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Thermal Comfort Assessment of Secondary School Classes In Kuala Lumpur, Malaysia

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Abstract: *Global warming causes rapid temperature and precipitation variations, with El Niño being a prolonged cycle of this phenomenon. In Malaysia, over 250 schools closed due to extreme heat waves caused by El Niño. This study monitored the thermal comfort of classrooms at National High School Bukit Jalil and National High School Taman Yarl in Kuala Lumpur, selected for their typical design, orientation, and floor levels. The study aimed to evaluate indoor environmental conditions in these classrooms based on ASHRAE Standard 55 and ISO EN 7730, assess students' thermal comfort perceptions, and identify influencing factors.Objective assessments were conducted for six days in March 2016, from 7:30 AM to 1:30 PM, during lesson hours. Thermal comfort variables were measured using an HD32.2 Delta Ohm Data Logger to generate the Predicted Mean Vote (PMV) model and calculate the Predicted Percentage Dissatisfied (PPD) value. Analysis revealed that none of the classrooms met ASHRAE Standard 55 comfort conditions, with all classified as warm to hot on a 7-point ASHRAE scale. A questionnaire survey assessed students' perceptions, showing that 80%-100% were dissatisfied. Key influencing factors included seating positions, clothing insulation, classroom floor levels, and orientation.*

Keywords: *thermal comfort, field study, PMV, PPD, students, school buildings*

1. INTRODUCTION

Thermal comfort is defined by ASHRAE as "the condition of mind that expresses satisfaction with the thermal environment and is assessed by subjective evaluation" [1]. The subjective consideration of thermal comfort is decided by the thermal environment and personal factors that affect the heat transfer within the environment, as well as, the psychological factors influencing the state of mind directly [2]. Three conditions for comfort were suggested by Fanger [3]: that the body is in heat balance, and the mean skin temperature and sweat rate are within limits. The equation of heat balance helps to determine the conditions required for heat balance, whereby, empirical investigations are used to derive the mean skin temperatures and sweat rates that are acceptable for comfort [3]. ASHRAE standards 55 [1], Fanger's theory [3] and ISO 7730 [4] stated that thermal comfort is affected by six variables: air temperature, relative humidity, globe temperature, air velocity (which is considered as microclimatic parameters that should be measured) and clothing insulation value (CLO). The physical activity to identify metabolic rate (MET) are personal factors which must be estimated to calculate Fanger's Predicted Mean Vote index (PMV). The ASHRAE [1] 7-point thermal sensation scale that calculates the PMV values refers to 3 = hot, 2 = warm, 1 = slightly warm, 0 = neutral, -1 = slightly cool, -2 = cool and -3 = cold. ASHRAE standard 55 [1] ISO7730 [4] suggested that the acceptable PMV range for thermal comfort is between -0.5 and +0.5. Meanwhile, the Predicted Percentage Dissatisfied (PPD) of less than 10% is considered a desirable value that is used to calculate the satisfaction of thermal comfort by occupants [5].

Previous studies stipulated that poor thermal comfort in schools may lead to student absences, as well as, adverse health symptoms and depleted academic performances [6-8]. Additionally, students spend around one third of their day within schools; it is very important to address health and wellbeing issues related to the indoor environment [9-10].

Wong and Khoo [11] found that thermal comfort of classrooms in Singapore Schools are above the thermal comfort zone of ASHRAE standard 55, however, the occupants still accept the conditions even though the operative temperature is beyond the comfort zone. Appah and Koranteng [12] assessed the thermal comfort at a junior high school classroom in Ghana and found that the majority of respondents can tolerate the higher temperatures, between 29.4°C and 32.3°C, which does not comply to ASHRAE standard 55. Mishra and Ramgopal [13] evaluated students' thermal comfort in naturally ventilated schools in India and the findings of the survey indicated a regression neutral temperature near 26°C, yet nearly 80% of respondents were satisfied with operative temperatures between 22.1°C to 31.5°C.

A number of thermal comfort studies in the tropics have been carried out by various researchers using the Malaysian climate conditions as their case studies [14][15][16][17]. Hussein et al. [14] conducted a field study on the environmental conditions and occupants' perceptions' in primary and secondary schools, along with another study in a public waiting area of a health clinic in Johor Bahru. Both studies showed that environmental assessment exceeded the standard, whereby, the neutral temperature and comfort range were derived from linear regression analysis of Thermal Sensation Vote (TSV) and Fanger's PMV model. Subjective assessment, which is the thermal comfort response assessment, revealed that 80% of occupants can accept thermal conditions beyond ASHRAE standard 55 comfort zone. Zailani et al. [15] was involved in the objective measurement and subjective assessment of the comfort level in an air conditioned classroom at the School of Manufacturing Engineering campus in Universiti Perlis, Malaysia. The results obtained demonstrated that the operative temperature and relative humidity fell within the standard comfort condition by ISO EN7730 (1994), while air velocity was beyond the standard limit by ISO EN7730 (1994). The occupants' comfort level and satisfaction were identified through Predicted Mean Vote (PMV) and Predicted Percentage Dissatisfied (PPD). Puteh et al. [16] investigated students' perceptions of thermal comfort in mechanically ventilated school buildings in Melaka. The results explained that the surveyed respondents have a high level of understanding regarding climate change and comfort level of learning classrooms falling within the comfort zone. Khadijah and Azimi [17] conducted a thermal comfort study in a classroom on the second floor of a local school in Bandar Baru Bangi, Selangor, Malaysia. As recorded by the direct measurement of thermal comfort of classrooms, most of them exceeded the standard comfort level and did not provide satisfaction for teachers and students since the environment of class 2 Lili was from "warm" to "hot" in the 7-point ASHRAE scale.

The primary objective of this research was to evaluate the indoor environmental conditions in naturally ventilated classrooms of secondary schools in Kuala Lumpur in order to identify prevailing classroom conditions that are failing within ASHRAE standard 55 and ISOEN7730. The second objective was to investigate occupants' perceptions regarding thermal conditions. The last objective was to determine the factors that influence occupants' perceptions on thermal comfort. This paper described the approach, data and results achieved from this research.

2. METHODOLOGY

The subject presented here included concurrent measurements of the environmental variables which affect thermal comfort and students' questionnaire surveys. This was carried out in two naturally ventilated classrooms of secondary schools in Kuala Lumpur, Malaysia. The field studies were accomplished during March 2016. The case study of the schools and the methodology applied were described below.

2.1 Case Study of Schools

Two different secondary schools located in Kuala Lumpur were taken into consideration. Sekolah Menengah Kebangsaan Bukit Jalil and Sekolah Menengah Kebangsaan Taman Yarl were chosen because of their typical design, number of floors and orientation of the blocks since Al-Tamimi et al. [18] mentioned that building orientation, especially in tropical regions, should really be taken into consideration due to its interaction with solar radiation, as well as, the wind direction. Besides orientation and floor levels, students' ages also became another consideration during the selection of classrooms since Parson [19] stated that thermal perception and metabolism depends on the age and sex. Upper secondary classrooms in Block A and Block C of SMK Bukit Jalil and upper secondary classrooms in Block A, Block D and Block C of SMK Taman Yarl were chosen to carry out the research. Both school buildings are naturally ventilated and each classroom has ceiling fans to aid in comfort ventilation.

