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Preliminary Study on Student's Performance and Thermal Comfort in Classroom

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ABSTRACT

In Malaysia, students spend up to 33% of their day in classrooms and school buildings. Previous research had shown that thermal comfort conditions in educational buildings can stimulate student productivity. This study aimed to preliminary investigate the relationship between thermal sensation and student performance in the classroom. Data collection was conducted in a selected classroom at a secondary school in Segamat, Johor. All data were collected for three days. Physical measurement data were taken using thermal comfort equipment, KIMO AMI 310 for indoor measurement (air temperature, mean radiant temperature, air velocity, relative humidity), and TSI VelociCalc for outdoor measurement (air temperature, relative humidity). The thermal comfort satisfaction questionnaire was distributed to 36 students in the classroom. The learning performance was assessed through a simple reaction test and digit span test based on the WHO Neurobehavioral Core Test Battery (NCTB) method. The results of the thermal comfort satisfaction questionnaire clearly showed that the lower the fan speed, the more students preferred the cooler option. Furthermore, students performed better when the fan speed was increased. Based on the correlation analysis, it can be concluded that the learning performance and thermal preference vote (TPV) are positively correlated. As a result, students tend to get higher scores when they feel cooler. This study provides important preliminary information on classroom conditions in secondary schools in Malaysia and provides a better understanding of the relationship between thermal perception and student learning performance in the classroom.

1. Introduction

Research revealed that people spent most of their time indoors. Previous studies stated that students spend up to 33% of the day in classrooms and school buildings [1-3]. Thus, the indoor environmental quality (IEQ) of the classroom is significant to be preserved. Besides that, thermal

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comfort conditions in educational buildings also encouraged student productiveness during the teaching and learning process [4]. Many researchers have studied the effect of environmental conditions on student performance. Lee *et al.,* [5] studied the effect of IEQ dissatisfaction on self-reported learning performance and found that increased dissatisfaction and complaints on the IEQ caused a decrease in learning performance. Cui *et al.,* [6] studied the influence of air temperature on memory typing performance and found that subject performance was optimum at 26℃ .In a recent study in China, Jiang *et al.,* [7] found that the optimum learning performance temperature was 14℃. Wang *et al.,* [8,9] discovered that the optimum performance temperature is 28℃ and that learning performance decreases as air velocity increases. However, the majority of the research was carried out in China, where the climate types differed from those found in Malaysia. Moreover, the studies were only conducted in air conditioned classrooms, and only Wang *et al.,* [9] conducted a study on the effect of air velocity on learning performance. Since one of the important factors influencing thermal comfort is air velocity [10,11], it is possible that it will influence learning performance. Therefore, the influence of air velocity and thermal comfort on learning performance in tropical climates is worth exploring.

In Johor, the most southern state in Malaysia, the number of secondary schools were around 226 units from 1996 to 2016 [12]. The ventilation for public schools in Malaysia were combination of natural ventilation and mechanical ventilation (fans). Program Transformasi Sekolah 2025 /School Transformation Programme 2025 (TS25) under the Malaysia Ministry of Education (MoE) highlighted one of the objectives was to provide an effective learning environment in schools [13]. In one of the aspects, an effective learning environment in the classroom should consider both the thermal acceptability range and its effect on the performance of the students [14].

Malaysia's climate was classified as tropical with constant temperature with hot and humid all year [15]. American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) 55 standard on thermal environmental conditions for human occupancy had been published and extensively being referred. However, no comfort standard for young school children or adolescents had yet been established. According to ASHRAE 55, thermal comfort is defined as "that condition of mind that expresses satisfaction with the thermal environment.". The thermal comfort of an area was determined by various factors, including personal and environmental factors. Personal factors include metabolic rate and clothing insulation. Environmental factors include air velocity, air temperature, relative humidity and mean radiant temperature [16].

Productivity and learning performance of students can be enhanced through school facilities. Classroom as learning areas at school buildings requires to be supplied with safe physical and social environments for effective interaction between students and teachers throughout the teaching and learning process. In line with a professional analysis, a classroom's physical atmosphere and environment will influence and affect students' accomplishments and improve student performance [17-20].

