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ADAPTIVE THERMAL COMFORT EVALUATION OF TYPICAL PUBLIC PRIMARY SCHOOL CLASSROOMS IN IMO STATE, NIGERIA

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Abstract

Climate change is causing high-temperature increase, which is affecting people's health especially the vulnerable group such as children. Literature reviews revealed various complaints about health issues caused by heat stress as they relate to this group exposed to poor indoor thermal conditions while they are engaged in class activities. This problem necessitated a need to evaluate the thermal conditions of occupants of some selected public primary schools, used as case studies, in which 134 pupils, aged 7-12 years, participated in the survey. The main objective was to determine the indoor thermal conditions of the classrooms and to compare the occupant's thermal sensations, thermal preference and thermal acceptability in these selected spaces. This paper presents the results of this field survey conducted in the months of October and early November 2017 in two categories of naturally ventilated spaces; the ''open plan'' and the ''enclosed space'' classrooms located in Imo State, Nigeria. The indoor and outdoor thermal variables were recorded together with the simultaneous administration of the questionnaire to evaluate how the pupils feel about the indoor thermal conditions in the classrooms. Results revealed that the mean thermal sensation vote in the combined ''open plan classrooms'' was -0.04, while that of the ''enclosed space classrooms'' was +0.32, adopting the American Society of Heating, Refrigerating and Air-conditioning Engineers (ASHRAE) scale. Though the two classrooms reported different thermal sensations votes, the indoor thermal conditions were generally accepted by the occupants probably attributed to their adaptive abilities and the season the survey was conducted. The results may not be generalized to apply to all seasons since this very study was conducted during the late part of the rainy season. This, however, provides useful information to architects and engineers who are keen on designing and constructing sustainable indoor spaces.

Keywords: *Children, Climate, Enclosed space, Naturally ventilated, Open plan, Thermal comfort*

INTRODUCTION

Young children coming out fresh from their homes in quest of education are exposed to different indoor environments that may have negative impacts on their health and overall well-being. The primary school is the foundation and the fulcrum of different levels of education and considering that children spend a good number of hours daily inside the classrooms engaging in all forms of academic activities, it is important to provide an enabling environment for them. There are various literature reports on the relationship between high temperatures and health issues. Exposure to high temperatures can increase the risk of heat stroke (Bouchama, 2002) and can cause health problems such as respiratory and cardiovascular hospitalizations and deaths (Anderson et al, 2013; and Hoshiko et al, 2010). In addition, young people's mental performance can be significantly affected by the slight temperature increase of only a very few degrees within the range in a typical classroom found in tropical countries.

Nigeria is a tropical country with a population of about 180 million people (United Nations, 2017) where 43% of this population is within the age range of 0-14 years (Nigerian Demographics, 2018). A majority of this age range is made up of primary school pupils who are susceptible to a climate change-induced problem such as heat stress. The poor conditions of the primary school infrastructure in the country, coupled with the exponential growth in the population of the primary school children have led to a high demand for more classrooms. As a result, there has been massive renovation and construction of new ones by organizations such as Education Trust Fund (ETF) and Imo State Primary Education Board. However, some of these classrooms when finally built and occupied leave the users in poor thermal condition probably because the design and the construction of such classrooms did not take into account the climate of the locality. According to Alozie et al, (2015), the architecture of a building contributes to the indoor thermal comfort of occupants, which may also have negative effects on their health.

Conceptual Framework

Thermal Comfort

Thermal comfort is defined by the American Society of Heating, Refrigerating, and Air Conditioning Engineers (ASHRAE) as ''that condition of the mind which expresses satisfaction with the thermal environment'' (ASHRAE, 2013). ASHRAE's definition of thermal comfort describes a person's psychological state of mind, and is used to describe a condition in which a person, who is assumed to be healthy and wearing a normal amount of clothing, feels neither "too hot nor too cold" or thermally neutral. When a majority (percentage of people satisfied above 80%) of occupants accept the thermal environment in a given indoor space, they are said to be thermally comfortable (ASHRAE, 2013). The percentage of people dissatisfied (PPD), on the other hand, predicts the percentage of occupants that will be dissatisfied with the indoor thermal conditions. PPD is a function of Predicted mean votes (PMV), given that as PMV moves further from zero, or neutral PPD increases. The maximum people that can be satisfied in a given indoor environment is 100%. Due to individual's preferences, it is unlikely that all people can be satisfied with the same indoor environment. Fanger (1970), suggests that the prominent variables that determine thermal comfort are air temperature, mean radiant temperature, air velocity, humidity and clothing insulation.