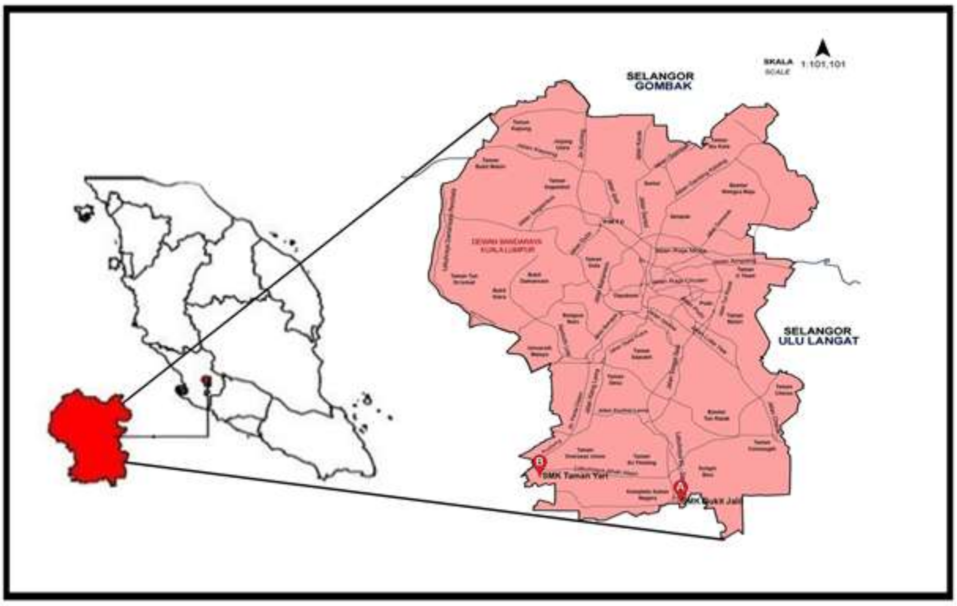


Figure 1: Location map of SM Bukit Jalil & SMK Taman Yarl

2.2 Physical Measurement of the Classrooms

The classrooms' microclimatic condition was measured using the data logger model HD32.2 Delta Ohm which is a combination of globe thermometer, temperature probe and anemometer. The measurements were taken in the interval of every hour by positioning the equipment at the centre of the classroom to avoid disturbance during lesson hours. In addition, it was placed roughly at 1.1m height from ground level in strict consonance with the recommendation by ASHRAE standard 55 [1] and ISO 7730 [4]. Measurements were conducted between 7.30 am and 1.30 pm for 6 days in the month of March 2016. The globe thermometer and the temperature probe had a response time of at least 15 minutes; the first 15 minutes recorded were not considered. This data logger equipment measured ambient microclimatic parameters such as air velocity (Va), globe temperature (Tg), radiant temperature (Tr), ambient temperature (Ta) and relative humidity (RH). The insulation of clothes was also taken into consideration in the thermal comfort where the thermal insulation given by clothing was calculated as clothing insulation with the unit "Clo", in which 1 Cl = 0.155 m2K/W by ASHRAE standard 55 [1]. Metabolic rate of the individual in the room concerned can be estimated by employing the method suggested by ASHRAE Standard 55 [1]. Clotting rate (0.6) and metabolic rate (1.2) were estimated by using the checklist for clothing and activity of the respondents in SMK Bukit Jalil and SMK Taman Yarl. It was obligatory for all students in both schools to wear the Malaysian standard school uniform which consist of white sleeve shirts and long dark green trousers for male students, and turquoise blue pinafore or 'baju kurung' (light blouse) and turquoise blue line skirts and hijabs for female students. All these parameters were used to calculate PMV and PPD based on Fanger's theory [2] and ISO 7730 [4].

2.3 Survey Questionnaire

A field survey is to investigate pupils' votes on thermal conditions were conducted in two schools; namely, SMK Bukit Jalil and SMK Taman Yarl. The number of students taken as respondents in both schools was a total of 198, and they were divided equally as 99 students for each location. About 82 students who responded to the questionnaire survey were Malays, 64 students were Chinese, 49 students were Indians and 3 students were Punjabi. From the total of 198 students, 88 were boys and

110 were girls who answered the questionnaires. The research was denoted in two schools involving 198 students in the age range of 16 (Form 4) and 17 (Form 5). 124 students were 16 years old and 74 students were 17 years old. The higher secondary students were chosen to answer the questionnaires as they have the ability to understand and their answers will be more reliable compared to lower secondary students. This statement was supported by Teli et al**.** **[20]** where their study had found that primary school students have difficulties in understanding and answering questionnaires. There were six classes involved in this study; three classes for each school. The questionnaires were subdivided into three parts: part (a) was demographic information, part (b) was thermal aspects which are the ruling on thermal environment and part (c) was about student activity to estimate the metabolic rate. To understand thermal sensation, the questions were designed based on ASHRAE standard 55 [1] 7-point scale (cold, cool, slightly cool, neutral, slightly warm, warm, hot) to evaluate the Thermal Sensation Vote (TSV).

2.4 Thermal Sensation Model

The subjective state's evaluation can be perspicacities and calculates using the integrated indexes that consider the ambient microclimatic parameters (Ta,Tg,Tr,Va ,RH), the energetic waste (metabolic rate waste MET) connected with working activity and clothing typology(thermal insulation CLO). Between these indexes, the most precise index reflects the physical variables' influence and physiological ones as mentioned above about the thermal comfort; it is PMV (Predicted Mean Vote). Overview, it comes from the equation of thermal balance whose results is related with a psycho-physical wellbeing scale and express the medium vote (predicted medium vote) on the thermal sensation of a sample of beings that are in the same environment. From the PMV comes a second index called PPD (Predicted Percentage Dissatisfied) which calculates the percentage "dissatisfied" beings in relation with precise microclimatic conditions **[3]**. ASHRAE standard 55 **[1]** ISO 7730 **[4]** regulation suggests PMV values between +0.5 and -0.5 for the state of desirable thermal comfort. These values correspond the percentage of dissatisfied regarding the thermal conditions (PPD) less than 10% as illustrated in Table 1. To calculate PMV and PPD indices, the equations obtained by Fanger 1970 **[3]**. The mathematical expression of Fanger`s PMV-PPD model are as stated by Eqs. (1) and (2).

