaviour, however, is not the same for the classroom on the first floor as it shows a rather high indoor temperature. Here, the temperature rises from 29.9°C in the morning and reaches a peak of 32.4°C. The reason for this contrast in the temperature is the absence of a ceiling in the class on the top floor; a situation attributed to lack of funds on the part of the school. As a result, the conductive heat gains into the space is high, hence the increase in indoor temperature (Szokolay, 2004, Hyde, 2000 and Alder, 1999).

Fig. 6 shows a temperature difference of 0.5°C between the indoor (first floor) and outdoor. This creates uncomfortable conditions during school hours. This accounts for the reason why about 45% of the respondents felt their thermal conditions was not acceptable when they were asked through the questionnaire. Though ceiling fans have been provided in an attempt to provide relief, the occupants still felt uncomfortable. The thermal performance of the space during the afternoon hours cannot be said to be healthy, considering the purpose of the building.

The relative humidity (R.H.) values during the school hours (9-15 hrs.) showed lower outdoor values than the indoor spaces (Fig. 9, 10 and 11). High values (above 70%) are recorded for the classroom on the ground floor followed by the classroom on the first floor but with a difference of less than 4% (Fig. 12).

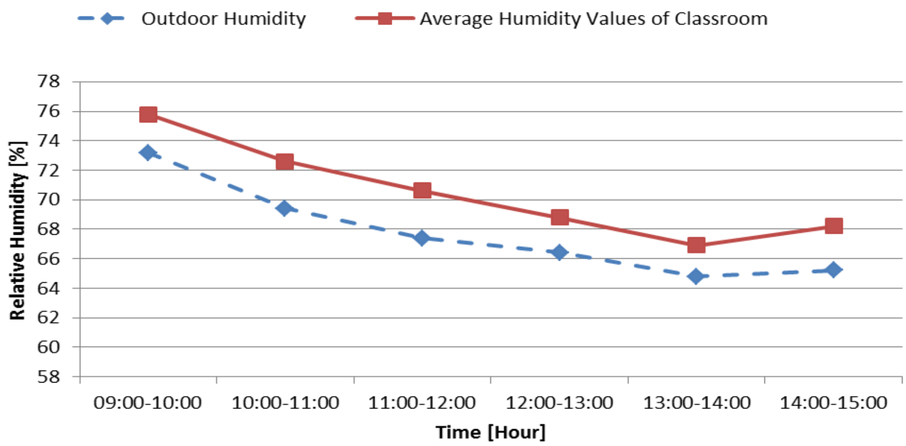

Fig. 9: Average values of classrooms related to outdoor in terms of relative humidity (R.H.)

