

Thermal Comfort Study in Vibration and Noise Laboratory at UTHM Pagoh

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DOI: <https://doi.org/10.30880/peat.2025.06.02.008>

Article Info

Received: 26 June 2025

Accepted: 11 August 2025

Available online: 30 October 2025

Keywords

Thermal comfort, laboratory,
parameter, air-conditioning

Abstract

Thermal comfort has a direct impact on people's health, well-being, and productivity. The purpose of this study is to assess thermal comfort in the Vibration and Noise Laboratory (MTGDK) UTHM Pagoh in response to student concerns regarding uncomfortably lecture situation. The objectives of this study are to measure the thermal comfort parameters, access thermal perception and analyzed the thermal comfort condition in MTGDK laboratory. The method used to collect data in the MTGDK laboratory is physical measurement (air temperature, relative humidity, air velocity and mean radiant temperature) and questionnaire survey. Thermal comfort parameters were analyzed and compared standard and guidelines. The collected data did not fully comply with the accuracy requirements set by ASHRAE Standard 55. The physical measurement Predicted Mean Vote (PMV) value 0.1 falls within the comfort zone, but the questionnaire survey -1.9 and CBE Thermal Comfort Tool -0.85 indicate discomfort. The physical measurement of Predicted Percentage Dissatisfied (PPD) is 5% and CBE Thermal Comfort Tool 20% while questionnaire survey shows 71% dissatisfaction range specified by ASHRAE 55 and ISO 7730. These different results raise highlight important differences and show that the MTGDK laboratory was in a thermally uncomfortable state. In conclusion, the findings of this study indicate that the thermal conditions in the laboratory do not comply with ASHRAE standards and improvements are needed, particularly in controlling indoor humidity and adjusting air-conditioning temperature, to enhance user satisfaction, and support the development of a sustainable and conducive learning environment.

1. Introduction

Thermal comfort has a direct impact on people's health, well-being and productivity. One of the main goals for improving people's quality of life in the future is to make indoor spaces better [1]. In tropical regions such as Malaysia, the challenge of maintaining optimal thermal conditions is intensified by consistently high ambient temperatures and humidity. Air-conditioning systems are essential in maintaining acceptable indoor conditions. discomfort can still occur if thermal conditions are not well regulated. Clarifying the human body's thermal comfort demand law is essential given the growing need for intelligent indoor thermal environment regulation on demand [2]. Heating or cooling a building won't solve the final factors' lack of comfort, but thermal conditions can be improved. ASHRAE standard 55 defines thermal comfort as "the state of mind that expresses satisfaction with the surrounding environment. For buildings to maintain thermal comfort and indoor air quality (IAQ),

ventilation is important, especially in enclosed environments. Poorly maintained or unbalanced systems can lead to thermal discomfort due to stagnant air or uneven cooling. Therefore, proper mechanical ventilation, is necessary to ensure thermal comfort and enhance the overall indoor environment [3].

In general, many people spend more than 90% of their time in the building [4]. Comprehensive study on thermal comfort in air-conditioned laboratories in tropical regions is crucial given the complexity and importance of the problem. These studies help to improve indoor environmental design, energy efficiency, and user well-being at educational institutions in addition to informing facility management methods. Targeted interventions can be created to improve comfort, lower energy consumption, and create more beneficial educational environments by knowing how occupants perceive and react to indoor thermal conditions. Moreover, laboratory environments in educational institutions are often overlooked in thermal comfort research, despite their unique usage patterns and reliance on mechanical ventilation. By studying thermal comfort in these settings, particularly through both objective measurements and subjective feedback, institutions can better align HVAC operations with actual user needs. This not only enhances comfort and satisfaction but also supports energy-efficient building management and promotes healthier, more productive learning environments.