The public school buildings in Malaysia were built in almost similar shapes, designs, and facilities. The Malaysian Public Works Department (JKR) created a standard plan for public schools for primary and secondary education. To promote thermal comfort, most Malaysian classrooms use a combination of natural ventilation and mechanical ventilation using fans [21]. However, limited studies had been conducted on students' thermal comfort perceptions and performance in Malaysian classrooms. Thus, this study was important to understand the thermal comfort problem in school and the long term to come out with a sustainable solution. This study aimed to conduct preliminary investigation on the relation of thermal acceptability with student performance in Malaysian classroom.

2. Methodology

There are three phases to the approach in this study, which are school building selection, data collection, and data analysis.

2.1 School Building Selection

In Malaysia, the public-school layouts were often designed in a linear spatial arrangement with a one-sided corridor. With a small rectangular courtyard in between, two blocks of three or up to five floors faced each other. Two blocks that faced each other were joined by a bridge with common stairwells in the middle or simply by a bridge for connection. Toilets were always at the end of the block, where staircases were either in the middle or at the end of the block. Normally, classrooms were designed in a typical rectangular style and strung along open corridors on one side. Furthermore, classrooms were single-row, with windows on both the leeward and windward sides to allow for cross ventilation. Figure 1 shows the general layout of the investigated school.

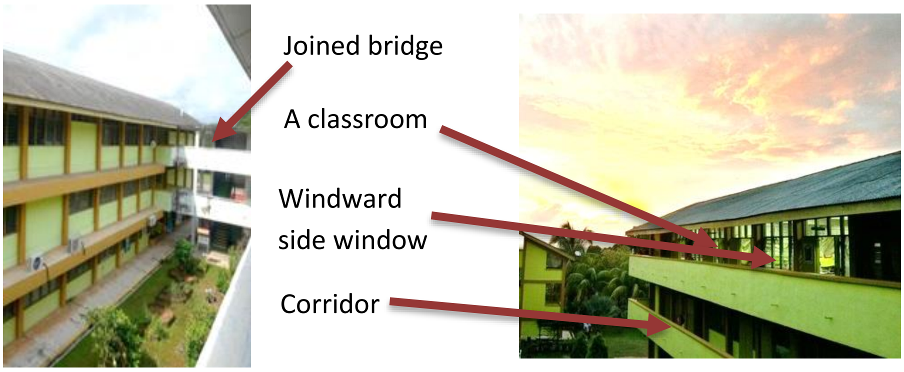


Fig. 1. General layout of the investigated school

2.2 Data Collection

Data collection was conducted in a secondary school located in Segamat, Johor. The data collection session was conducted for three days from 11:00 am to 12:00 pm in three classes (Class 1, Class 2, and Class 3). Data collection included four parts, which were adaptation time, physical measurement, thermal comfort satisfaction questionnaire, and a performance assessment as in Figure 2. Table 1 shows the Latin-square design for assessing thermal comfort satisfaction questionnaire and learning performance. The Latin-square design was utilized by changing the fan speed regulator on each investigated class. The ceiling fan speed varied from 3 to 5 speed as specified in the speed regulator. The ceiling fans used in the classroom were 2 units, 3 blade ceiling fans (KDK Regular type K15VC) with the length of each fan blade was 150cm. The fan speed can be varied from 216 RPM to 264 RPM, and the fan speed used in the study was 18.0 m/s (speed 3), 19.5 m/s (speed 4), and 21.0 m/s (speed 5) [22].

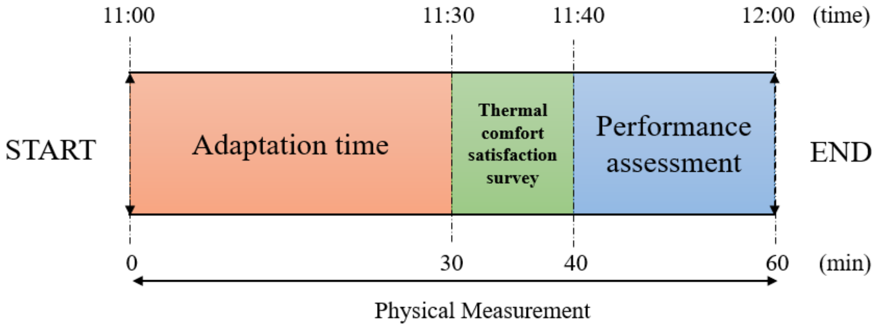


Fig. 2. Data collection session and duration

Table 1
Latin-square design for assessing thermal comfort satisfaction questionnaire and learning performance