Two popular models that evaluate thermal comfort of building occupants are the heat balance model and the adaptive model. While the first model is reported to be more suited to be applied in artificially ventilated buildings, the second model is proven to be more suitable for free running buildings predominantly found in the tropical countries. All the public primary schools in the southeast, precisely in Imo State, are free running with few of them additionally ventilated with fans. There still exists in some of these public primary schools the old pattern classrooms (''open plan'') which is gradually being phased out in preference for the conventional classroom structure (referred in this paper as ''enclosed space'' classrooms). These two categories of classrooms are used for class lessons and it is likely that the children may report different thermal perceptions in these categories of classrooms because of the differences in their architectural and construction characteristics.

There are reports in the literature about various thermal conditions in classrooms located in the tropics. An investigation was carried out by Mors et al (2011) to investigate the thermal comfort of seventy-nine children in primary school classrooms, which was conducted in non-air conditioned classrooms in three different schools in the Netherlands. One of the findings was that the indoor operative temperature followed the exterior running mean temperature. Appiah and Koranteng (2012) investigated peoples' perception of comfort as well as the prevailing thermal conditions in the naturally ventilated classrooms located in the warm and humid climate of Medina, Ghana, a tropical country, to validate the level of acceptability of the findings with ASHRAE standards 55. A total of 116 respondents participated in the survey conducted in two classrooms; one on the first floor while the other was on the second floor and each classroom had two ceiling fans. It was observed that the indoor air temperature in the occupied zones was between 29.4^{o}C and 32.3^{o}C while the indoor relative humidity was between 60.8% and 74.2%, which exceeded the indoor summer air temperature range of 26^{o}C to 28^{o}C, and the indoor relative humidity range of 30% to 79% recommended by ASHRAE Standard 55. Furthermore, Wargochi and Wyong (2011) conducted two independent field intervention experiments in elementary public school classrooms of 10 to 12 years old children to determine the effects of moderately raised classroom temperatures and classroom ventilation rate on the performance of schoolwork. The result showed that reducing moderately high classroom air temperature from the region of 25^{o}C to 20^{o}C by providing sufficient cooling improved the academic performance of the children.

Wong and Khoo (2003) conducted a study in naturally ventilated classrooms in tropical Singapore to determine the thermal conditions of the classrooms. A total of 506 respondents participated in the survey, out of which 493 were students and 13 were teachers. The outdoor temperature within the study time varied from 26.2^{o}C to 30.0^{o}C with a relative humidity variation from 76.6 % to 85.1 %. Findings showed that none of the classrooms had thermal conditions falling within the comfort zone of ASHRAE standard 55. However, occupants found temperature range beyond the comfort zone acceptable. In addition, the acceptable temperature range was from 27.1^{o}C to 29.3^{o}C, implying that the ASHRAE standard 55 is not acceptable in the free running buildings in the local climate. A neutral temperature of 28.8^{o}C was obtained by regression analysis of Thermal Sensation Votes (TSVs) on Operative Temperature (OT). Mohamed (2009) assessed the thermal comfort of occupants of naturally ventilated primary school classrooms in hot, humid Egypt and observed that the majority of them were thermally uncomfortable, attributing the reasons to the high occupancy density of children in classrooms and to inadequate natural ventilation.

The above reports suggest that there is a need to evaluate and understand the thermal conditions of the primary school children and to examine the differences between the thermal conditions in the two categories of classrooms in the study area. According to Nicol *et al.* (2012), comfort studies done in a place cannot be generalized to apply to other places where the study has not been done since the context, culture, buildings, and climate unique to a particular place could imply that the comfort needs and expectations of its inhabitants may not be the same. Trebilcok et al (2017) confirmed this argument, in their recent finding from a field study, of a correlation between thermal comfort and socioeconomic backgrounds of the participants. Yao *et al* (2009) also supports the common concern that thermal comfort conditions be verified in the local context where local climate, culture and social backgrounds may have an influence on the thermal comfort perception of the inhabitants.