The tropical climate of Malaysia, characterized by high temperatures and humidity, can lead to discomfort in indoor environments if not managed properly. This discomfort could affect focus, productivity, and overall satisfaction. Therefore, thermal comfort requires continuous monitoring and adaptive strategies to ensure occupant well-being [5]. High humidity levels can create a sticky, unpleasant atmosphere, making it harder for students to stay comfortable. Additionally, inadequate air circulation can lead to a sense of suffocation, causing drowsiness, fatigue, and even headaches. The research demonstrated that improved ventilation modes, particularly HVAC systems, led to better thermal comfort and higher student performance in design studios and classrooms [6].

The goal of this study is to measure the thermal comfort parameters in MTGDK laboratory. The parameters that measure are air temperature, relative humidity, air velocity and mean radiant temperature. Another goals are to access thermal perception in MTGDK laboratory through a questionnaire survey. Last goals are to analyze the thermal comfort condition in laboratory using CBE Thermal Comfort tool and Microsoft Excel. It to analysis the range of PMV and PPD in the laboratories and need to analysis the relationship between the parameters and the occupants' thermal perceptions, gathered through a structured questionnaire based on ASHRAE Standard 55. By integrating objective environmental measurements with subjective feedback, the study aims to understand how these parameters influence perceived comfort in the MTGDK laboratory environment. This holistic approach not only supports the evaluation of existing HVAC performance but also contributes to optimizing indoor climate control strategies tailored to the needs of laboratory users in a tropical context.

2. Methodology

The methodology flowchart presents outlines the systematic process of the study that followed by data collection through physical measurements and questionnaire surveys in the MTGDK laboratory, continuing with analysis and interpretation, and concluding with results and recommendations as shown in Figure 1. The chart highlights the key stages respondents survey and data analysis. Each step was designed to ensure the accuracy and reliability of the findings, with a clear framework for validating the results.

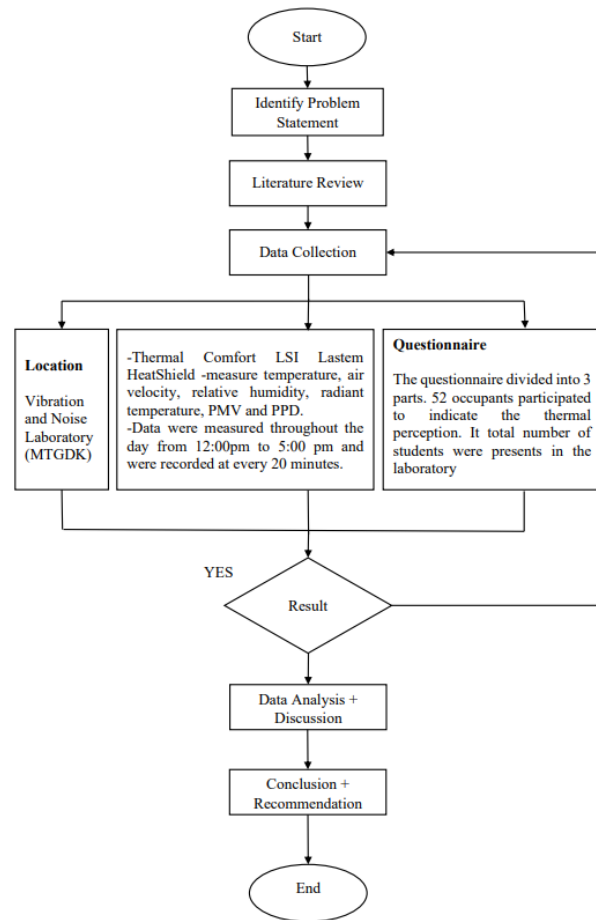


Fig. 1: Flow chart

2.1 Measurement Methods

The measurement techniques used in this study aimed to gather both objective and subjective information concerning thermal comfort. Objective measurements were taken using a thermal comfort instrument kit which is LSI Lastem Heatshield, while subjective data were collected via a structured questionnaire survey completed by the occupants. By combining these two methods, the study was able to provide a well-rounded analysis of thermal comfort levels, accounting for thermal conditions in the MTGDK laboratory.