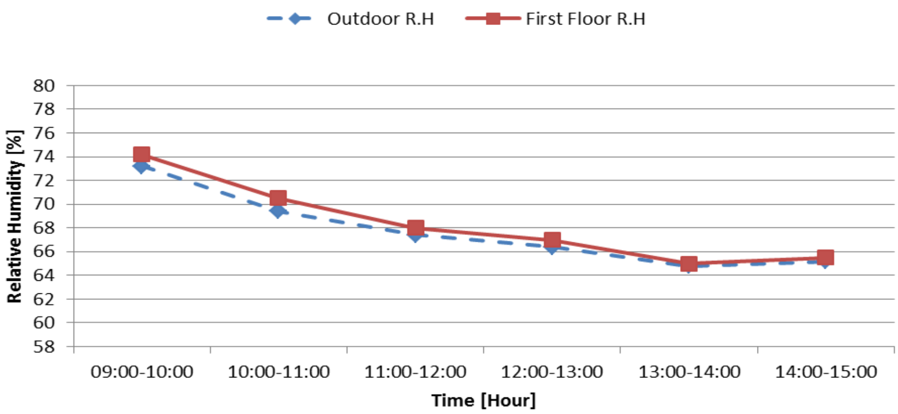

Fig. 10: First floor as related to outdoor in terms of relative humidity

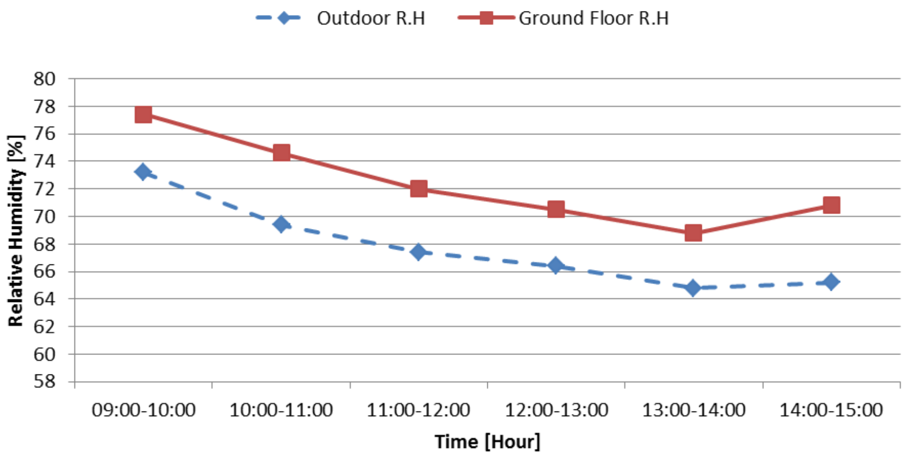

Fig. 11: Ground floor as related to outdoor in terms of relative humidity

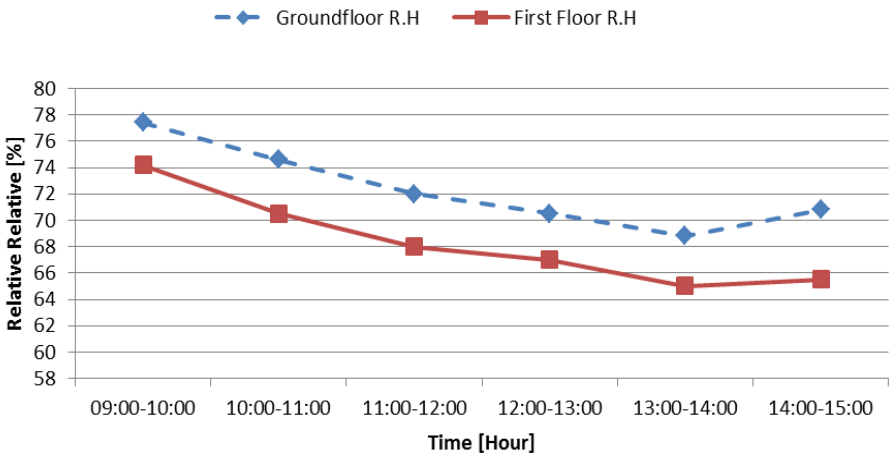

Fig. 12: Ground floor as related to first floor in terms of relative humidity (R.H.)

The highest values for relative humidity were recorded in the mornings and the least in the afternoon. It should be noted that even though high humidity levels result in inefficient evaporative cooling of the skin which leads to discomfort (SBM, 2008), some studies (e.g. Klein and Schlenger, 2008) indicate that people, when exposed to low relative humidity condition may develop signs of a dry and irritated skin (mainly due to the increase in evaporation rate from the skin). However, based on the above findings, the average relative humidity the occupants are exposed to is 60% to 80% (Fig. 9). Again, from the subjective analysis, 81% of the respondents were satisfied with the humidity levels in the classroom. This result confirms the study conducted by Arens et al. (2002) on thermal comfort, saying that a high relative humidity has no significant psychological or physiological influence in human response. In addition, Olesen and Brager (2004) confirmed in their study that humidity has little or no effect on thermal comfort when within 60% to 90%.

A long term study on humidity in buildings by Koranteng (2011) showed that values could go as high as 98-100% during the rainy seasons in Ghana. The problems of discomfort and danger to building construction were also reported.

The results of subjective responses to temperature (thermal sensation) are presented in Fig. 13. The results show that the majority of the respondents voted hot and slightly warm sensation.