Table 1. Thermal environment evaluation scale

PMV	PPD %	Thermal Environment Evaluation
+3	100	Hot
+2	75.7	Warm
+1	26.4	A little bit warm
+0.85	20	Acceptable thermal environment
-0.5 < PMV <+0.5	<10	Thermal well -being
-0.85	20	Acceptable thermal environment
-1	26,8	Cool
-2	76.4	Cold
-3	100	Very Cold

PMV

(0.303e-0.036M + 0.028) {(M – W) - 3:05 x 10-3 (5733 – 6.99 (M –W – Pa) – 0.42 (M –W) – 58.15} – 1.7 x 10-5M (5867- Pa) -0.0014M (34-Tmrt) – 3.96 x10-8fcl (Tcl + 273)4- (Tmrt + 273)4 -fclhc (Tcl – Tmrt)] [1]

PPD

100-95exp^[-(0.03353PMV4 + 0.2179PMV2) [2]

3. RESULTS AND DISCUSSION

3.1 Classroom Climate

The overall indoor air temperature in occupied zones ranged from 29.1°C to 36.3°C and the indoor humidity was between 45.3% to 80.5%. The air temperatures of all classes at SMK Bukit Jalil and SMK Taman Yarl exceeded the standard comfort zone. Table 2 and Table 3 illustrated the recorded ambient microclimatic parameters for SMK Bukit Jalil and SMK Taman Yarl. According to ASHRAE standard 55**[1]**, it is recommended that the temperature should be between 26°C to 28°C, while the relative humidity should be between 30% and 70%. The highest values for relative humidity were obtained in the morning and the lowest values were obtained in the afternoon. These values should be recognized, while the condition of high relative humidity reacts to be incompetent as the evaporative cooling of the skin which leads to displeasing conditions **[21]**. According to the study done by Klein and Schlenger **[22]**, it was mentioned that exposure to low levels of humidity may bring about dryness and irritation to the skin. Based on the obtained results, the average level of humidity that the occupants were exposed to was 60% to 80%. Relative humidity in all classrooms at SMK Bukit Jalil and SMK Taman Yarl ranged between 60-90%. This condition will give little or no effect on thermal comfort, as found in another study by Olesan and Brager **[23]**.

Air speed measurement for all classrooms varied even though each classroom is provided with more than two ceiling fans. The highest reading of air speed recorded was 2.06m/s and the lowest reading was 0.05m/s at class 5A of SMK Taman Yarl. Measurement confirmed no significant differences found for air speed in highest floor compare to the lower floor. However another study conducted by Wafi et al. **[24]** found that the air speed was better on the higher floors compared to the lower ones. The globe temperature value rises from 29.2°C in the morning to a peak of about 36.5°C in the afternoon during lesson hours. As the globe temperature rises with increasing solar radiation, indoor temperature also gradually increases. Mean radiant temperature is one of the microclimatic variable that influences indoor thermal comfort **[2]**. Mean radiant temperature was obtained through air temperature, air velocity and globe temperature **[2]**. The findings illustrated that the highest reading of radiant temperature was 38.1°C in class 5A in SMK Taman Yarl, while the lowest reading was 28.9°C in class 4A4 in SMK Bukit Jalil; this showed a difference of 9.2°C. Globe temperature above 28°C and below 16°C are not desirable and will influence the radiant temperature to fail in achieving the comfort level **[24]**.

Table 2. Minimum and maximum values of the ambient microclimatic parameters for SMK Bukit Jalil

CLASS 5A4 ,EAST ,3RD FLOOR							
Time	7.30 AM	8.30AM	9.30AM	10.30AM	11.30AM	12.30PM	1.30PM
Va(Air velocity)	1.04	1.71	1.59	0.64	1.68	1.02	0.7
Tg (globe temperature	29.5	31.1	32.6	33.4	34.5	34.8	36.5
T (Temperature)	29.4	31.2	32.4	33.3	34.5	34.9	36.3
Tr (Radiant temperature)	29.9	30.4	37.4	33.9	34.1	33.9	37.7
RH (Relative Humidity	75.2	65.9	59.5	54.4	50.4	49.9	45.3

CLASS 4A4, NORTH, GROUND FLOOR							
Time	7.30 AM	8.30AM	9.30AM	10.30AM	11.30AM	12.30PM	1.30PM
Va(Air velocity)	1.69	1.9	1.84	0.46	0.51	0.98	0.3
Tg (globe temperature	29.2	30.3	30.9	30.9	32.2	32.5	33.2
T (Temperature)	29.2	30.1	30.8	31	32.3	32.4	33.4
Tr (Radiant temperature)	28.9	32.7	31.9	30.4	31.9	33	32.6
RH (Relative Humidity	76.9	73.9	66.3	66.4	58	56.9	53.3
CLASS 4A5, NORTH ,3RD FLOOR							
Time	7.30 AM	8.30AM	9.30AM	10.30AM	11.30AM	12.30PM	1.30PM
Va(Air velocity)	0.34	0.24	0.55	0.74	0.14	0.6	0.77
Tg (globe temperature)	30.9	31.3	32.2	32.2	33.1	33.6	33.7
T (Temperature)	30.6	31.3	32.1	32.2	33.3	33.7	33.5
Tr (Radiant temperature)	32	31	32.8	32.3	32.7	33.1	35.1
RH (Relative Humidity	70.2	32.1	62.2	62.3	52.8	54.2	54

Table 3. Minimum and maximum values of the ambient microclimatic parameters for SMK Taman Yarl

CLASS 5A, NORTH ,2ND FLOOR							
Time	7.30 AM	8.30AM	9.30AM	10.30AM	11.30AM	12.30PM	1.30PM
Va(Air velocity)	0.05	2.06	0.38	0.24	0.93	0.43	1.27
Tg (globe temperature	29.3	30.8	31.5	31.5	32.7	34	34.6
T (Temperature)	29.1	30.6	31.5	31.5	32.76	33.8	34.3
Tr (Radiant temperature)	29.6	33.4	31.6	31.5	33	35.3	38.1
RH (Relative Humidity	79.8	75	66	65.5	56.5	49.2	50.7
CLASS 4A, WEST ,2ND FLOOR							
Time	7.30 AM	8.30AM	9.30AM	10.30AM	11.30AM	12.30PM	1.30PM
Va(Air velocity)	1.47	0.18	0.37	0.77	1,26	0.54	0.48
Tg (globe temperature	30.2	29.4	31.9	32.2	33.4	34.16	34.9
T (Temperature)	30	29.2	31.7	32.1	33.1	34.4	34.6
Tr (Radiant temperature)	32	30.1	32.6	32.9	35.3	35.5	36.4
RH (Relative Humidity	76.2	80.6	67.1	63.2	55.4	48.6	50.4

CLASS 4S, WEST, 3RD FLOOR							
Time	7.30 AM	8.30AM	9.30AM	10.30AM	11.30AM	12.30PM	1.30PM
Va(Air velocity)	0.07	0.8	0.73	0.29	0.79	0.96	0.75
Tg (globe temperature	29.2	30.6	31.5	32.3	33.3	34.13	34.2
T (Temperature)	29	30.4	31.5	32.2	32.9	34.2	34.4
Tr (Radiant temperature)	29	31.6	31.6	32.5	35.6	35.65	35.2
RH (Relative Humidity	80.5	75.1	67.3	59.4	56.3	50.8	51.7

3.1.2 Predicted Mean Vote (PMV) and Predicted Percentage Dissatisfied (PPD)

Predicted Mean Vote (PMV) and Predicted Percentage Dissatisfied (PPD) of thermal comfort indices were calculated based on Fanger's theory **[2]**. There were significant differences in their climatic conditions and PMV and PPD readings. The acquired PMV and PPD readings increased from 7:30 am to 1:30 pm, with the highest reading recorded at 1.30 pm (fig. 2, 3). The reading obtained in SMK Bukit Jalil and SMK Taman Yarl showed correlation. In SMK Bukit Jalil, the results obtained from Classroom 5A4, which is located in the topmost floor (the 3rd floor facing the east orientation), was 36.3^{o}C with the PMV reading of 3.86 (fig.2) and PPD reading of 99.99% (fig .3). The results obtained gave rise to the answer regarding which orientation has the highest temperature, as proven by Surya et al. **[25].** The study verified that the lecture hall which is facing the east orientation showed the highest temperature in comparison to the west orientation. In addition, there was another study accomplished by Al-Tamimi et al. [18] that confirmed that the residential rooms which face the east orientation are subtler to solar radiation in comparison to north and west orientations.