2.2 Questionnaire Survey

The survey utilized an online questionnaire approach to collect data, facilitating direct interaction between participants and researchers to obtain in-depth insights into thermal comfort conditions within the MTGDK laboratory. The survey was developed in accordance with the guidelines outlined in ASHRAE Standard-55 (2017). The questionnaire was distributed to laboratory users using Google Forms, and a total of 52 respondents participated. The content of the questionnaire was divided into three sections, as shown in Table 1.

Table 1: Questionnaire Content

Section	Title of Content
A	Personal information
B	Situations
C	Survey of Thermal Comfort Perception

2.3 Physical Measurement

Physical measurement was taken over the course of a single day during the class session. These measurements were start at 12:00 PM until 5:00 PM. The parameters that measured were air temperature, air velocity, humidity, mean radiant temperature, Predicted Mean Vote (PMV) and Predicted Percentage Dissatisfied (PPD). Thermal comfort measurements were conducted in the center of the are MTGDK laboratory using the ASHRAE

Standard 55-2017. The selected location for placing the thermal comfort measuring device was positioned at a height of 1.1 meter above the floor, which corresponds approximately to the level of occupants. Proper sensor height is critical, as recommended by standards such as ISO 7730, to reflect actual human exposure to the thermal environment during sedentary tasks. In Figure 2, shows the location and placement of LSI Lastem Heatshield in MTGDK Laboratory.



Fig. 2: Placement of LSI Lastem Heatshield

3. Result and Discussions

This section presents the result of the research, followed by an in-depth discussion of the findings. The results were obtained through a combination of occupant surveys and environmental measurements. This discussion were interpret the results, highlight key patterns, and relate them to existing research while addressing potential limitations and their implications for future research.

3.1 Questionnaire Result

The questionnaire was measured as the same day physical measurement. A 52 total of respondents was the occupants who were present in the laboratory which took place from 12:00 PM to 5:00 PM. To analyze the data, the questionnaire responses collected and organized in Microsoft Excel to calculate the average values and make comparisons. The data were analyzed to evaluate occupants' thermal comfort levels based on parameters such as air temperature, relative humidity, and air velocity.

3.1.1 Thermal Comfort Perception

In Figure 3, shows the occupant thermal occupant perception during the examination periods, 42.30% of respondents felt "too cool", 34.60% respondents felt "comfortably cool" and 21.20% respondent felt "much too cool". It shows that majority of respondents felt uncomfortable with the air temperature in that laboratory. This aligns with the findings, that particularly higher temperatures, can lead to reduced concentration and discomfort in classrooms [7]. This finding aligns with earlier research emphasizing the importance of air temperature in educational settings, where even minor variations can influence cognitive performance and focus [8].

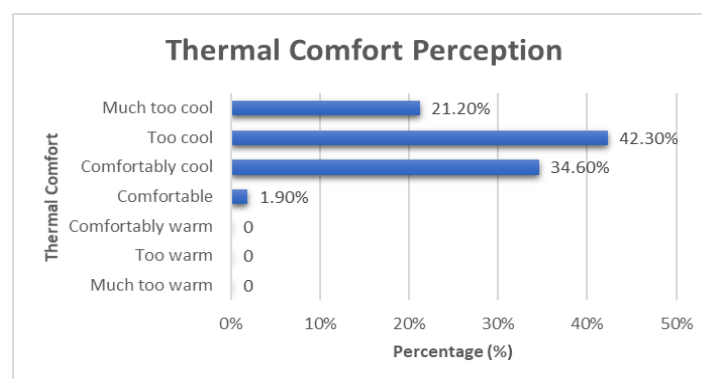


Fig. 3: Respondents Thermal Comfort Perception

3.2 Thermal Comfort Measurement

The thermal comfort at the MTGDK laboratory was influenced by key factors such as air temperature, air velocity, humidity and mean radiant temperature. These parameters were measured using the LSI Lastem Heatshield system on 19th May 2025. The data from these measurements are summarized in Table 2, which presents the Excel results from the Heatshield system.