CASE STUDY AND METHOD

Study Area and Selected Schools

Premier public primary school denoted as A in figure 1, is situated in Umuaka town in Imo State Nigeria and has a geographical coordinate: $5^{o}39'0''$North, $7^{o}1'0''$East. Central school Ogbaku denoted as B in Figure 2 is situated in Orogwe town in Imo State Nigeria. It has a geographical coordinate: $5^{o}33'0''$ North, $6^{o}59'0''$ East. Both study areas fall within the warm and humid climate where the dry season runs from November to March, and the rainy season from April to October.

Both case study of public schools are typical ones that have both categories of classrooms used for lessons by primary school children. On the left of Figure 1 is the ‘’Open classroom’’ at school A, and pupils can be seen marching into the classroom after the morning assembly. By the side of the ‘’Open’’ classroom is the ‘’Enclosed “classroom. Figure 2 shows the ‘’Open’’ classroom at school B. This study was conducted in four classrooms (including the enclosed classroom not captured by the camera in school B). School A was surveyed from October 12 to October 24, 2017, while school B was surveyed from October 25 to November 3, 2017. All the classrooms were naturally ventilated and none had fans during the survey.

Figure1: Shows part of school A

Figure 2: Shows part of school B

Survey Questionnaire

Some researchers raise doubts whether children are capable of understanding the wordings of a questionnaire. However, Christensen and James (2008) argue that children are seen as worthy of investigating in their own right and may not need parents or caregivers to guide them. Clark and Moss (2011) added that children should be seen as strong, capable, and knowledgeable experts on their lives. The United Nations (UN) convention of 1989 reflected in Article 12 the Rights of children to participate, say and have their opinions taken into account on what affects them. The contemporary children’s rights movement also emphasizes allowing children to exercise their rights and to express their own beliefs seriously.

It is important that questionnaires for children be structured to be brief and clear devoid of complex wordings or statements that may be difficult for them to understand. Some wordings used in thermal comfort questionnaires such as ‘’neutral’’, ‘’thermal comfort’’, ‘’ just right’’, ‘’much too humid’’ and some statements such as ‘’How are you feeling at the moment’’? and ‘’ right now I would prefer’’ may be misunderstood or misinterpreted by children, especially those who do not use English language as their medium of communication. That may lead to wrong collection of data. However, some thermal comfort researchers have found ways of navigating through this difficult terrain of finding appropriate thermal comfort questionnaires for children. For instance, Ali, S et al, (2016); and Al-Maiyah et al (2015) converted the 7-point ASHRAE scale into three categories in their separate thermal comfort study on children. In doing this, the first and last two extreme categories on the scale were merged into one group each in the questions under thermal comfort, while the three central categories formed the ‘’moderately comfortable’’ group. In other thermal comfort researches done for children aged 7-11 years, the same standardized thermal comfort questionnaires used for adults were adopted but some of the studies reduced the number of questions and modified the wording so that the children could understand them better. For example, the original word ‘’ neutral’’ used by Fanger P.O to determine the central category of 7 - point ASHRAE scale was modified by Martinez (2007) in his own thermal comfort study of children to the word ‘’good’’ for better understanding of his respondents. In the survey conducted by Karyono (2016) the word ‘’comfort’’ was adopted in place of ‘’neutral’’, while Teli (2012); Trebilcock (2017) and Montazami (2017) used the word ‘’Ok’’.

Karyoro and Delyuzir (2016) used Indonesia language to investigate the thermal comfort conditions of primary school students in Tangerang, Indonesia. In adopting a different language, what is important is that the researcher has to ensure the language is translated correctly to comply with ASHRAE standard. While investigating the thermal comfort perception of primary school children Wong and Khoo (2003) left out numbers in the questionnaire with the reason that the numbers will confuse the children and Trebilcock et al, (2014) adopted this method. Mors et al, (2011), suggested that the ASHRAE scale is easier for children to understand because of its simplicity. Previous thermal comfort research works on children conducted by Auliciens (1969) and Kwock (1998) and the recent ones by Hwang et al, (2009) Liang & Hwang (2012), De dear et al (2014) and Haddad et al (2014) adopted the standardized ASHRAE thermal comfort questionnaires used for adults.