Ceiling fans speed (m/s)	Day 1	Day 2	Day 3
18.0	Class 1	Class 2	Class 3
19.5	Class 3	Class 1	Class 2
21.0	Class 2	Class 3	Class 1

2.2.1 Equipment

The physical measurement data was collected for both indoor and outdoor environments of the classroom by using thermal comfort equipment. A set of KIMO AMI 310 was placed at the center of the classroom to measure the mean radiant temperature, relative humidity, air velocity, and air temperature as shown in Figure 3(a). A set of TSI VelociCalc for measuring air temperature and relative humidity was also set up outside the classroom as Figure 3(b). According to ASHRAE 55, all physical measurements were obtained at a height of 1.1 m above the floor. Both sets of equipment were left running for around 60 minutes, with 1-minute measurement intervals recorded [16].

(a) (b)

Fig. 3. Equipment set up at classroom (a) Center (b) Outside

2.2.2 Thermal comfort satisfaction questionnaire

The data on thermal comfort satisfaction from students were collected through the questionnaire distributed. A total of 36 students were involved in the thermal comfort satisfaction questionnaire.

There were 18 male and 18 female students. 6 male and 6 female students were combined into a group. A total of 3 groups are formed. They were required to answer the questionnaire under three different conditions; 18.0 m/s, 19.5 m/s, and 21.0 m/s following the Latin-square design.

The thermal comfort satisfaction questionnaire was used to evaluate the students' thermal perception in the classroom. Students were required to answer open-ended questions related to their opinion on the current condition. The classroom thermal comfort questionnaire consisted of seven items to observe the thermal comfort of the classroom. It included temperature, humidity, wind speed, sunlight, comfortable, satisfaction, and personal preference.

2.2.3 Learning performance

A neurobehavioral cognitive smartphone application was developed for evaluating students' performance. The application called "NeuroTest" was used to evaluate students' learning performance following the WHO Neurobehavioral Core Test Battery (NCTB) [23]. Two neurobehavior test were conducted; simple reaction tests (SRT) and digit span test (DS). SRT was used for assessing attention and DS was for immediate memory. The learning performance test will take roughly 20 minutes to complete. A total of 36 students participated in the learning performance following the Latin-square design. The SRT and DS score were recorded. Then, the raw mark will convert to a standard score by using Eq. (1) and Eq. (2).

$$Simple\ Reaction\ Test = Raw\ Score - Mean = Adjusted\ Score$$

$$z\ score = \frac{Adjusted\ score}{Standard\ deviation}$$

$$Standard\ Score = [z\ score(reverse) \times 10] + 50 \tag{1}$$

$$Digit\ Span\ Test = Raw\ Score - Mean = Adjusted\ Score$$

$$z\ score = \frac{Adjusted\ score}{Standard\ deviation}$$

$$Standard\ Score = [z\ score \times 10] + 50 \tag{2}$$

2.3 Data Analysis

Based on both the physical measurement and the thermal comfort satisfaction questionnaire, statistical analysis was performed. The significant relationship between thermal perception and the performance of the students was analyzed. Statistical analysis was performed by using Statistical Package for the Social Sciences (SPSS) software. Firstly, thermal perception and learning performance scores were tested for normal distribution by using the Shapiro-Wilk test. Secondly, the Pearson correlation coefficient was obtained to find the strength of the correlation between thermal perception and learning performance score.

3. Results

3.1 Average Physical Data for Three Days

Table 2 presents the total mean of physical measurement data of the investigated classroom for three days. The highest air temperature inside the classroom was 29.64℃ on the first day, the lowest was on day 2. The highest and lowest mean radiant temperature was 29.11℃ and 27.41℃ on day 1 and day 2, respectively. The highest air velocity was 0.66 m/s on day 1, the lowest was 0.58m/s on day 2. The highest relative humidity was on day 3, which was 85.88%, while the lowest was 78.38% on day 1. For outdoors, the highest air temperature was also on day 1, which was recorded at 30.37℃, and the lowest was 27.92℃ on day 2. The highest relative humidity was 70.65% on day 3, the lowest was 68.15% on day 2.