Table 2: Result Parameter on LSI Lastem Heatshield

Time	Outdoor Air Temperature (°C)	Air Temperature (°C)	Mean Radiant Temperature (°C)	Relative Humidity (%)	Air Velocity (m/s)
12:00 pm		22.1	22.6	79.2	0
12:20 pm		21.7	22.3	79.5	0
12:40 pm		21.6	22.2	79.2	0
1:00 pm		21.6	22.2	79.2	0
1:20 pm		21.6	22.2	79.0	0
1:40 pm		21.6	22.1	79.1	0
2:00 pm	28.0	21.6	22.2	79.0	0
2:20 pm		21.7	22.2	79.2	0
2:40 pm		21.6	22.2	79.4	0
3:00 pm		21.6	22.2	79.6	0
3:20 pm		21.5	22.2	80.0	0
3:40 pm		21.6	22.2	79.6	0
4:00 pm		21.5	22.1	80.1	0
4:20 pm		21.6	22.2	80.8	0
4:40 pm		21.6	22.2	81.8	0
	Average	21.6	22.2	79.6	0

The average outdoor and indoor air temperatures were 28.0°C and 21.6°C, respectively. The recorded variation in air temperature was not significant due to the use of a mechanical ventilation system in the laboratory. The mean radiant temperature (MRT) was also low, averaging 22.2°C, mainly due to the overcast weather conditions at the time of measurement. Recent research also indicates that MRT has a stronger correlation with occupants' thermal perception than air temperature in certain settings, especially in low air velocity environments [9]. Humidity levels in the MTGDK laboratory started at 79.2% in the morning and increased slightly to 81.8% by late afternoon. The difference in humidity throughout the measurement period was minimal, with the lowest point recorded at 79.0% around midday. This midday dip was due to increased indoor heating and air movement, which reduced moisture levels. The gradual rise in the afternoon resulted from the accumulation of heat and moisture within the laboratory and from outdoor conditions. Air velocity remained static at 0 m/s, as the space relied entirely on mechanical ventilation.

Figure 4(a) illustrates the variation in Predicted Mean Vote (PMV) over time, from 12:00 PM to 4:40 PM, based on data recorded in the MTGDK laboratory. The PMV values ranged approximately from 0 to +0.1, indicating a neutral thermal sensation. According to the physical environmental data, the laboratory maintained thermal comfort within the acceptable limits recommended by ASHRAE Standard 55, where PMV values between -0.5 and +0.5 are considered comfortable for 90% of occupants. Figure 4(b) displays the variation in Predicted Percentage Dissatisfied (PPD) over time, with values ranging between 5% and 5.1%, indicating that the thermal conditions were highly acceptable for the majority of occupants.

