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Student Perception and Indoor Environmental Quality Assessment of Classrooms at UTAR

Hassan Youssouf[1], Khor Soo Cheen[1*], AbdulLateef Olanrewaju[1]

[1] Faculty of Engineering and Green Technology, Universiti Tunku Abdul Rahman, Kampar, Perak, Malaysia

* Corresponding Author: khorsc@utar.edu.my

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Abstract: *This study at Universiti Tunku Abdul Rahman (UTAR), Malaysia, investigated student perceptions of the classroom environment and thermal comfort within the Learning Complex, correlating subjective feedback with objective environmental measurements. The goal was to identify critical factors influencing student satisfaction, well-being, and academic performance. A student survey (n=68) revealed thermal comfort issues, particularly regarding temperature and ventilation. Environmental measurements were conducted, using a Particle Counter for fine particulate matter (PM2.5 and PM10) and a Heat Stress Tracker for temperature and humidity, across six classrooms in the Learning Complex. The results indicated alarmingly high PM2.5 levels, averaging 108.63 µg/m3 per classroom, more than three times the WHO-recommended threshold of 35 µg/m3. In contrast, PM10 levels complied with WHO guidelines. These high PM2.5 emissions are likely due to inadequate ventilation and filtration systems, suggesting an internal source of pollution, given the university's natural setting. The findings emphasise the urgent need to optimise ventilation systems and improve air filtration to ensure a healthier, more comfortable learning environment, directly addressing factors critical to student satisfaction and performance.*

Keywords: Classroom Environment; Indoor Air Quality (IAQ); Student Perception

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1. Introduction

The maintenance of university facilities, including classrooms, significantly impacts student well-being and academic performance. The Learning Complex, a significant academic building, faces challenges with thermal comfort, ventilation, and air quality. This study aimed to integrate student perceptions and objective environmental data to guide facility maintenance and improvement initiatives. The central question guiding this research was “What are the main determinants of student satisfaction regarding the maintenance of university facilities, and how do these factors impact their well-being and academic performance?”

The classroom environment is a critical factor influencing student health, well-being, and academic outcomes. Studies consistently show that students spend a significant portion of their day indoors, underscoring the paramount importance of the classroom environment. Thermal comfort is defined as the "condition of mind which expresses satisfaction with the thermal environment" (ISO 7730). It is a subjective response determined by a combination of personal and environmental factors.

The Malaysian context in which UTAR is located is characterised by a hot, humid tropical climate. This necessitates a focus on studies specific to similar regions. The literature on indoor environments highlights the critical role of IEQ parameters, particularly in learning spaces such as classrooms. The study focuses on three key physical parameters, which are established determinants of indoor quality: Thermal Comfort, Air Quality, and Particulate Matter (PM).

1.1 Study Objectives

- Evaluate student perceptions of the current state of facilities, focusing on thermal comfort, ventilation, and cleanliness.
- Identify critical factors influencing student satisfaction with facility maintenance.
- Propose actionable recommendations based on student feedback and data to improve facility quality.

2. Literature Review

2.1 IEQ as a Determinant of Learning Performance

A substantial body of research supports a correlation between a satisfactory Indoor Environmental Quality (IEQ) and improved student performance. Poor IEQ, encompassing factors such as thermal discomfort, inadequate lighting, high noise levels, and poor indoor air quality (IAQ), can lead to distractions, reduced concentration, decreased cognitive function, and increased absenteeism (Lee et al., 2012; Lan et al., 2021).

Optimal environmental conditions, particularly temperature, have been linked to enhanced emotional and cognitive states. Studies indicate that thermal discomfort, whether too warm or too cold, can negatively impact memory, typing performance, and overall task performance (Abbasi et al., 2019; Wang et al., 2022).

While primarily focused on environmental factors, the physical characteristics of classrooms, such as size, distribution, and furniture quality, are also reported to influence student engagement and performance, forming part of the broader perception of the classroom environment (Rands & Gansemer-Topf, 2017).