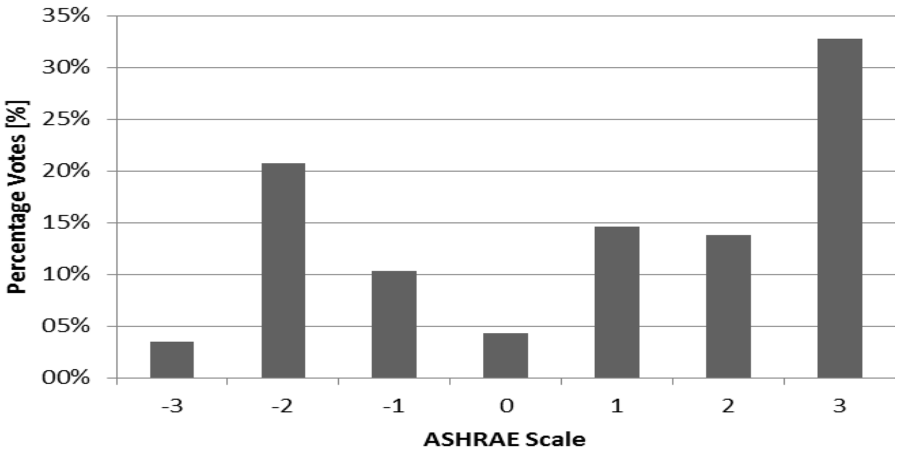

Fig. 13: Thermal sensation vote by the occupants

The ASHRAE Standard 55 (2004) specified that an acceptable thermal environment should have 80% of occupants vote for the central three categories -1 (slightly cool), 0 (neutral), 1 (slightly warm). In this study, only 29% out of the 116 respondents voted within the central three categories, showing that most of the students and teachers were not in thermal acceptable conditions within their classrooms. Against the background of a good orientation, shading by trees, cross ventilation and the use of fans, the thermal situation would have been severe if unsustainable measures were employed in the design and construction of the school building. The subjective scale used for thermal preference was the McIntyre scale (Hussein and Rahman, 2009) (-1(Cooler), 0 (no change) and 1 (warmer)). The results of the subjective thermal preference amongst the respondents are presented in Fig. 14. It can be seen that the respondents preferred to be 'cooler' and no 'change' in their environment.

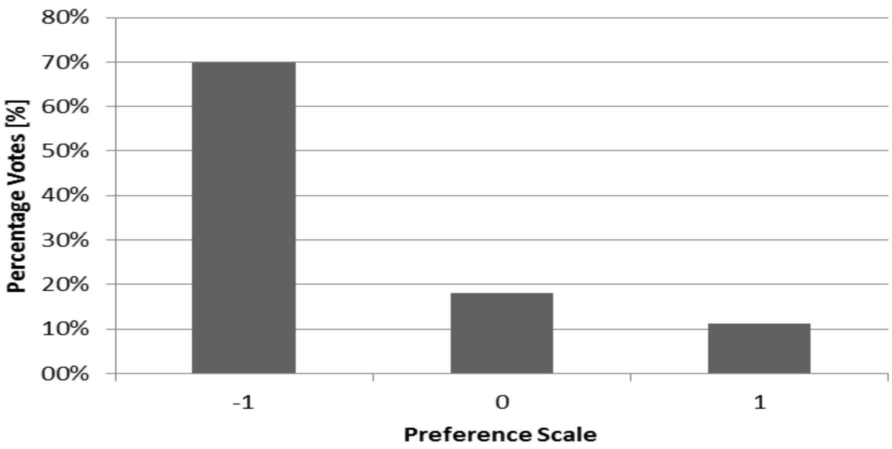

Fig. 14: Thermal preference vote by the occupants

Humidity assessment uses the subjective scale of -3 (much too dry), -2 (too dry), -1 (slightly dry), 0 (just right), 1 (slightly humid), 2 (too humid) and 3 (much too humid). The subjective responses on humidity are presented in Fig. 15.

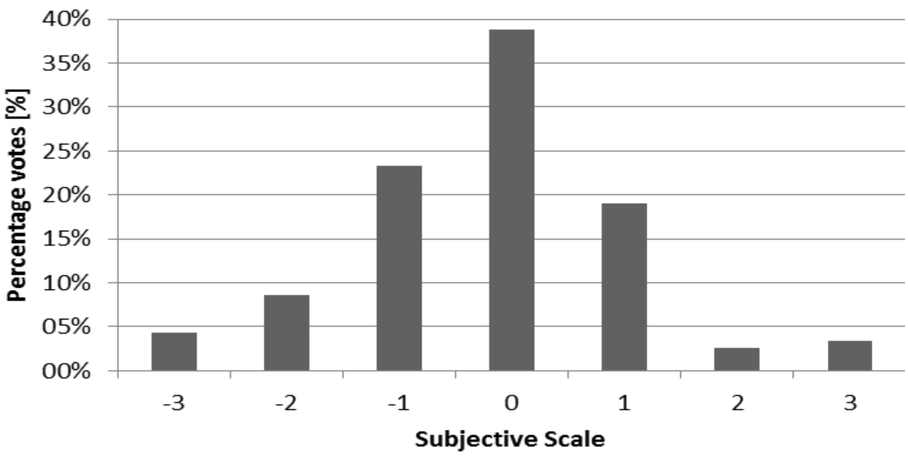

Fig. 15: Occupnts vote on humidity sensation

It was observed that for the overall votes, the occupants were comfortable with the relative humidity, 81% of the respondents voted within the central categories (-1, 0, 1). Hence, the relative humidity was comfortable for most of the respondents. This conclusion demonstrates that occupants were not too sensitive to humidity variation and perceived their condition to be comfortable, independent of the humidity level (Arens et al., 2002 and, Olesen and Brager 2004).