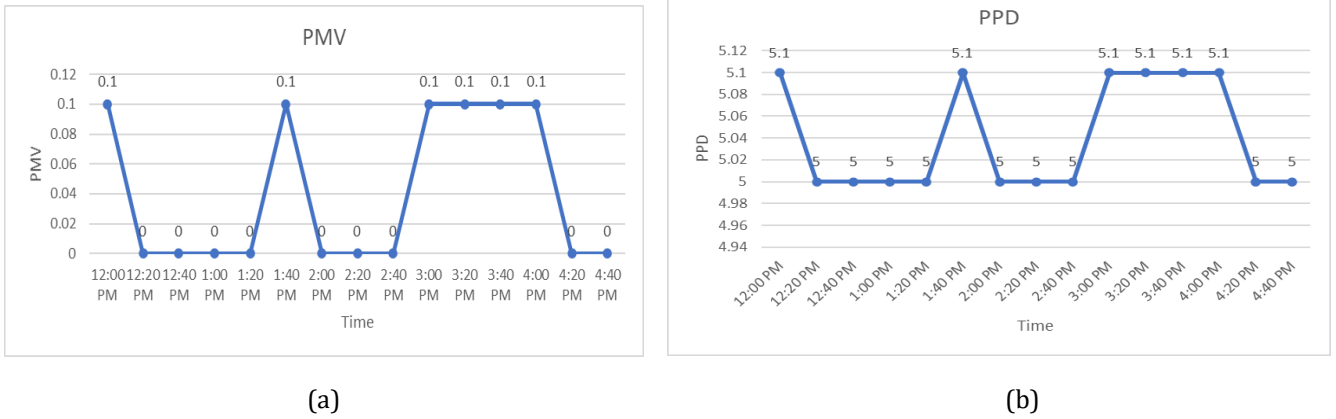


Fig 4: (a) PMV vs time (b) PPD vs time

3.3 Thermal Sensation Votes (TSV)

Table 3 shows the thermal sensation votes from the questionnaire survey analysis. The majority of respondents chose cool to indicating satisfaction. From the 52 respondents, there were only 15 of respondents were satisfied with the comfort levels of the laboratory.

Table 3: Thermal Sensation Votes

Cold	Cool	Slightly Cool	Neutral	Slightly Warm	Warm	Hot
7	30	14	1	0	0	0
Dissatisfied = 37			Satisfied = 15		Dissatisfied = 0	

$$\begin{aligned}
 \text{PPD} &= \frac{\text{the number of questionnaire having discomfort level}}{\text{the total number of questionnaire in any direction}} \times 100 \\
 &= \frac{37+0}{52} \times 100 \\
 &= 71\%
 \end{aligned}
 \tag{1}$$

Based on the questionnaire survey analysis, there were 71% of respondents that are dissatisfied with the thermal conditions. Figure 5 illustrates the gap between PPD and PMV, showing that 71% of occupants are dissatisfied. The PMV result, determined by the mean vote of respondents is -1.9, falling between slightly cool (-1) and cool (-2) conditions, which exceeds the below limit of -0.5, recommended by ASHRAE Standard-55. The value below the ASHRAE 55 standard's below limit of -0.5, indicating significant thermal discomfort.

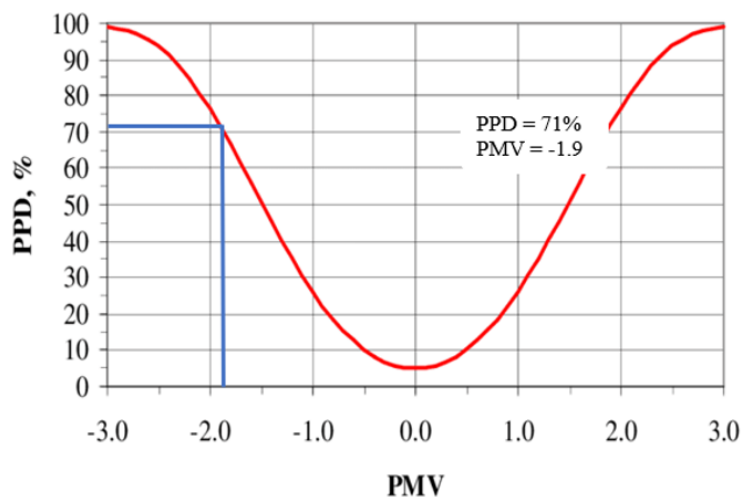


Fig. 5: PPD versus PMV graph

3.4 CBE Thermal Comfort Tool

The average measurements of parameters were considered for use in the calculation of the Predicted Mean Vote (PMV) and Predicted Percentage Dissatisfied (PPD) using the CBE Thermal Comfort Tool. The integration of thermal feedback mechanisms within smart buildings, using the CBE Thermal Comfort Tool to monitor and adjust thermal conditions in real-time [10]. Table 4 presents the data used in this calculation. The metabolic rate was set at 1.0 met, as all respondents were in a seated posture, while the average clothing insulation value was set at 0.65 clo. This clo value was determined through a questionnaire survey, where the majority of respondents reported wearing long-sleeved shirts, long pants, shoes, socks and headscarves (for muslim female respondents).