Procedure

Participants in both schools were primary school children aged 7-12 years, made up of 64 (48%) male and 70 (52%) female. The survey lasted three weeks in total from October 12 to October 24, 2017 (for school A) and from October 25 to November 3, 2017 (for school B), during which Tinytag Ultra 2 (TGU-4500) Gemini Loggers were used to record the 24-hour indoor air temperatures and relative humidity, while Tinytag Plus 2 (TGP-4500) recorded the corresponding outdoor temperatures. However, relevant information was extracted from the data and used to analyse the thermal perception of the children within the occupied time from 7.30am - 2.30pm. The data loggers were located at the center of each of the surveyed classrooms, one hour prior to the survey, where they did not disturb class activities. Their locations were also away from potential heat sources and placed at 0.6m above the floor level, based on the recommendations of ASHRAE standard 55 (ASHRAE, 2013). Occasional spot checks made at the heights of 0.1m and 2.1m to check for vertical thermal asymmetry revealed negligible differences in temperatures.

Responses were deemed invalid under two circumstances:

•If a subject found the thermal environment unacceptable and yet voted for ''no change'' in the thermal preference question.

•If a subject voted an extreme thermal sensation (+3) and again voted for more of the same sensation in the thermal preference (Teli, et al, 2012).

The inconsistent responses were first eliminated from the data including cases where thermal sensation vote of a respondent is [-3, -2] or [+2, +3], considered as an expression of dissatisfaction (Fanger, 1970), and one still wishes to enhance that sensation. However, based on previous research a ''neutral'' temperature is not always the preferred option (Wong & Khoo, 2003).

Primary school pupils in Imo state wear uniforms as dress code and the clothing pattern is similar for both age groups. At the time of the study, the pupils were reading and writing which were assumed as sedentary activities. As a result, their metabolic rates were estimated to be 1.2-met (70w/m2) for both genders, which corresponded to light office activity in the ASHRAE handbook of fundamentals. The ASHRAE adaptive comfort is applicable to spaces where the occupants are engaged in near sedentary physical activities with metabolic rates ranging from 1.0 to 1.3 (ASHRAE, 2013).

To get answers to the thermal perception of the pupils in the case study classrooms, questions were asked to determine their thermal sensation, thermal preference and thermal acceptability. For thermal sensation, ASHRAE rating scale was adopted which asked them to indicate if they felt -3 (cold), -2 (cool), -1(a bit cold), 0 (okay), +1(a bit warm), +2 (warm) or +3 (hot). For thermal preference, McIntyre rating scale was used to ask the question ''Right now I would prefer to be: -1(cold), 0 (no change) or +1 (warm)''? to which each respondent was expected to pick one answer. Acceptability asked the simple question ''Are the conditions (temperature) in this classroom accepted by you right now''? to which the respondent was expected to pick ''accepted'' or ''not accepted''. Thereafter, data collected from the data loggers were downloaded, the information from the questionnaire was collated, and both were used to analyse their thermal perceptions in these classrooms.

RESULTS AND DISCUSSION

Summaries of Measured Thermal Variable

Figure 3 shows the graphical details of the indoor thermal variables in one of the classrooms, while Tables 1 to 3 show the statistical summaries of the measured indoor operative temperatures, outdoor temperatures and indoor relative humidity captured in the late part of the rainy season during occupied hours (7.30am – 2.30pm).