Air movement uses the subjective scale of -1 (slightly still), 0 (just right), 1 (slightly breezy), 2 (breezy), (much too breezy) (ASHARE, 2004). The results of the subjective response on air movement indicate that the majority voted 'slightly still 'and 'just right'. This shows acceptance of the air movement in their classrooms (Fig. 16). The reason is the possibility to cross ventilate and use fans to induce air velocity. The positive effects of high window to wall ratios and the installation of fans have been proven in recent studies (Koranteng, 2011).

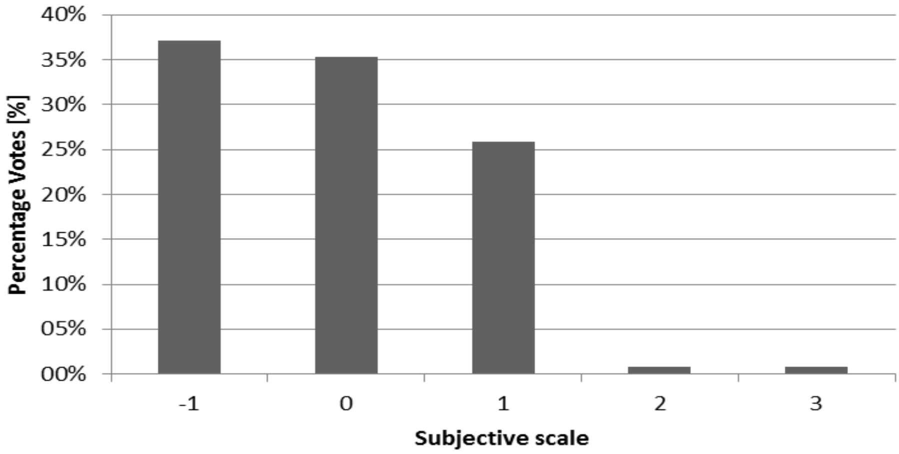

Fig. 16: Occupants vote on air movement

The subjective scale used for the overall thermal comfort assessment is as follows; -3 (Very uncomfortable), -2 (uncomfortable), -1(a little uncomfortable), 0 (just right), 1 (a little comfortable), 2 (comfortable), 3 (very comfortable). The distribution of subjective responses on overall thermal comfort is presented in Fig. 17. The results obtained showed that 74% voted ranging from a little uncomfortable to very comfortable. Though the level of the vote falls slightly short of the 80% required by ASHRAE, it generally shows that the majority of the respondents accept their overall thermal comfort conditions.

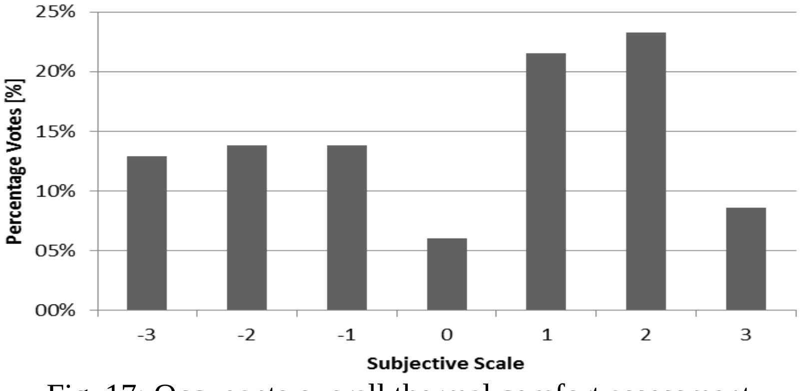

Fig. 17: Occupants overall thermal comfort assessment

The distribution of subjective responses on thermal acceptability is presented in Fig. 18. Majority (55%) of the respondents voted 'acceptable'. Even though the previous section had the respondents voting slightly below the standard of 80% for thermal sensation, it seems that most of the respondents can still accept their thermal conditions regardless of the high temperatures. This results obtained indicate people's ability to adapt or acclimatize to the environment they live in (Hussein et al., 2002).