The classroom with second highest temperature was classroom 5A from SMK Taman Yarl with PMV reading of 3.34 (fig. 2) and PPD reading of 99.87% (fig.3). The classroom is located on the second floor and it faces the north orientation. Next were the obtained results by classroom 4A with PMV reading of 3.29 (fig.2) and PPD reading of 99.82% (fig.3). The classroom is located on the second floor and it faces the west orientation. The fourth and fifth highest readings were recorded by classrooms 4S and 4A5 with PMV readings of 3.02 and 2.9 (fig.2) and PPD readings of 99.27% and 98.58% (fig.3), respectively. Both classrooms are located on the 3rd floor but with north and west orientations. The classroom facing north possesses a higher reading than the one facing the west. Lastly, the classroom 4A4 showed the lowest reading as it is located at the ground floor. The orientation is north and the reading of PMV was 2.6 (fig.2) and PPD was 95.29% (fig.3). As per the obtained results, the maximum reading of air temperature was 33.4% and the relative humidity was 53.3% (Table 2). This reading was obtained at 1.30 pm for the classroom 4A4. From the obtained results, it was clearly observed that the classroom which is located on the highest floor definitely possessed higher temperature than the classroom located on the ground floor. The results obtained were comparable with another finding by Appah and Koranteng [12]. They found that classroom spaces of a Junior High School in Ghana which is located on the ground floor showed lower temperatures, while those on the first floor had higher temperatures; and the differences was by 2°C.

Figure 2 shows the calculated Predicted Mean Vote (PMV) and Figure 3 shows the Predicted Percentage Dissatisfied (PPD) for every class of SMK Bukit Jalil and SMK Taman Yarl. The environment of each classroom is from "warm" to "hot" starting from 10am onwards while 80% to 100% of occupants felt dissatisfied since ASHRAE standard 55 recommends acceptable PMV range for thermal comfort to be between -0.5 and +0.5, which in the 7-point scale is between slightly cool and slightly warm for an indoor space, and PPD should be below 10%. Fig. 4 represents the PPD versus PMV for each classroom of SMK Bukit Jalil and SMK Taman Yarl while Fig.5 illustrates overall PMV versus PPD. The Anova test was used to determine whether a significant relationship exists among PMV and PPD. The significant value obtained was: [F(2,39)=2415.88, p<.05]. The higher the number of PMV, the higher the percentage of PPD. Figure 6 illustrates a significant relationship between PMV with OP. The value was [F(1,40)=474.92, p<.05]. The minimum desirable indoor temperature is 26°C [1].