Table 2
Total mean of physical measurement data

Day	Total Mean 1	2	3
Air Temperature, °C	29.638	27.810	28.183
Mean Radiant Temperature, °C	29.113	27.405	27.673
Air Velocity, *m/s*	0.664	0.578	0.659
Relative Humidity, %	78.375	83.045	85.878
Outdoor Air Temperature, °C	30.365	27.917	28.390
Outdoor Relative Humidity, %	69.418	68.150	70.653

There were differences in parameter values during these three days. It is mainly due to the weather conditions of the day. The weather was hottest on the first day and coldest on the second day based on the observation and outdoor temperature measurement. Furthermore, because no radiant heating source was present in the classroom, the mean radiant temperature was slightly lower compared to air temperature. Moreover, it shows that there is a slight difference between indoor and outdoor parameters because of the sunlight effects outdoors.

3.2 Thermal Perception

Two thermal perception votes were investigated through the thermal comfort satisfaction questionnaire, which were the thermal sensation vote (TSV) and thermal preference vote (TPV).

3.2.1 Thermal Sensation Vote (TSV)

Table 3 presents the TSV results from three groups under different conditions. Students answered the question of how they felt about the temperature at the specific moment, as question no. 8 in the thermal comfort satisfaction questionnaire. Seven-point scale was used in TSV: (-3) very cold, (-2) moderate cold, (-1) slightly cold, (0) normal, (+1) slightly hot, (+2) moderate hot, (+3) very hot. When the speed of the fans was controlled at 18.0 m/s, 4 students felt slightly hot, and 6 students felt moderately hot. When the speed of the fans was controlled at 19.5 m/s, 4 students felt normal, and 5 students felt slightly hot. Out of 12 students, 3 students felt moderate cold, 4 students felt slightly cold, and 4 students felt normal when the speed of the fans was controlled at 21.0 m/s. The mean value of TSV for each speed of fans was obtained. At the speed of 18.0 m/s, the mean of TSV was 1.58, which indicated that students felt between slightly hot and moderately hot. While, when the speed of fans was controlled at 19.5 m/s, the mean value of TSV was 0.08, suggesting most of the students felt normal. The mean value of TSV was -0.75 when the speed of fans was set at 21.0 m/s, which means that students felt between normal to slightly cold. The average mean of TSV was 0.30, which indicated that students felt between normal to slightly hot in the classroom. The TSV result shows that thermal comfort condition can be influenced by the speed of fans, which means that the higher the air velocity, heat loss increased through convection and eventually affect the student's thermal sensation.

Table 3
TPV results

Speed of the fans (m/s)	Scale -3	-2	-1	0	+1	+2	+3	Mean
18.0	0	0	0	1	4	6	1	1.58
19.5	0	1	2	4	5	0	0	0.08
21.0	0	3	4	4	1	0	0	-0.75
Average:								0.30

3.2.2 Thermal Preference Vote (TPV)

Table 4 presents the TPV result from three groups under different conditions. Students answered the question of what they would prefer most to their prevailing environment, as question no. 13 in the thermal comfort satisfaction questionnaire. The seven-point scale was used in the TSV were: (-3) prefer very cold, (-2) prefer moderate cold, (-1) prefer slightly cold, (0) normal, (+1) prefer slightly hot, (+2) prefer moderate hot, (+3) prefer very hot. When the speed of the fans was controlled at 18.0 m/s, 8 students preferred moderate cold, and 4 students preferred slightly cold. When the speed of fans was controlled at 19.5 m/s, 2 preferred moderate cold, and 10 students preferred slightly cold. Out of 12 students, 7 preferred slightly cold and the other 5 students preferred no change or normal when the speed of fans was controlled at 21.0 m/s. The results clearly showed that the lower the fan speed, the students' preferences were on the cooler side of the vote. These were aligned with the results of TSV.