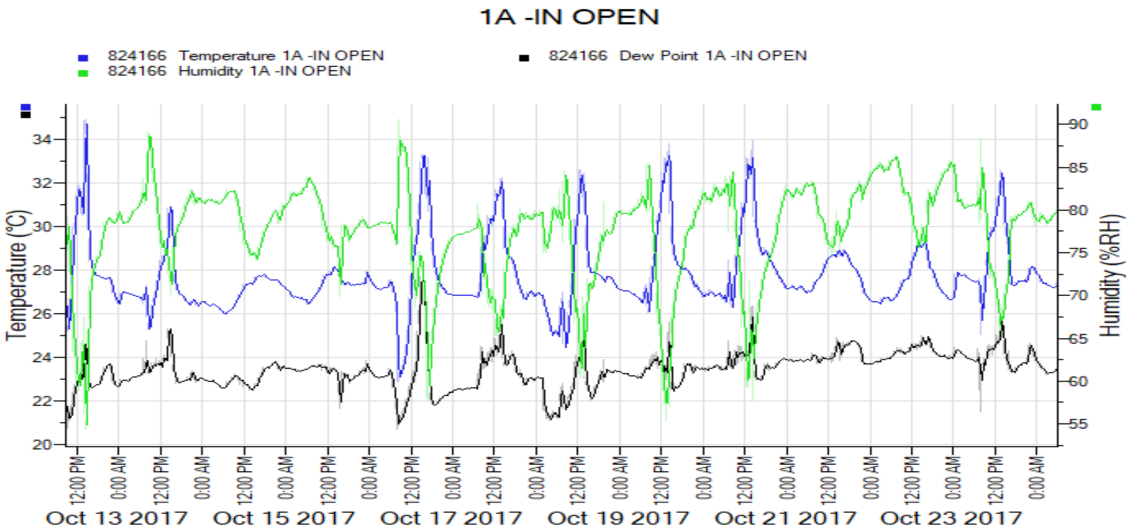

Figure 3: Sample graph of Indoor thermal variables at school A (A_{OP})

Table 1: Statistical summary of indoor operative temperature

School	Classroom type	Max (°C)	Min (°C)	Mean (°C)	St Dev	Coefficient of variation
A	A_{OP}	34.70	22.85	28.50	2.20	0.077
	A_{EN}	33.60	25.90	29.00	1.42	0.049
B	B_{OP}	37.26	25.00	29.30	2.10	0.072
	B_{EN}	30.60	25.00	29.20	1.60	0.055
A + B	A_{OP} + B_{OP}	37.26	22.85	28.77	2.07	0.072
A + B	A_{EN} + B_{EN}	33.60	25.90	29.11	1.51	0.052
A + B	All types	37.26	22.85	28.93	1.83	0.063

A= Premier school Orogwe, B=Central school Ogbaku, A_{OP} =Open classroom, A_{EN}= Enclosed classroom

Table 2: Statistical summary of outdoor temperature

School	Classroom	Max (°C)	Min (°C)	Mean (°C)	St Dev (%)	Coefficient of variation
A	A_{OP} & A_{EN}	37.4	23.0	28.96	2.54	0.088
B	B_{0P} +B_{EN}	36.5	24.0	29.36	2.09	0.071
A + B	All types	37.4	23.0	29.2	2.332	0.080

Table 3: Statistical summary of indoor relative humidity

School	Classroom type	Max (%)	Min (%)	Mean (%)	St dv (%)	Coefficient of variation
A	A_{OP}	90.6	56.7	76.2	6.87	0.088
	A_{EN}	93.5	60.8	81.3	5.25	0.065
B	B_{OP}	87.5	24.0	70.5	13.70	0.194

	B_{EN}	92.9	27.4	79.1	9.59	0.121
A + B	**A_{OP} + B_{OP}**	90.6	24.0	73.4	11.17	0.152
A+B	**A_{EN} + B_{EN}**	93.5	27.4	80.3	7.69	0.096
A+B	**ALL types**	93.5	24.0	77.1	10.07	0.131

Results show that during the survey, the maximum operative temperature recorded in the classrooms reached the 37.1^{o}C that would require a minimum indoor air speed of 0.3m/ before the Central for the Built Environment Thermal Comfort tool is applied (Efeoma and Uduku, 2014). However, the operative temperature adopted for the analysis during the occupied time did not exceed this specified maximum temperature (31.7^{o}C).