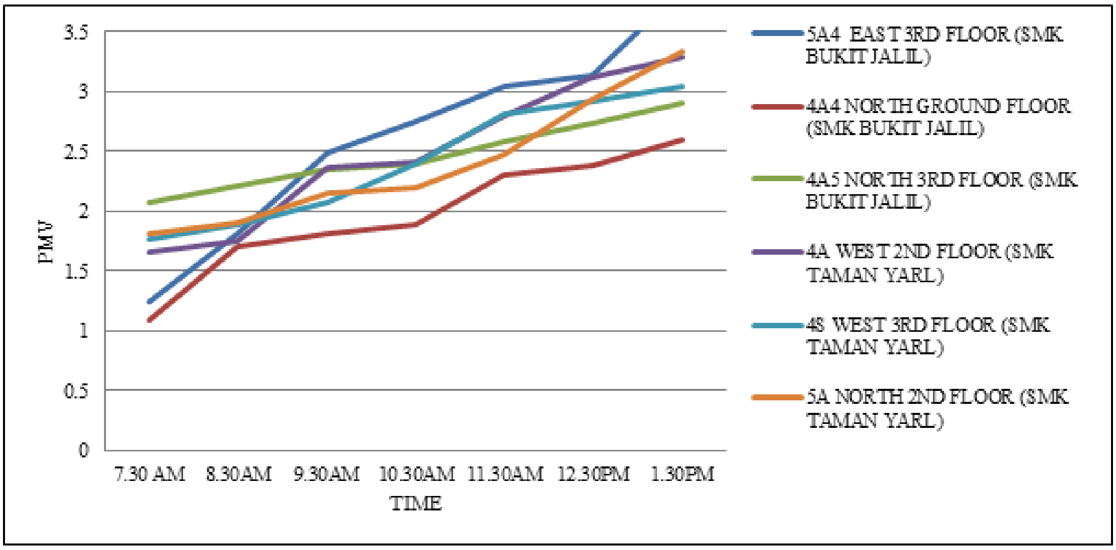


Fig. 2. Graph showing Predicted Mean Vote (PMV) for 6 days

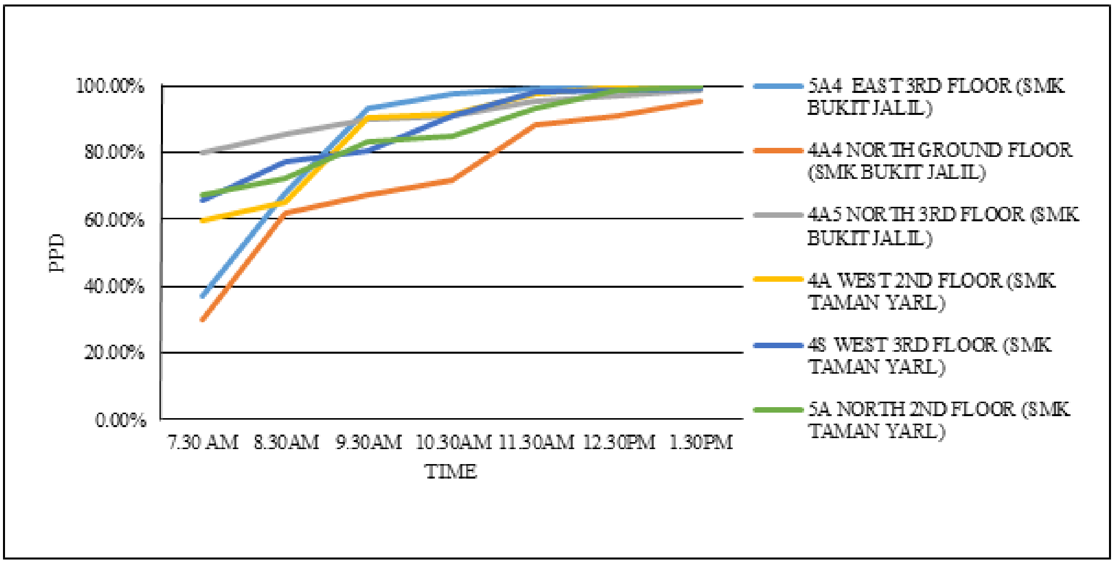


Fig. 3. Graph showing Predicted Percentage Dissatisfied (PPD) for 6 days

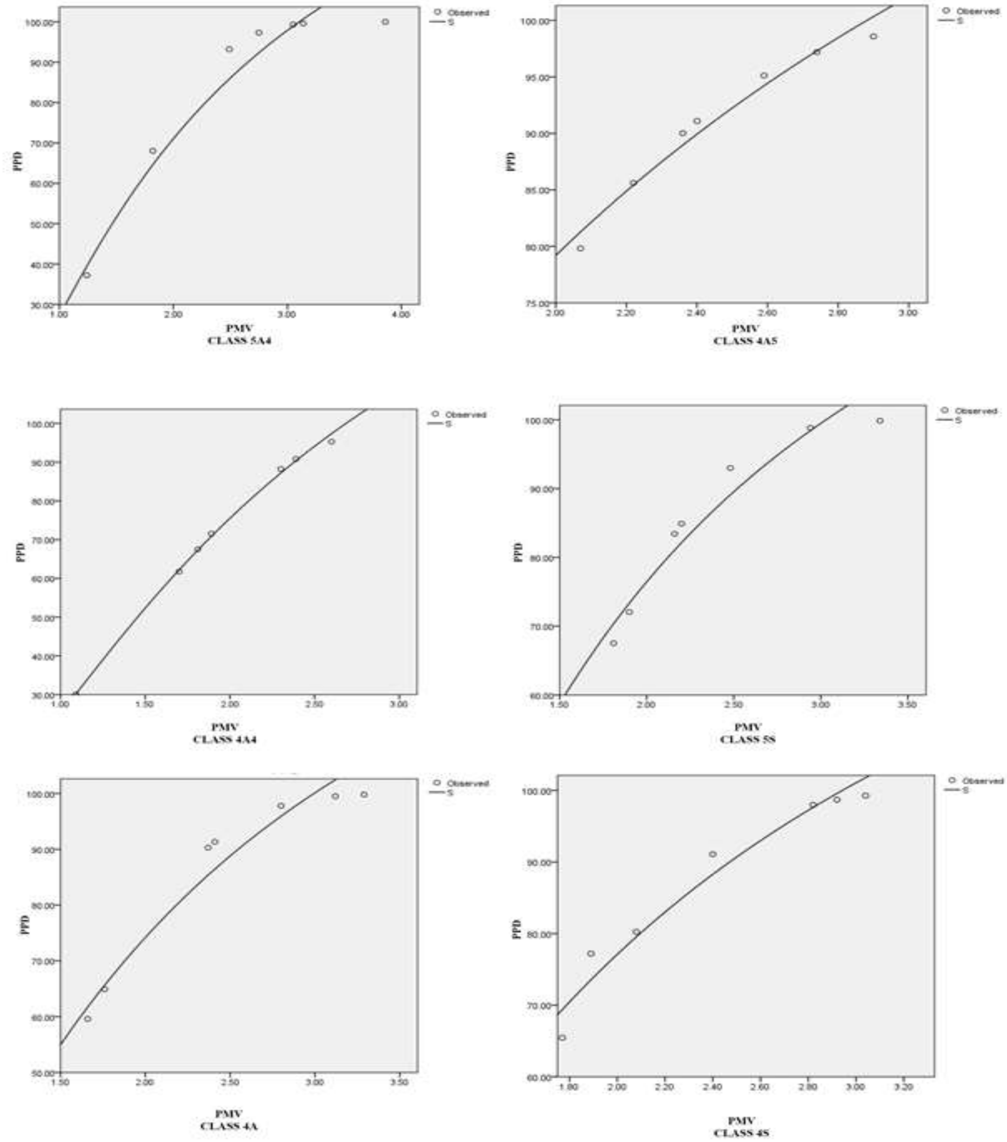
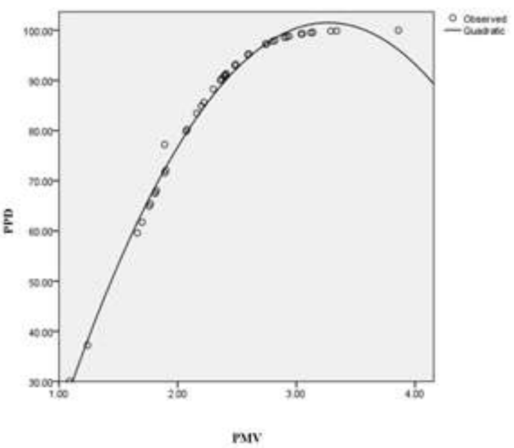


Fig. 4. PPD versus PMV for each classroom of SMK Bukit Jalil and SMK Taman Yarl



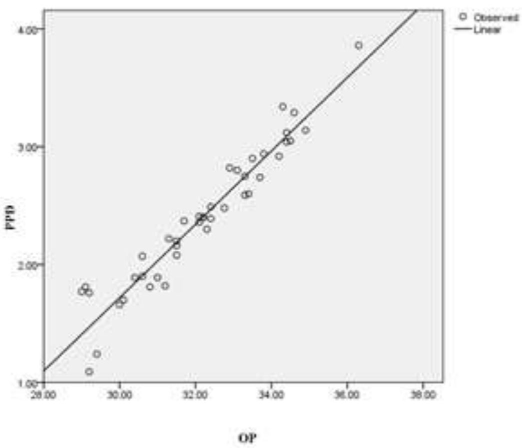


Fig. 5. Overall PMV versus PPD; Fig. 6. PMV versus OP

3.2 Thermal Comfort Responses

Thermal Sensation Vote (TSV) (Fig.7) illustrates the majority of respondents in a warm environment as 57.10%, and those concentrated in a hot environment were 23.7%. At least 80% of occupants should have voted for the central three categories -1 (slightly cool), 0 (neutral), 1 (slightly warm) and it will be considered as the desirable thermal environment **[1]**. In this study, only 19.1% out of the 198 respondents voted within the central three categories and by that, it can be explained that most of the students were not in thermal desirable conditions within their classrooms. However, in class 4A4 of SMK Bukit Jalil, 9.1% of occupants voted for slightly cool and 12.10% of occupants considered neutral even though the PMV model and PDD percentage did not fall within the comfort zone. These findings were supported by another research done by Hussein and Rahman **[14]** in which they conducted a study in primary and secondary schools and revealed that environmental assessment exceeded the standard, yet 80% of occupants can accept the current condition. They mentioned that occupants in tropical climates have a higher heat tolerance and can adapt to the hot environment.