Table 4
TPV results

Speed of the fans, m/s	Scale -3	-2	-1	0	+1	+2	+3	Mean
18.0	0	4	8	0	0	0	0	-1.33
19.5	0	2	10	0	0	0	0	-1.17
21.0	0	0	7	5	0	0	0	-0.58
Average:								-1.36

3.3 Learning Performance Assessment
3.3.1 Simple Reaction Test (SRT)

When the speed of fans was controlled at 18.0 m/s, the highest score was 57.92. The highest standard score on the simple reaction test was 63.56 with 19.5 m/s fan speed. When the speed of fans was set at 21.0m/s, the highest score was 70.54. The mean standard score was 45.75, 48.56, and 55.68 for fan speed 18.0 m/s, 19.5 m/s and 21.0 m/s respectively. Figure 4 shows a positive trend for the means standard score of SRT with different fans' speeds. The result indicates the faster the fans' speed, the higher the reaction time score. Students performed better when they thermally comfort.

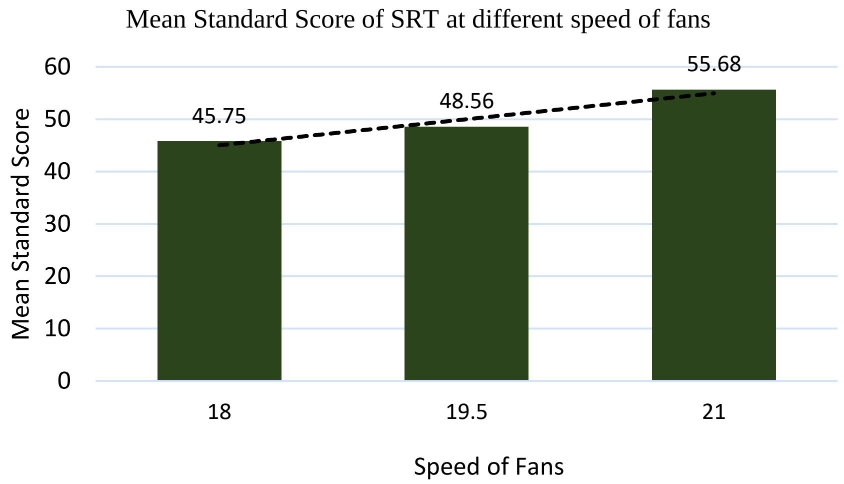


Fig. 4. Mean Standard Score of SRT at different fan's speed

3.3.2 Digit Span Test (DS)

This test requires the student to complete both a forward digit span and a backward digit span part. Both standard scores were combined. When the speed of fans was controlled at 18.0 m/s, the highest score was 60.67. The highest score on the digit span was 66.67 with 19.5 m/s and 21.0 m/s fans' speed. The average standard scores at 18.0 m/s, 19.5 m/s, and 21.0 m/s fan speeds were 43.67, 48.92, and 57.42, respectively. The results show a positive trend as shown in Figure 5, which indicates that the faster the fans' speed, the higher the standard score. These results were aligned with SRT results.

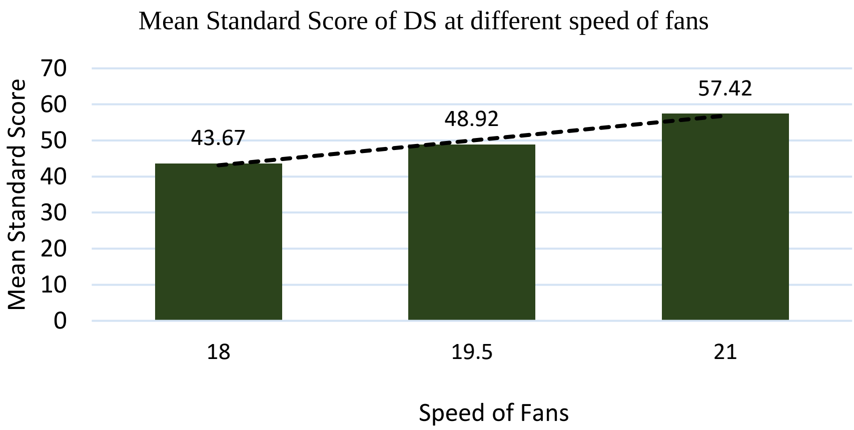


Fig. 5. Mean Standard Score of DS at different fans speed

3.3.3 Mean standard score for both test

Figure 6 presents the mean standard score for both the SRT and the DS. The standard score of both tests were added together and obtained as the mean score. The result shows that 21.0 m/s fans speed has the highest mean score among the three fans' speeds. While, when the fans' speed was controlled at 18.5 m/s, it obtained the lowest mean score.