Developed by Fanger (1970), the PMV/PPD (Predicted Mean Vote and Predicted Percentage of Dissatisfied) model is the most widely recognised standard for defining thermal comfort and is often embedded in standards such as those of the American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE). This model, based on steady-state heat transfer theory, calculates an index that predicts the mean thermal sensation of a large group. The PMV value is a function of six variables:

- Personal Factors: Metabolic rate and clothing insulation.
- Environmental Factors: Air temperature, mean radiant temperature, air velocity, and relative humidity.

In many studies, the PMV model has been observed to overpredict occupants' thermal responses, especially in naturally ventilated (NV) buildings in warm climates, where people tend to tolerate a broader range of temperatures than the standard suggests (Rivera et al., 2019).

Research conducted in tropical and subtropical educational settings (e.g., Singapore, Malaysia) frequently finds that students are comfortable at higher temperatures than those prescribed by international standards (e.g., ASHRAE 55), which were often developed for temperate climates or air-conditioned office environments.

Studies in the tropics have suggested that a neutral temperature (where students feel neither warm nor cool) often falls around 27°C to 29°C, with acceptable temperature ranges extending beyond 29°C (Kwok, 1997; Castilla et al., 2017). This is a crucial finding for assessing UTAR students' subjective perceptions.

In hot, humid climates, air velocity is often identified as the most critical factor influencing thermal perception and comfort. Increased air movement, particularly via fans, has been shown to improve student comfort and, in some cases, to correlate positively with better learning performance by enhancing evaporative cooling (Wang et al., 2022). Perceiving air movement, rather than just temperature, is key to achieving satisfaction in these environments.

2.2 Facilities Maintenance and Student Satisfaction in University Settings

The maintenance and quality of university facilities are presented as having a direct and crucial role in students' daily experience and academic performance. University facilities encompass classrooms, libraries, leisure spaces, and sports facilities, and their condition directly impacts student well-being. Institutions like UTAR are committed to improving the quality of facilities. Therefore, considering the perceptions and needs of the students, the primary users, is essential for guiding maintenance efforts and improvement initiatives.

The study focuses particularly on the Learning Complex at UTAR. The central issue identified is understanding the key factors that influence student satisfaction with facility maintenance. The key elements impacting this perception are thermal comfort, ventilation, and cleanliness. Thermal comfort, defined by classroom temperature and humidity levels, is a crucial factor for concentration and student well-being. Low temperatures and humidity can negatively affect indoor air quality and occupant health.

Indoor air quality is a key determinant of comfort and health in enclosed spaces. The report specifically focuses on fine particle emissions, or particulate matter (PM), which are minute solid or liquid particles suspended in the air (WHO, 2021). These particles are categorised by size:

- PM10 (less than 10 microns)
- PM2.5 (less than 2.5 microns)
- PM1 (less than 1 micron)

These particles can originate from external sources, such as vehicle emissions and industrial processes, or from internal issues, such as inadequate ventilation systems or filters. For comparison, a human hair has a diameter of around 70 microns, highlighting the minute size of these particles (See Fig. 1). They originate from sources such as vehicle emissions, industrial processes, and inadequate ventilation systems, including those that require filter changes or system upgrades.

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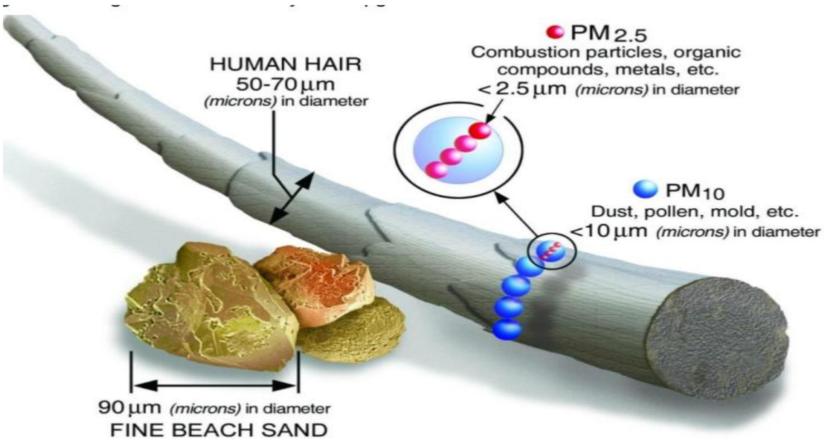