Table 4: Data Input in CBE Thermal Comfort Tool

Parameter	Average Data
Air temperature (°C)	21.6
Mean radiant temperature (°C)	22.2
Air speed (m/s)	0
Relative humidity (%)	79.6
Metabolic rate	1
Clothing level (clo)	0.65

In Figure 6 shows the psychrometric chart of PMV and PPD using the CBE Thermal Comfort Tool, illustrates a PMV value of -0.85 shows that occupants feel slightly cool based on thermal sensation. The result is allign with the questionnaire survey responses that majority of respondents felt overcooling in the MGTDK laboratory. The PPD value of 20%, which indicating that the thermal conditions are under standard comfort criteria. It shows it did not comply with ASHRAE Standard 55-2023 where the red dot which represents the actual condition in the lab was located outside the blue zone in psychrometric chart.

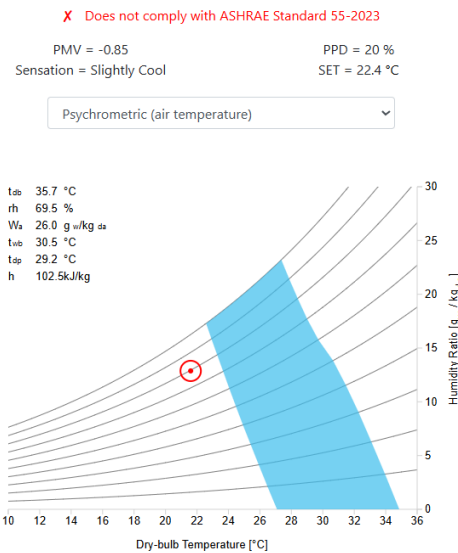


Fig. 6: Calculation using CBE Thermal Comfort Tool

3.5 Linear Regression

Figure 7 shows data analysis result relationship between air temperature and PMV. It shows that relationship has weak positive relationship with $R^2 = 0.012$. This indicates that as the air temperature rises, the PMV value also increases slightly, reflecting a warmer perceived thermal sensation.

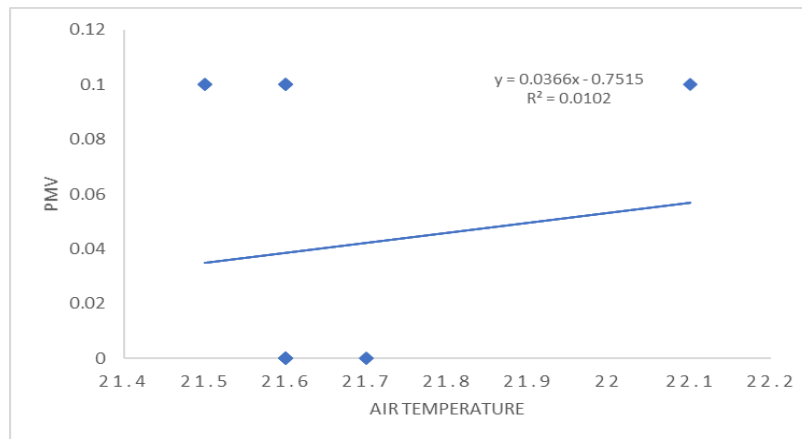


Fig. 7: Linear regression analysis of air temperature and PMV

$$y = mx - b \quad (2)$$

$$PMV = 0.0366Ta - 0.7515$$

$$Ta = \frac{0.7515}{0.0366} = 20.5 \text{ } ^\circ\text{C}$$

To find the optimum air temperature that corresponds to PMV used equation $y = 0.0366x - 0.7515$ and got 20.5 °C. However, a temperature of 20.5°C may feel too cold in a laboratory environment, particularly in a tropical climate, as indicated by respondents who reported feeling cool or cold in the questionnaire. To attain a slightly warm yet acceptable PMV range of +0.3 to +0.5, the ideal air temperature is likely around 23°C to 24°C.