The combined open classrooms recorded a mean operative temperature of 28.77^{o}C with a standard deviation of 2.07K, while the combined enclosed space classrooms produced a mean operative temperature of 29.11^{o}C with a standard deviation of 1.51K. The combined difference in the mean operative temperature for all the categories of classroom spaces surveyed during the rainy season was 0.34^{o}C. A comparison of the coefficient of variation of operative temperature for all the spaces surveyed shows close similarities and differences in temperature variations according to classroom type. For example, the open classrooms reported similar coefficient variations in indoor operative temperatures. The disparity in the coefficient variation of the enclosed classrooms may be because one of them had no ceiling at the time of the survey. It was also observed that the indoor air temperatures in both categories of classrooms followed the outdoor temperatures closely. As shown in Tables 1 and 2, the combined classrooms produced maximum and minimum indoor operative temperatures of 37.26^{o}C and 22.93^{o}C respectively, while the combined outdoors of the classrooms produced maximum and minimum temperatures of 37.4^{o}C and 23.0^{o}C respectively. This agrees with the finding of (Nicol, 2004) which reports that in free running buildings, the mean indoor temperature tends to reflect the mean outdoor temperature and because of this relationship, the temperature which people find comfortable also tracks the outdoor temperature.

For the combined open classrooms, the mean relative humidity was 73.4% with a coefficient variation of 15.2%, while the mean relative humidity of the enclosed classroom was 80.3% with a coefficient variation of 9.6%. The overall mean relative humidity of all the spaces surveyed during the period was 77.1% with a coefficient variation of 13.1%. With this high relative humidity (77.1%), a large majority of the participants (88%) in the combined classrooms still found the indoor classrooms comfortable. This agrees with previous research conducted by Appiah (2012) which reports that high relative humidity has minimal effect on the thermal perception of occupants of indoor spaces.

Children's Thermal Sensation

Table 4: Thermal sensation votes by season in both categories of classrooms

CLASSROOM		**Votes**								**Mean**			
		-3 cold	-2	-1	0 Okay	1	2	3	-1 0 1	Mean TS	T_{op} ^{o}C	t_{out} ^{0}c	RH %
A_{OP}	NUM	1	9	50	233	50	9	5	333	+0.02	28.5	29.0	77.6
	%	0	3	14	65	14	3	1	93%				
A_{EN}	NUM	23	22	92	275	88	40	15	455	+0.01	29.0	29.0	82.9
	%	4	4	17	50	16	7	3	82%				
B_{OP}	NUM	0	24	54	350	41	7	0	445	-0.10	29.3	29.5	73.7
	%	0	5	11	74	9	1	0	93%				

B_{EN}	NUM	1	1	8	81	139	44	15	228	+0.90	29.2	29.5	78.3
	%	0	0	3	28	48	15	5	79%				
A_{OP}+B_{OP}	NUM	1	34	104	583	91	16	5	778	-0.04	28.8	-	73.4
	%	0	4	12	70	11	2	1	93%				
A_{EN} + B_{EN}	NUM	24	23	100	356	227	84	30	683	+0.32	29.1	-	80.3
	%	3	3	12	42	27	10	3	81%				
All types	NUM	25	57	204	939	318	10	35	1461	+0.03	28.9		77.1
	%	2	3	12	56	19	6	2	87%				

OP= Open classroom; EN=Enclosed classroom; t_{OP} =classroom operative temperature; t_{out} = outdoor temperature of the classroom; RH= classroom relative humidity; (-1 0 1) = votes around the three central points on ASHRAE scale; TS = Thermal Sensation.