Figure 1: Highlighting the minute size of particulate matter (PM)

The health implications of PM are profound, particularly for PM2.5 and PM1. While the upper respiratory tract often filters coarse particles (PM10), finer particles can penetrate the lower respiratory tract, the alveoli, and even enter the bloodstream, leading to respiratory and cardiovascular issues. The concentration of PM is measured in µg/m^3, with countries setting acceptable thresholds based on guidelines from organisations such as the World Health Organisation (WHO), which generally recommends that PM2.5 levels remain below 35µg/m^3.

This situation poses serious health risks. The "fine particulate impact indicator" reflects an increase in disease incidence as emissions of fine particles rise. Fine particles exhibit varying levels of toxicity depending on their size, chemical composition, and tendency to aggregate with other pollutants. While the upper respiratory tract filters out coarse particles (PM10), fine particles can penetrate the lower respiratory tract, alveoli, and even enter the bloodstream, leading to various health complications.

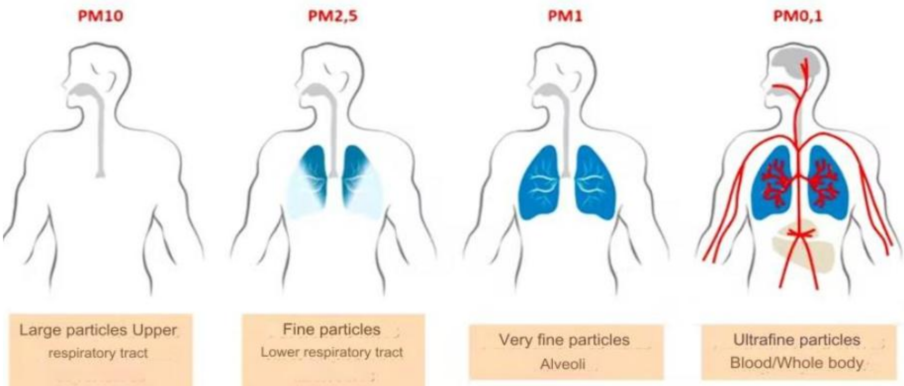

Figure 2: Fine Particulate Impact Indicator

This research is driven by the challenge of determining which environmental factor has the most significant direct impact on students' overall satisfaction, academic comfort, and personal well-being. By addressing this, the university can contribute to efficient resource management by prioritising maintenance efforts and enhancing student engagement (See Fig. 2).

3. Research Methodology

The study aims to establish a link between objective environmental data (temperature, humidity, and fine particle concentration) and students' subjective perceptions, thereby providing a comprehensive view of environmental conditions. A combination of methods is generally recommended, aligning with the principles of Post-Occupancy Evaluation (POE). By combining this data, the research is well-positioned to offer UTAR valuable, actionable insights to prioritise maintenance and improve the overall learning environment.

3.1 Environmental Measurements

Following the survey, quantitative data were gathered using two specialised instruments.

i. Particle Counter: Used to measure delicate particulate matter, PM2.5 and PM10, to assess indoor air quality.
ii. Heat Stress Tracker: Used to measure temperature and humidity for assessing thermal comfort.

Measurements were conducted across six classrooms (two on each of the three floors) to ensure representativeness. Within each room, nine measurement points were established (three at the front, three in the middle, and three at the back) to track condition variations by seating location. A "zero filter" calibration was performed on the particle counter before each session to ensure accurate readings.