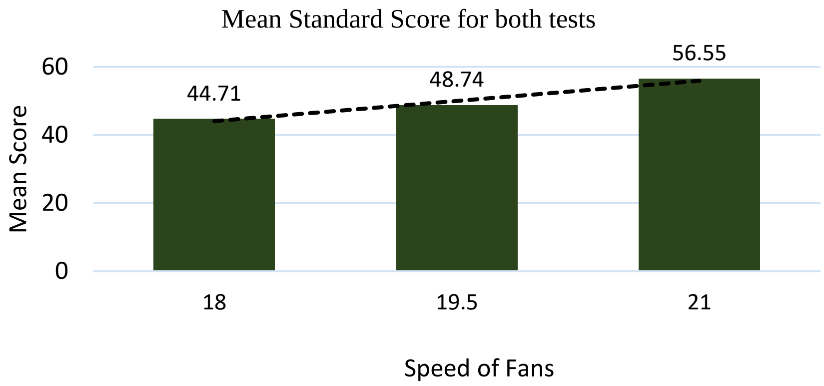


Fig. 6. Mean Standard Score for both tests

3.4 Statistical Analysis

3.4.1 Shapiro-Wilk test

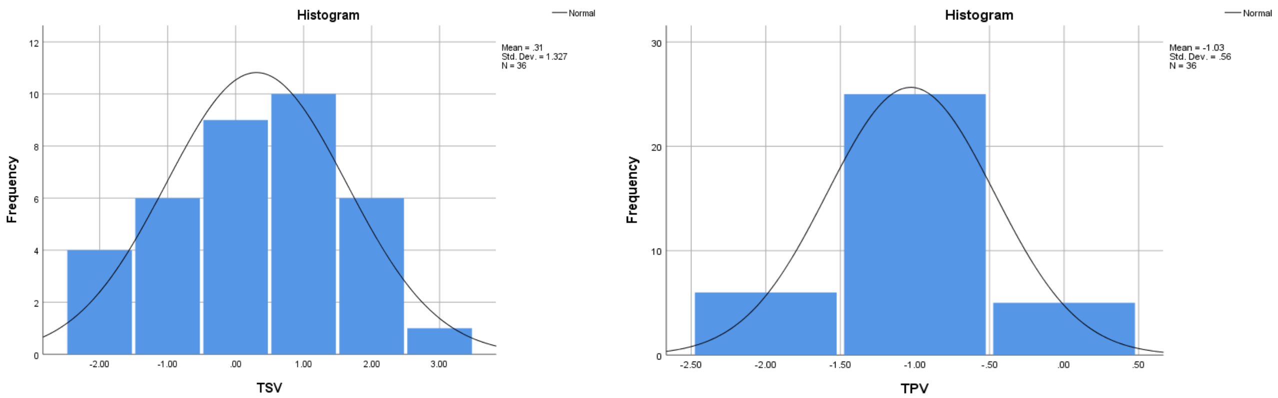
3.4.1.1 Thermal Perception Vote (TPV)

Table 5 shows the significant value of the Shapiro-Wilk test for thermal perception vote of TSV and TPV. The significant value of the Shapiro-Wilk test for TSV was 0.035, which was less than 0.05. It can conclude that the null hypothesis can be rejected and assume the variable was not normally distributed. The significance value of TPV was equal to 0, which means the null hypothesis was rejected and the test was statistically significant.

Table 5
The significant value of the Shapiro-Wilk test for thermal perception vote

Tests of Normality	Shapiro-Wilk		
	Statistic	df	Sig.
TSV	.935	36	.035
TPV	.732	36	.000

Figure 7 shows the histogram of the Shapiro-Wilk test for the thermal perception votes. By interpreting the histogram, the TPV distribution shows a normal distribution, the mean was -1.03. It means it was symmetric around the mean, indicating that data close to the mean occur more frequently than data further from it. TSV distribution shows a right-skewed distribution, the mean was 0.31, which means the mean is more than the median.



(a) (b)

Fig. 7. The Distribution graph of the Shapiro-Wilk test for (a) TSV, (b) TPV

3.4.1.2 Learning performance assessment

Table 6 shows the significant value of the Shapiro-Wilk test for learning performance assessment. The value of the significant normality test for Shapiro-Wilk was 0.058. It can be assumed that the data was normally distributed, and the null hypothesis cannot be rejected. Figure 8 shows the histogram of the normality test of learning performance assessment. It shows a right-skewed distribution, which means the mean was more than the median. Besides that, the learning performance distribution shows a narrow spread, the spread indicates that the variable was less consistent, and it might be due to lesser samples that have sufficient data points to adequately describe the data distribution.