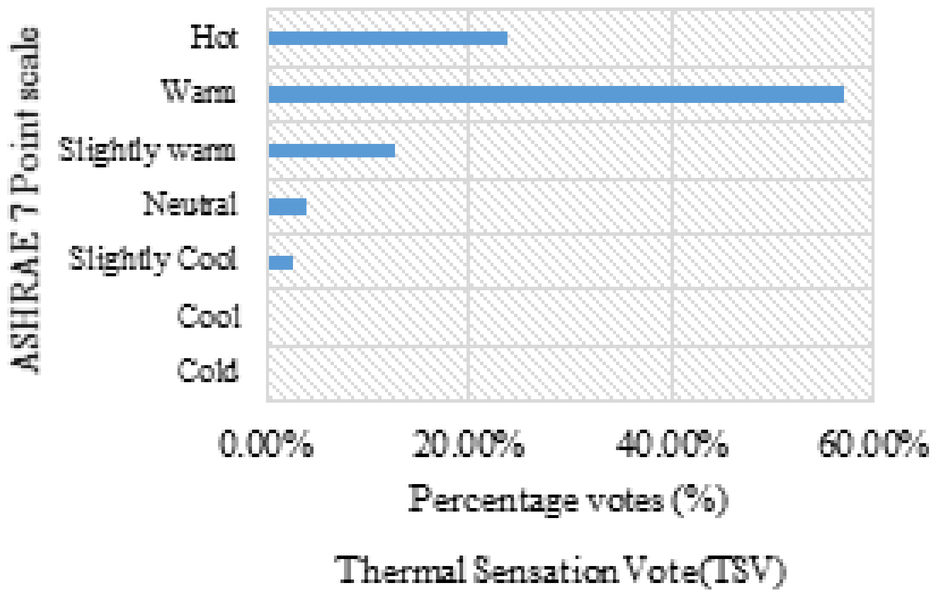


Fig. 7. Thermal sensation vote by students in SMK Bukit Jalil and SMK Taman Yarl

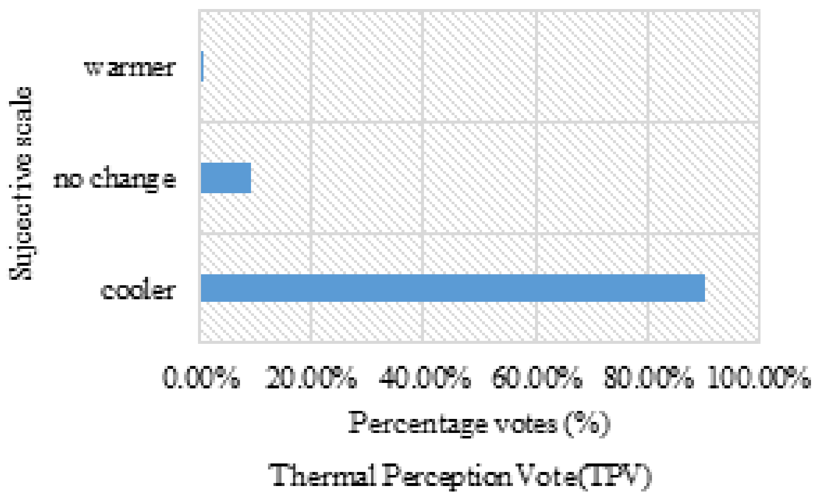


Fig. 8. Thermal Preference vote by students in SMK Bukit Jalil and SMK Taman Yarl

In order to identify the Thermal Perception Vote (TPV), the three (3) point scale of (Cooler, No Change, Warmer) by McIntyre **(14,26)** was used. Thermal Perception Vote (TPV) was illustrated in

Figure 8, and it was observed that 90.40% of students preferred the classroom environment to be cooler, 9% had no change as their consideration and 0.5% of students chose the environment to be warmer.

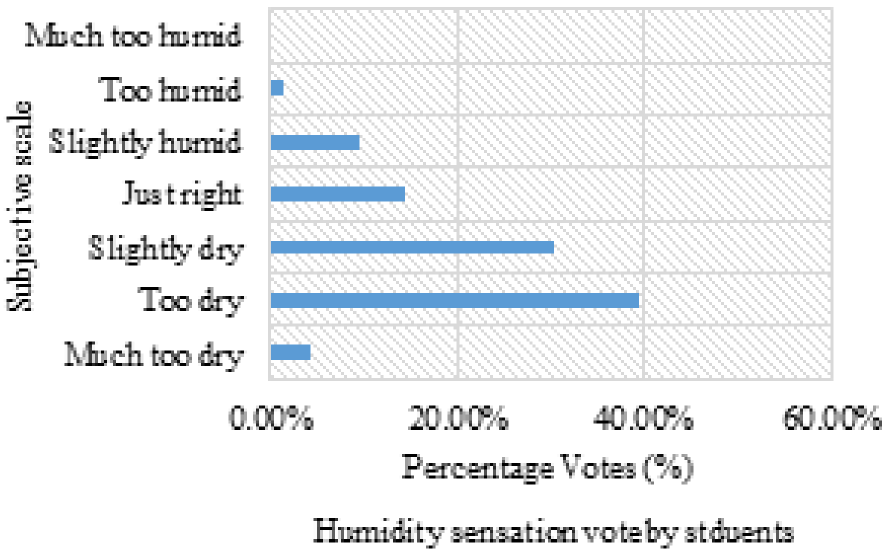


Fig. 9. Humidity sensation vote by students of SMK Bukit Jalil and SMK Taman Yarl

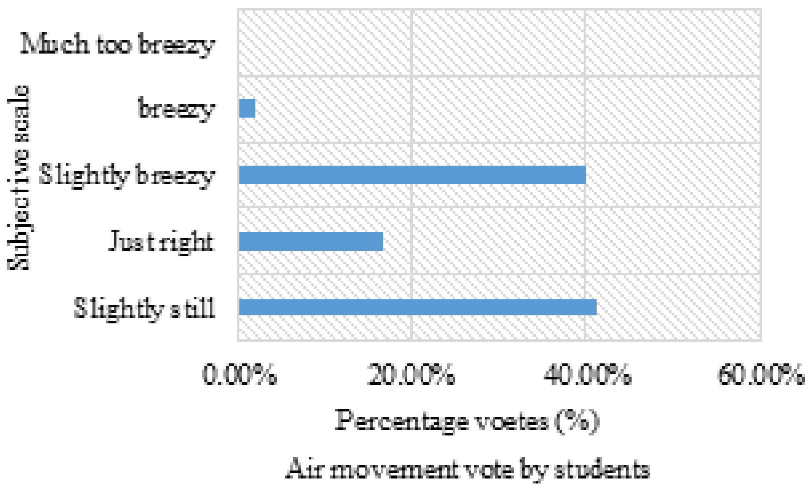


Fig. 10. Air movement vote by students of SMK Bukit Jalil and SMK Taman Yarl

To understand the humidity sensation, the subjective scale used was based on (-3 = too dry, -2 = dry, -1 = slightly dry, 0 = just right, 1 = slightly humid, 2 = humid, 3 = too humid). Based on Figure 9, 54.5% of votes were within the three central categories, which are slightly dry, just right and slightly humid, and the majority of votes obtained were for the dry category with 39.4%. This result denoted that half of the total number of students were not too sensitive to humidity in contrast to their condition **[23]**. Air movement applied the subjective scale [1] which was -1 (slightly still), 0 (just right), 1 (slightly breezy), 2 (breezy), 3 (much too breezy). Fig. 10 describes that the majority of students voted within the central three categories (slightly still, just right, and slightly breezy) which was 97.7%. This indicates the acceptance of air movement in their classrooms due to the possibility of cross ventilation and the usage of ceiling fans. Koranteng **[27]** proved installation of ceiling fans has a positive effect on the indoor environment. The climatic condition of the classrooms is slightly breezy based on the speed of air movement