3.6 Comparison with the Standard

Table 5 shows the comparison between the measurement results with standard. The air temperature was lower than range requirements of standard ASHRAE Standard-55 217 and MS1525-2014. Relative humidity also failed to meet the standard. The high humidity levels in tropical climates can significantly affect the perceived temperature, as it hampers the body's natural cooling mechanisms, such as sweating, leading to a heightened feeling of warmth [11]. Air velocity is 0 m/s because its fully mechanical ventilation system and distance the diffuser and respondents are a far so that the air velocity is slow.

Table 5: The comparison between the measured results with standard

Parameter	Data at MTGDK	ASHRAE Standard-55 2017	MS1525-2014
Air temperature (°C)	21.6°C	23-26°C	24-26°C
Relative humidity (%)	79.6%	20-60%	40-70%
Air velocity (m/s)	0	<0.15 m/s	0.15 - 0.50 m/s

Table 6 shows the comparison data PMV and PPD with standard. The PMV for data from the questionnaire survey and from CBE Thermal Comfort Tool are not complying with standard while PMV data from the physical measurement of 0.1 which is in the range of requirement -0.5 - +0.5. Research in educational environments indicated that classrooms with PMV values close to neutral correlated with better student concentration and academic performance [12]. However, the PPD data from the measurement and CBE Thermal Comfort Tool are meet the requirement of standard which it in the recommended in the ASHRAE Standard-55 and ISO 7730-2005. Other, PMV data from questionnaire survey tool are not meet the standard.

Table 6: Comparison between PMV and PPD with standard

Parameter	Data from measurement	Data from questionnaire survey	Data from CBE Thermal Comfort Tool	ASHRAE Standard-55 2017	ISO 7730-2005
PMV	0.1	+1.9	-0.85	-0.5 - +0.5	-0.5 - +0.5
PPD %	5%	71%	20%	<20%	<10%

4. Conclusion

Based on the questionnaire survey involved 52 of respondents, found that respondents reported on “too cool” and “comfortably cool” dissatisfaction. The physical measurements indicated that air temperature, mean radiant temperature, air velocity and relative humidity did not meet ASHRAE Standard 55 and MS1525-2014 guidelines. For optimal thermal comfort, it is recommended to maintain an indoor temperature range 23°C-26°C and relative humidity levels between 20%-60%. The Predicted Mean Vote (PMV) of 0.1 a generally acceptable range of standard and guidelines while Predicted Percentage Dissatisfied (PPD) of 5% also meet the range of standard which are recommend in the standard and guidelines.

To ensure thermal comfort in MTGDK laboratory, a few recommendations should be implemented. By installing the controlling indoor humidity that can help to maintain the relative humidity below 60% and can prevent issues such as dampness, mold growth and discomfort. Another suggesting to improve thermal comfort in the MTGDK laboratory is setpoint the air-conditioning temperature to around 24°C-25°C from 22°C. By this strategy can promotes energy efficiency because it can reduce to energy consumption and thermal comfort can be improved to due majority of respondents feeling cold.

Acknowledgement

This author would like to thank the Faculty of Engineering Technology at Universiti Tun Hussein Onn Malaysia for providing the necessary resources, facilities and resources used for the progression of this study. This study could not have been completed without the invaluable guidance and unwavering support of project supervisor, to whom extend the deepest appreciation, along with heartfelt thanks to everyone who kindly contributed to the success of this research.

Conflict of Interest

Authors declare that there is no conflict of interests regarding the publication of the paper.

Author Contribution

All authors of this study have a complete contribution for data collection, data analysis and manuscript writing.

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