Table 6
The significant value of the Shapiro-Wilk test for learning performance assessment

Tests of Normality	Shapiro-Wilk		
	Statistic	df	Sig.
Learning Performance Assessment	0.942	36	0.058

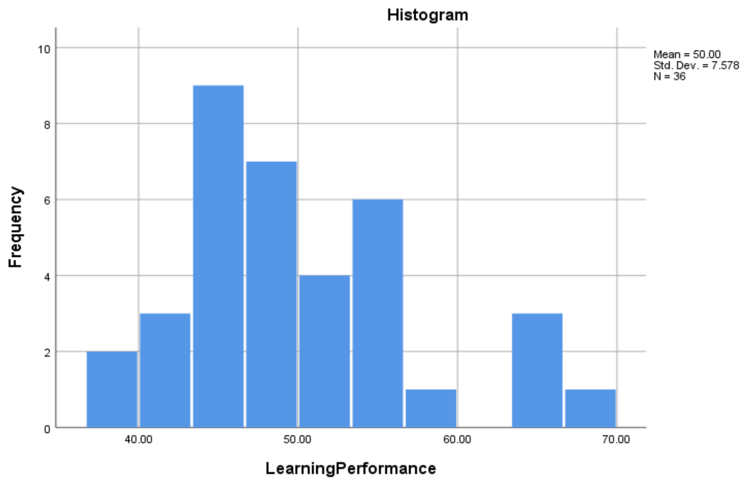


Fig. 8. The Distribution graph of the Shapiro-Wilk test for learning performance assessment

3.4.2 Correlation
3.4.2.1 Correlation relationship between TSV and learning performance assessment

Table 7 shows the Pearson correlation between TSV and learning performance assessment. The Pearson correlation value between TSV and learning performance assessment was -0.446. It indicates these two variables had moderate correlations. Then, the p-value was 0.006, which was lower than 0.05. It means the correlation was statistically significant and has strong evidence to reject the null hypothesis.

Table 7
Pearson correlation between TSV and learning performance assessment

Correlations			
		TSV	Learning Performance
TSV	Pearson Correlation	1	-.446**
	Sig. (2-tailed)		.006
	N	36	36
Learning Performance	Pearson Correlation	-.446**	1
	Sig. (2-tailed)	.006	
	N	36	36

Figure 9 presents the scatterplot of TSV and learning performance assessment. These two variables have a negative association, in general, as a TSV increase, learning performance decreases. When TSV was higher, which means students felt hot in the classroom, then, the learning performance score was lower.

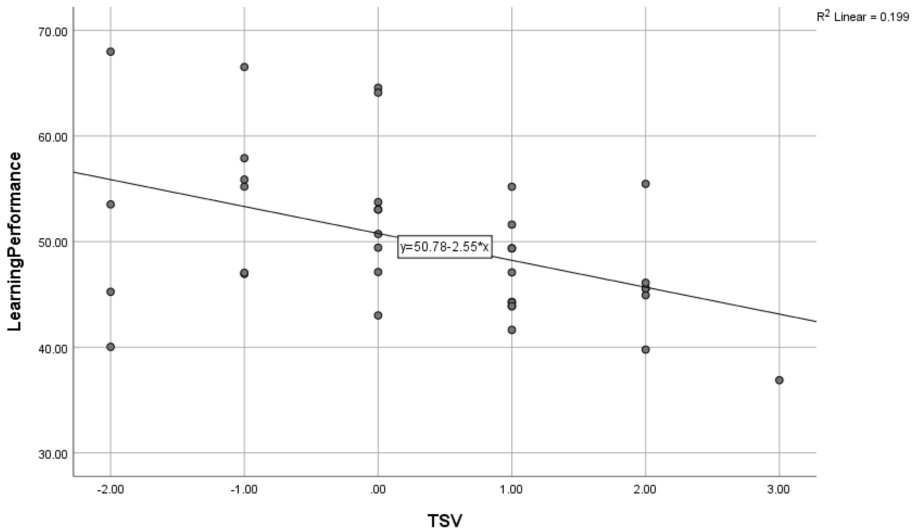


Fig. 9. Scatter plot of TSV and learning performance assessment

3.4.2.2 Correlation relationship between TPV and learning performance assessment

Table 8 shows the Pearson correlation between TPV and learning performance assessment. The Pearson correlation value between TPV and learning performance assessment was 0.350. It indicates these two variables had moderate correlations. Then, the p-value was 0.036, which was lower than 0.05. It means the correlation was statistically significant and has strong evidence to reject the null hypothesis.