The methodology for measuring PM concentration relies on a Particle Counter that employs light-scattering technology. This technique uses a laser beam to detect scattered light from particles in a sampled airflow, enabling the counting and sizing of particulate matter. Furthermore, the calibration procedures for such instruments are governed by standards like ISO 21501-4 to ensure measurement accuracy.

3.2 Preliminary Results

Before using the particle counter, it was essential to calibrate it using a "zero filter" to reset all the values to zero. This step ensured that the readings started from a clean slate, free of any interference from previous data. The calibration is to be performed in a different classroom before each session to maintain accurate measurements. Resetting the device with the zero filter after each room change ensured that the collected data reflected the actual conditions of each classroom, without carryover from the previous environment.

3.3 Student Survey

The study aims to examine students' subjective perceptions of the classroom environmental conditions at Block B of the Learning Complex. This building is primarily used for tutorial sessions and small-scale lectures. The research is positioned to provide UTAR with valuable, actionable insights for prioritising maintenance. A questionnaire was designed and distributed to capture student perceptions of environmental conditions, particularly air quality and thermal comfort, in the Learning Complex classrooms. The survey used simple random sampling to ensure unbiased data collection and more reliable, representative results. In addition, the survey period was short, lasting only approximately a month, and a total of 68 responses were collected for this small-scale study.

4. Research Findings

4.1 Thermal Comfort Perceptions

The responses related to thermal comfort show a high degree of perceived temperature stability, yet a significant portion of students experience temperature variations. According to Fig. 3, 92% of students reported that the classroom temperature was generally stable during classes. This suggests that the temperature, once set, does not fluctuate drastically. Despite the perception of high stability, a combined 88% of students often (23%) or sometimes (65%) experience temperature variations throughout the day.

This contrast might imply that, while the temperature remains stable within a single class, students perceive variations when moving between different times of day (e.g., morning vs afternoon) or between different classrooms (see Fig. 4). The system may be operating reliably. Still, the perceived comfort level varies throughout the day, possibly due to external conditions or fixed setpoints that are not ideal at all times.

4.2 Air Quality and Ventilation Perceptions

Student ratings of air quality are generally acceptable, but issues with discomfort, odours, and ventilation adequacy are noted. Based on the air quality rating (Fig. 5), the vast majority of students rate the air quality as Acceptable (73%) or Good (23%), for a total of 96%. Only 3% rated it as "Very good," and 0% rated it as "Poor" or "Very poor". While the overall rating for breathing problems or discomfort is positive (Fig. 6), 26% of students often (11%) or sometimes (15%) experience breathing problems or discomfort related to air quality. Half of the respondents (50%) reported never experiencing discomfort.

A significant proportion of students (30%, 11% often and 19% sometimes) report persistent unpleasant odours (Refer to Fig. 7). However, the majority report rarely (38%) or never (30%) experiencing odours. Most students feel the classrooms are well-ventilated sometimes (65%) or always (26%), totalling 91% (Refer to Fig. 8). When asked about the adequacy of the ventilation systems (windows, AC, etc.), the responses are split: 46% say Yes, and 46% have No opinion. Only 7% say No. (Refer to Fig. 9)

While most students do not rate air quality as poor, the presence of discomfort and unpleasant odours suggests that the ventilation system's performance, while generally acceptable, may have intermittent or localised issues or may not meet the highest comfort standards for all students. The high number of "No opinion" responses regarding the system's adequacy suggests a lack of information or certainty among students about its technical performance.

4.3 Humidity Perceptions

The humidity level is perceived chiefly as comfortable, though some students report discomfort. According to Fig. 10, 75% of students rate the humidity level as Comfortable. 19% rated it as Humid, while only a small percentage rated it as Dry (3%) or Very Humid (3%). A combined 33% of students often (3%) or sometimes (30%) feel discomfort related to humidity (dry skin, dampness, etc.). The majority rarely (38%) or never (26%) experience discomfort (see Fig. 11). Humidity levels are generally well managed, aligning with a "Comfortable" rating for most. The reported discomfort among about a third of students, notably the 30% who feel it "sometimes," suggests that humidity levels may occasionally drift outside the comfort zone.