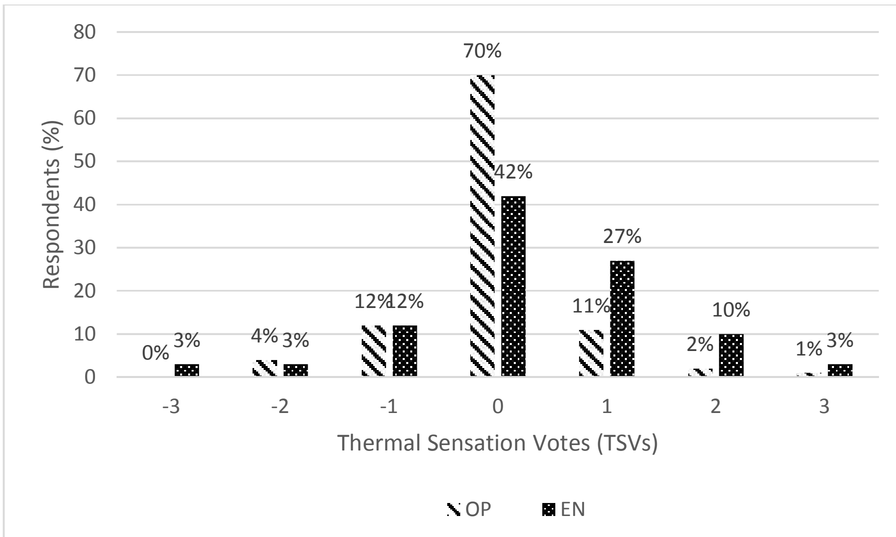

Figure 3: Relative frequency of Thermal Sensation Votes (TSVs) of the children according to classroom type and occupation period (7.30am – 2.30pm) viz the ASHRAE comfort scale.

The thermal sensations of the respondents during the rainy season (October to early November) were determined through occupant questionnaire and the measured indoor thermal variables of the classrooms during the occupied hours (7.30am – 2.30pm). The mean air speed recorded within the occupied zone during the survey was approximately 0.06m/s and this did not exert much effect on the subject's thermal sensation. As shown in Table 4, the mean thermal sensation vote for the pupils in the combined open classroom was slightly below ''okay'' (neutral) and tended toward ''a bit cold'' with a mean vote value of -0.04 where 93% voted around the three central categories (-1, 0, and +1) of the ASHRAE scale with an average classroom operative temperature of 28.8^{o}C. For the combined enclosed space classroom, the children voted slightly above ''okay'' shifting toward ''a bit warm'' with a mean vote value of +0.32, where 81% voted within the three central category with an average classroom operative temperature of 29.1^{o}C. Meaning that the children in the combined open classroom found their indoor classroom cooler than those in the combined enclosed classrooms. The overall (combined) mean thermal sensation of votes was +0.03 where 87% voted within the central points with an average indoor operative temperature of 28.9^{o}C. At this temperature, occupants of the classrooms still found the indoor environment comfortable. Earlier survey conducted by Humphreys (1975) showed that the temperature which people find comfortable is closely related to the mean temperature they experience. He explained that people find ways in which to make themselves comfortable in the conditions they normally experience by adapting to them behaviourally.

The thermal comfort index is based on the assumption that people voting in the middle three categories (a bit/slightly cool -1, okay/neutral, 0 and a bit/slightly warm, +1) of the seven-point thermal sensation scale are satisfied with their thermal environment (ASHRAE, 2013). When the overall votes within the three categories are more than 80%, the thermal environment is said to be acceptable. The percentage of pupils who were satisfied by the thermal conditions in both categories of classrooms surveyed during the rainy season exceeded this 80% minimum standard. Furthermore, adopting the same ASHRAE Standard 55, but this time, from its specification that the indoor space is thermally conducive if more than 20% of the occupants do not vote beyond the central category of the thermal sensation scale. From this angle, the two categories of classrooms also satisfied this condition by voting, 7% and 19% in open plan and enclosed space classrooms respectively, on the +2 (warm), +3 (hot), -2 (cool) or -3 (cold) side of the thermal sensation scale.

The percentage of votes around this central category between the two categories of classrooms vary significantly by 12%, suggesting that building characteristics have a lot of influence on the thermal conditions of the classroom occupants. Further comparison, shows that more people (40%) in the combined enclosed classrooms voted on the warm side (+1, +2, +3) of the ASHRAE scale while only 14% of those in the combined open classrooms voted on the warm side. The percentage of subjects who indicated thermal sensation of ‘’neutral’’ represented 70% in the open classrooms, while 42% indicated ‘’neutral’’ sensation in the enclosed classrooms. However, the votes of the occupants in both categories of classrooms dispersed on the ASHRAE scale indicating that children have wide and different thermal perceptions due to differences in metabolic rate and activity rates.

Thermal Preference

McIntyre preference scale was adopted to ask the subjects to indicate if they felt “cooler”, “No change” or “Warmer “to their immediate indoor thermal environment. The thermal preference of the combined open classrooms was compared with that of the combined enclosed space classroom during the occupied time (7.30am – 2.30pm).