Table 8
Pearson correlation between TPV and learning performance assessment

Correlations		TPV	Learning Performance
TPV	Pearson Correlation	1	.350*
	Sig. (2-tailed)		.036
	N	36	36
Learning Performance	Pearson Correlation	.350*	1
	Sig. (2-tailed)	.036	
	N	36	36

Based on the scatter plot of TPV and learning performance assessment that showed in Figure 10, these two variables were positively related because when TPV increases, learning performance assessment increases as well. The slope showed there was a weak relationship between the variables. The scatter plot shows a higher learning performance assessment at TPV of -1. When they vote to feel slightly cool, students tend to have higher performance scores.

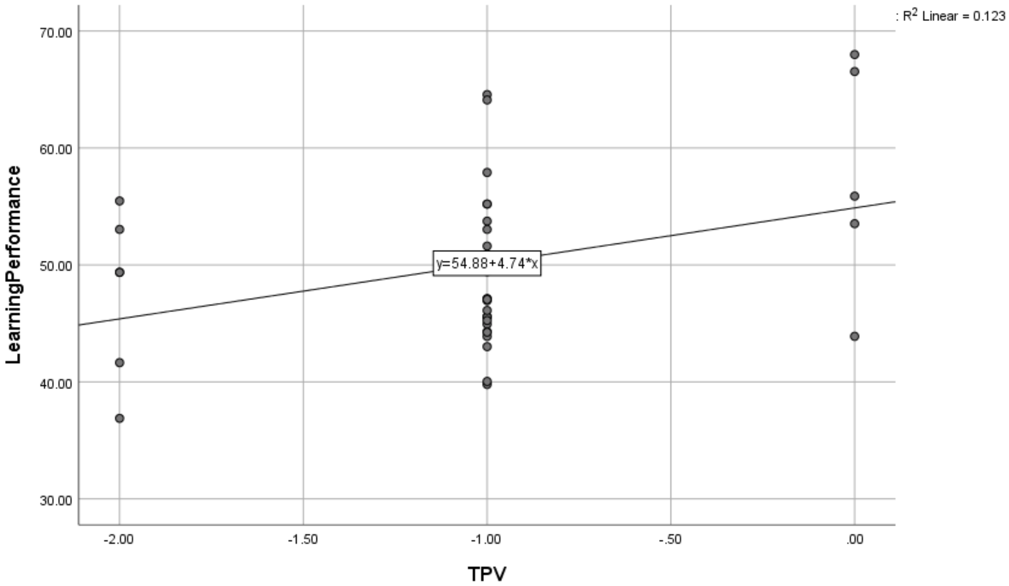


Fig. 10. Scatter plot of TPV and learning performance assessment

4. Conclusions

According to the result from the thermal comfort satisfaction questionnaire, the average mean of TSV was 0.30, which indicated that students felt between normal to slightly hot in the classroom. The fan speed can affect the air velocity in the classroom. Moving air in warm or humid conditions can increase heat loss through convection without any change in air temperature and eventually students felt colder. The mean value of TPV was -1.36 which was between (-2) preferring moderate cold, and (-1) preferring slightly cold conditions. These results revealed that the lower the fan speed, the more likely the students were to choose the cooler option. Besides that, based on the learning performance assessment, students perform better when the fan speed was increased. Students felt more at ease and performed better in the classroom when the airflow was higher, and the air temperature was cooler. Correlation analysis revealed a negative correlation between TSV and learning performance and a positive correlation between TPV and learning performance.

For future studies, some suggestions were proposed such as; the sample size need to be increased to get more significant data for learning performance. Moreover, a longer physical measurement duration was suggested to obtain more consistent and accurate data.

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