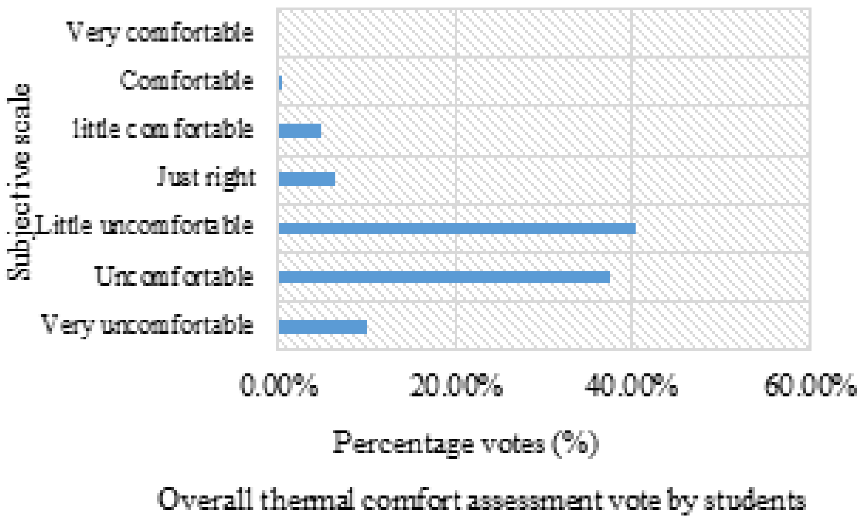


Fig. 11. Overall thermal comfort assessment vote by students of SMK Bukit Jalil and SMK Taman Yarl

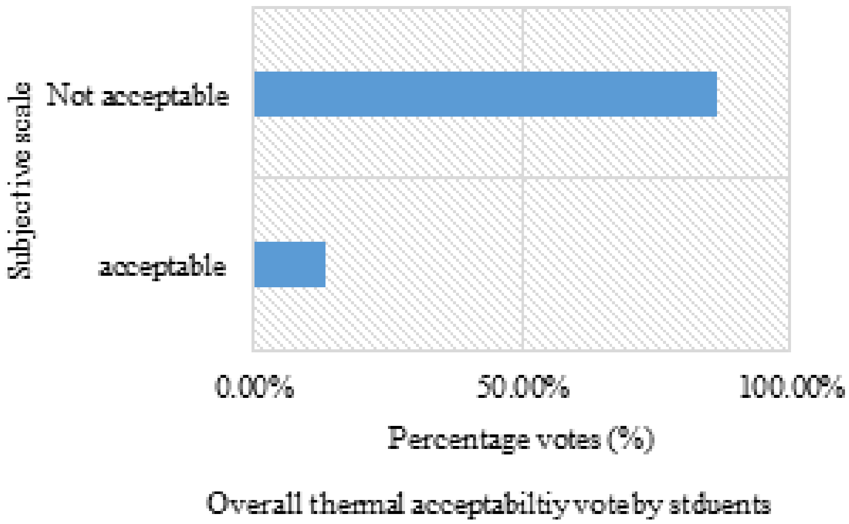


Fig. 12. Overall thermal acceptability vote by students of SMK Bukit Jalil and SMK Taman Yarl

Thermal comfort assessment used the subjective scale [12] which was -3 (very uncomfortable), -2 (uncomfortable), -1 (little discomfort), 0 (just right), 1 (little comfort), 2 (comfortable), 3 (very comfortable). The overall assessment of the subjective responses of thermal comfort was illustrated in Fig. 11. The results obtained shows that the majority of votes ranged from very uncomfortable to little discomfort which was 77.8%, and these generally explains that most students do not accept their current thermal comfort conditions. ASHRAE standard 55 [1] specified that 80% of occupants should have voted in between the range of little comfort to very comfortable in order to have acceptable thermal conditions. Fig. 12 represented the subjective responses of the overall thermal acceptability and it described that 80.40% of students do not accept the immediate thermal condition in their classroom based on the ASHRAE standard 55 [1].

3.3 Factors Influencing Students' Perceptions regarding Thermal Comfort

The MANOVA analysis was carried out to determine factors influencing students' perception regarding thermal comfort. The significance value of the factors which influence students' perceptions was illustrated through the multivariate Pillai's trace results, as shown in Table 4. The tests among the subjects and the effects were represented in Table 5.

Table 4. Multivariate Pillai's trace results.

Effect		Value	F	Hypothesis df	Error df	Sig.
Under Fan	Pillai's Trace	.246	4.472	12.000	382.000	.000
Clothing	Pillai's Trace	.412	1.379	60.000	1122.000	.032
Physical activity	Pillai's Trace	.114	1.258	18.000	573.000	.210
Class	Pillai's Trace	.456	3.195	30.000	955.000	.000
Gender	Pillai's Trace	.027	.881b	6.000	191.000	.510
Orientation	Pillai's Trace	.208	3.692	12.000	382.000	.000

Table 5. Tests between subjects' effects.

Source	Dependent Variable	Type III Sum of Squares	df	Mean Square	F	Sig.
Under fan	How do you feel about thermal environment in the classroom (sensation)?	23.887	2	11.943	18.676	.000
	Is the thermal environment of this classroom acceptable?	1.092	2	.546	4.789	.009
	What is your feeling of overall comfort in the classroom?	5.058	2	2.529	2.737	.067
	At this time how you assess air movement in the classroom?	2.327	2	1.163	1.300	.275
	How do you prefer about thermal environment in the classroom?	.032	2	.016	.155	.856
	How will you rate humidity level of the classroom?	12.020	2	6.010	5.052	.007
Source	Dependent Variable	Type III Sum of Squares	df	Mean Square	F	Sig.
Clothing	How do you feel about thermal environment in the classroom (sensation)?	15.105	10	1.510	2.116	.025
	Is the thermal environment of this classroom acceptable?	1.716	10	.172	1.485	.148

	What is your feeling of overall comfort in the classroom?	**12.540**	**10**	**1.254**	**1.358**	**.203**
	At this time how you assess air movement in the classroom?	**9.014**	**10**	**.901**	**1.004**	**.441**
	How do you prefer about thermal environment in the classroom?	**.918**	**10**	**.092**	**.900**	**.534**
	How will you rate humidity level of the classroom?	**31.919**	**10**	**3.192**	**2.815**	**.003**

Table 5. Tests between subjects' effects (continue).