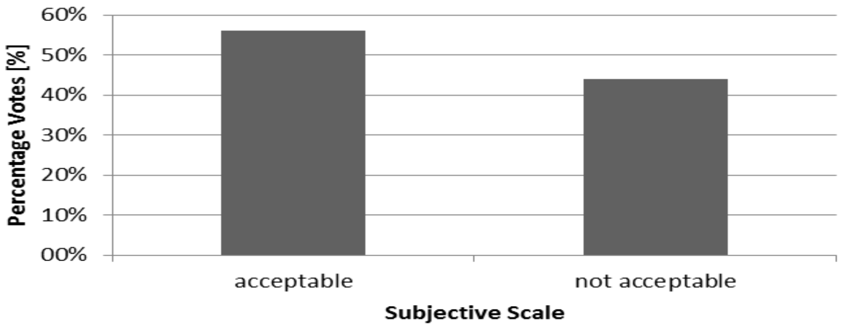

Fig. 18: Respondents vote on thermal acceptability

Responses to thermal preference questions revealed very different results in the naturally ventilated classrooms. A comparative approach on the votes (thermal sensation and preference scales) is illustrated in Table 3. Among the respondents, thus, 80% of those voting within the three central categories: -1 (slightly cool), 0 (neutral), 1 (slightly warm) of the ASHRAE thermal sensation scale preferred to feel cooler (-1), 11.4% of the respondents preferred warmer (1) and the remaining 8.6% wanted no change (0). Overall, the results suggest that neutral thermal sensations are not always the preferred thermal state for building occupants. Most of the respondents favoured 'cooler' as well as no 'change'.

Table 3: Occupants' thermal sensation versus thermal preference

Thermal Sensation Scale [%]	**Thermal Preference**		
	Cooler (-1)	**No Change (0)**	**Warmer (1)**
-3, -2 (cold, very cold)	44.4%	44.4%	11.2%
-1, 0, 1 (slightly cool, neutral, slightly warm)	80%	8.6%	11.4%
2, 3 (warm, very warm)	75.9%	11.1%	13%

The results obtained are comparable with the findings of Nyuk and Shan (2003) in Singapore. They found that 24.1% of respondents in a naturally ventilated classroom wanted to feel cooler even when experiencing neutral thermal sensations. Another study conducted by Zhang et al. (2007) in China in naturally ventilated classrooms revealed that 22.7% of the respondents wanted to feel cooler, 26.5% respondents preferred warmer and the remaining 50.9% wanted no change. Another study by Busch (1990) in Thailand found that 64% of respondents in naturally ventilated offices preferred a cooler thermal state while feeling "neutral". These results give an indication of the difficulty involved in satisfying building occupants, especially in central air-conditioned spaces. Therefore, the ability of occupants to regulate the installed systems towards comfort is propagated in all thermal comfort studies (e.g., Mahdavi et al., 2007).

These findings prove that acceptable thermal sensations do not correlate to peoples' thermal preference. It also indicates that those occupants who preferred 'no change' with their environment, were not always having "neutral" thermal sensation. Finally, even though all surveyed classrooms were mechanically ventilated by ceiling fans to improve the indoor thermal environment (Salmon, 1999 and Heerwagen, 2004), they were not quite able to satisfy all the respondents' thermal feelings towards comfort.

CONCLUSIONS

The main objective of the study presented was to investigate peoples' perception of thermal comfort as well as relate findings from the study to ASHRAE standard 55. Therefore, environmental parameters were recorded and questionnaires issued on building occupants' subjective feelings. The analysed data showed that even though a large majority of the respondents accepted their overall thermal conditions, a number of them still voted far below the standard set by ASHRAE of 80% for thermal sensation. This suggests a wider thermal comfort range of building occupants. Besides, all the environmental parameter values (air temperature and relative humidity) exceeded the stipulated recommendations set by ASHRAE. However, most of the respondents found that the prevailing relative humidity and air velocity levels were acceptable, although 53% of the respondents preferred to have a greater flow of air. In addition, it was realized that even if the class on the ground floor experienced lower temperatures, this was not the same for the class on the first floor.

The class experienced higher temperatures as a result of the absence of a ceiling, a situation which was attributed to lack of funds on the part of the school. The study showed that respondents in a tropical environment, such as Ghana, may have a higher heat tolerance, since they accept the thermal conditions which exceed the standard. Future school buildings need to make use of sustainable design principles (form, orientation, shading, high window to wall ratios, high room heights, mount ceilings, etc.) and make sure that spaces are installed with low energy consuming fans to promote health and facilitate learning.

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