(i) Comparing Overall Thermal Preference of both types of classrooms during occupied time (7.30am – 2.30pm)

The McIntyre preference votes follows the same trend with the ASHRAE votes where the respondents in the combined enclosed classroom who voted thermal sensation around the neutral - slightly warm side of the ASHRAE scale (+0.32), as earlier seen in table 4, voted higher to prefer the ‘’more cooler’’ category (35%). Comparatively, the occupants of the open classroom preferred to be ‘’more cooler’’ by voting only 23% on that category state having voted around the neutral slightly cold side of the ASHRAE scale (-0.04). The differences in perceptions can be attributed to the higher average indoor temperature in the combined enclosed classrooms when compared with the one in the combined open classrooms. The consistency in the voting regarding the thermal perceptions supports the argument that children are capable of understanding and responding well to thermal comfort questions. Comparing the findings in thermal sensation and thermal preference in this study, it is observed that neutral thermal sensations are not always the preferred thermal state of building occupants, which agrees with the previous results of thermal comfort studies conducted by Kwok (1998); Wong & Khoo, (2003); Kwok & Chun, (2003); Hwang et al, (2006); Al-Rashidi, (2011).

Furthermore, the occupants of the combined open classrooms in both schools voted 63% to ''no change'' while those in combined enclosed classroom voted 47% to remain in the same state of ''no change''. Generally, both occupants of the two categories of classrooms preferred to be cooler rather than warmer agreeing with previous findings that occupants in the tropics would always prefer to be cooler rather than warmer.

Thermal Acceptability

Results of the thermal acceptability of the combined classrooms are presented according to occupation hours (7.30am – 2.30pm) by asking them thermal comfort acceptability question ''Are the conditions (temperature) acceptable to you right now''? to which they were expected to answer ''Accepted" or "Not accepted''.

(i) Overall comparison of acceptability in both schools A & B during occupied time (7.30am – 2.30pm)

Occupants of the combined open classrooms voted 85% to accept the indoor thermal conditions compared to 73% votes by the occupants of the combined enclosed classrooms as shown in Table 5. One observes that occupants of classroom A_{EN} accepted the indoor conditions more than the occupants of classroom B_{EN}. This may also be attributed to the higher indoor operative temperature in classroom B_{EN} because it had no ceiling at the time of the survey.

Table 5: Summary distribution of the children's acceptability votes according to classroom type in schools A & B

School		Acceptable	Not acceptable
A	A_{OP}	80%	20%
	A_{EN}	79%	21%
B	B_{OP}	91%	9%
	B_{EN}	66%	34%
A + B	$A_{OP} + B_{OP}$	85%	15%
	$A_{EN} + B_{EN}$	73%	27%

Referring back to the thermal preference, 63% of the occupants of the combined open classrooms voted ''no change'' with the indoor thermal conditions, while 47% of those in the enclosed classrooms wanted to remain in the same ''no change''. Regardless of the high percentages of the occupants who would prefer to be warmer or cooler in the combined open classroom (37% total) and in the combined enclosed classrooms (53% total), a good percentage of occupants (85%) in the case of open classrooms and 73% in the case of enclosed classrooms (Table 5), still accepted the indoor thermal conditions. The result indicates people's ability to adapt or acclimatize to the environment they live, which agrees with the previous studies.

CONCLUSION

The following are the summary of the findings of the survey:

- The mean operative temperature of the combined open plan classroom was 28.8^{o}C while that of the combined enclosed space classroom was 29.1^{o}C and majority of the occupants found these temperatures comfortable. This agrees with previous studies that people find ways in which to make themselves comfortable in the conditions they normally experience by adapting to them behaviourally.
- This study has shown that the indoor operative temperatures of all the classrooms surveyed followed the pattern of the outdoor temperatures closely. This agrees with the findings from previous studies in free running buildings.
- A wider variation in the operative temperature (OT), with a standard deviation of 2.0K, was observed in the open plan compared with a SD of only 1.15K observed in the enclosed classroom. This could be linked to differences in building characteristics.
- This study shows that children have larger variation in thermal sensation votes when compared with that of adults as reported in other studies. This could be because of children's higher activity rate.
- Results indicate peoples' ability to adapt or acclimatize to the environment they live, which agrees with previous studies.
- The consistency in the voting regarding thermal perception supports the argument that children aged 7 years and above, are capable of understanding and responding to thermal comfort questionnaires.

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