Source	**Dependent Variable**	**Type III Sum of Squares**	**df**	**Mean Square**	**F**	**Sig.**
Physical	How do you feel about thermal environment in the classroom (sensation)?	1.780	3	.593	.784	.504
activity	Is the thermal environment of this classroom acceptable?	.351	3	.117	.988	.400
	What is your feeling of overall comfort in the classroom?	1.924	3	.641	.678	.566
	At this time how you assess air movement in the classroom?	4.205	3	1.402	1.575	.197
	How do you prefer about thermal environment in the classroom?	.376	3	.125	1.242	.296
	How will you rate humidity level of the classroom?	5.499	3	1.833	1.491	.218
Source	Dependent Variable	Type III Sum of Squares	df	Mean Square	F	Sig.
Class	How do you feel about thermal environment in the classroom (sensation)?	12.980	5	2.596	3.675	.003
	Is the thermal	3.442	5	.688	6.649	.000

	environment of this classroom acceptable?					
	What is your feeling of overall comfort in the classroom?	17.368	5	3.474	3.972	.002
	At this time how you assess air movement in the classroom?	6.461	5	1.292	1.456	.206
	How do you prefer about thermal environment in the classroom?	.283	5	.057	.552	.737
	How will you rate humidity level of the classroom?	32.801	5	6.560	5.964	.000
Source	Dependent Variable	Type III Sum of Squares	df	Mean Square	F	Sig.
Gender	How do you feel about thermal environment in the classroom (sensation)?	1.002	1	1.002	1.331	.250
	Is the thermal environment of this classroom acceptable?	.000	1	.000	.000	1.000
	What is your feeling of overall comfort in the classroom?	2.784	1	2.784	2.990	.085
	At this time how you assess air movement in the classroom?	.158	1	.158	.175	.676
	How do you prefer about thermal environment in the classroom?	.025	1	.025	.248	.619
	How will you rate humidity level of the classroom?	2.425	1	2.425	1.968	.162
Source	Dependent Variable	Type III Sum of Squares	df	Mean Square	F	Sig.
Orientation How do you feel about thermal environment						

in the classroom						
	(Sensation)?	3.397	2	1.698	2.281	.105
	What is your feeling of overall comfort in the classroom?	12.095	2	6.048	6.810	.001
	Is the thermal environment of this classroom acceptable?	2.149	2	1.074	9.896	.000
	How do you prefer about thermal environment in the classroom?	.092	2	.046	.452	.637
	At this time how you assess air movement in the classroom?	.757	2	.379	.419	.658
	How will you rate humidity level of the classroom?	2.585	2	1.292	1.044	.354

3.3.1 The Sitting Location Influence
Based on Pillai's Trace result (Table 4) the relationship between students who are positioned under the fan with thermal comfort perception provided significant values on all dependent variables [F(2195) = 4.47, P<.05]. In addition, the tests among subjects and the effects indicate that the thermal sensation relationship among students who sat under the fan were [F(2195) = 18.68, P<.05] and it contributed 16%. The acceptability level among students who sat under fan was [F(2195) = 4.79, p<.05] and it contributed 4.7%. Another finding shows a significant relationship between humidity sensation and students who are located under the fan with [F(2,195)=5.05, p<.05] which contributed 4.9%.Another study done by Indraganti et al. **[28]** indicated that occupants who are using fans had higher comfort sensation than the ones who are not using fans.

3.3.2 The Clothing Influence
Clothing is another factor that shows a significant finding which was [F(10,187)=1.38, p<.05] and for the test of between subjects' effects, students' sensation contributed 10.2% of the significant value [F(10,187)=2.12, p<.05], while humidity sensation contributed about 13.1% of the significant value [F(10,187)=2.82, p<.05]. Layers of clothing insulation inhibits heat loss and can either help retain a person to warmth or lead to overheating **[29]**.

3.3.3 The Physical Activity Influence
Physical activity will determine the metabolic rate and it is one of the important personal factor influencing thermal comfort **[2]**. However, in this study, there was no significant value shown [F(3,194)=1.26, p>.05] since the majority of students are involved in sedentary activity and do not have much effect.

3.3.4 The Floors Levels Influence
The floor level of the classrooms provided a significant value [F(5,192)=3.20, p<.05]. Tests between subjects' effects shows students' sensation contributed 8.7% of the significant value [F(5.192)=3.68, p<.05], the acceptable level contributed 14.8% of the significant value [F(5,192)=6.65, p<.05], the overall comfort level contributed 9.4% of the significant value [F(5,192)=3.97, p<.05] and, lastly, the humidity sensation contributed 13.4% of the significant value [F(5,192)=5.94, p<.05].Based on the

results, students sitting in classrooms on higher floors have a different perception compared to students on lower ground classroom since higher floors recorded the highest air temperature. Emir **[30]** explained in his study that high temperatures may cause fatigue, weariness and sloppiness, and this will decrease perception and interpretation and increase the making of mistakes.

3.3.5 The Gender Influence

In this study, gender did not show a significant value as the value was [$F(1,196)=0.88$, $p<.05$]. Wafi et al. **[24]** also mentioned in his study that there were not much differences identified on the responses between male and female respondents regarding thermal comfort.

3.3.6 The Orientation Influence

Orientation was another factor which shows a significant value of [$F(2,195)=3.69$, $p<.05$], whereby, tests between subjects effects explains acceptable level which contributed 9.2% of the significant value [$F(2,195)=9.90$, $p<.05$] and the overall thermal comfort contributed 6.5% of the significant value [$F(2,195)=6.81$, $p<.05$]. The results obtained can be referred to another study by Kushari et al. **[31].**They explained that the window facing the east and west directions allowing direct heat transmission into the indoor environment and affected respondents' perception regarding thermal comfort. The same scenario happened in this study since students of classroom 5A4 have open windows facing the east and west directions, and students of classrooms 4A and 4S have open windows facing the west and east directions; students of classrooms 5A4, 4A and 4S have different perception compared to other students.

4. CONCLUSION

A study on thermal comfort was conducted in SMK Bukit Jalil and SMK Taman Yarl to understand the immediate indoor environment of classrooms. It clearly states that all classrooms' thermal conditions exceeded the stipulated recommendation specified by ASHRAE standard 55. Based on the subjective assessment of students' perception regarding thermal comfort, the results described that 80% to 100% of respondents do not accept the prevailing condition of the classrooms. Students who sat under ceiling fans have different thermal sensations and this was considered to be one of the main influencing factor towards students' perception regarding thermal comfort. In addition, clothing insulation, levels of the classrooms' floor and orientation of the blocks were also a few other factors that influenced the overall respondents' perception. To improve current condition of the classrooms, the exposed surface has to be preserved by planting more vegetation within the school compound. Implementation of architectural passive techniques, such as adding shading devices, should be considered to obtain better indoor environment in classrooms.

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