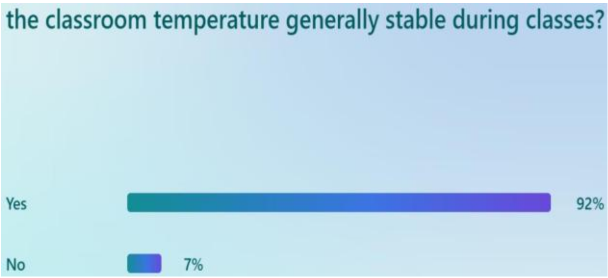

Figure 3: Temperature Stability

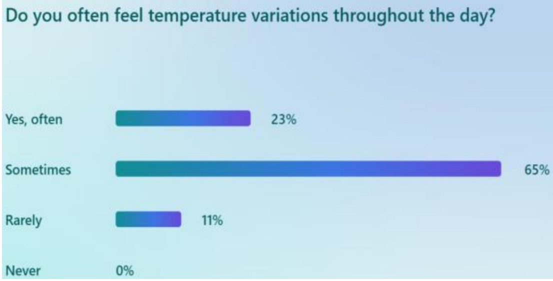

Figure 4: Temperature Variations

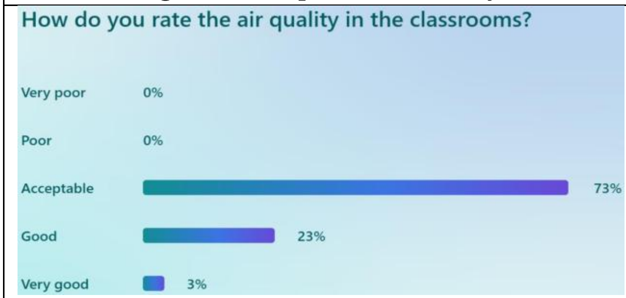

Figure 5: Air Quality Rating

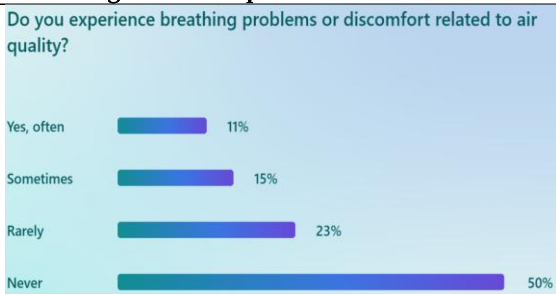

Figure 6: Breathing Problems/Discomfort

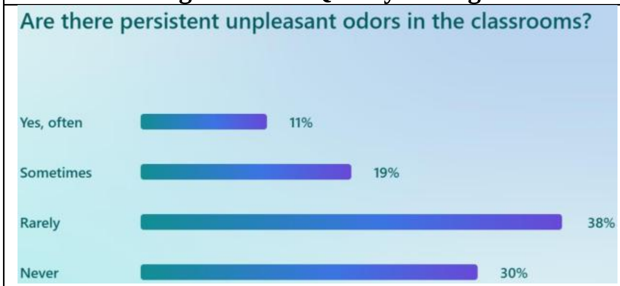

Figure 7: Persistent Unpleasant Odours

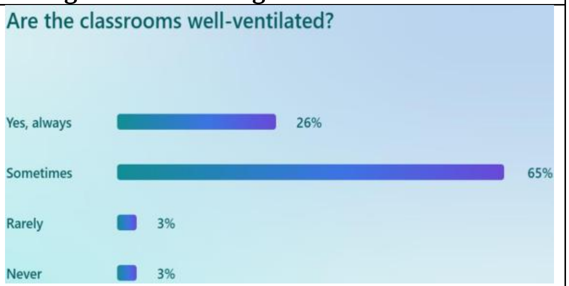

Figure 8: Classroom Ventilation

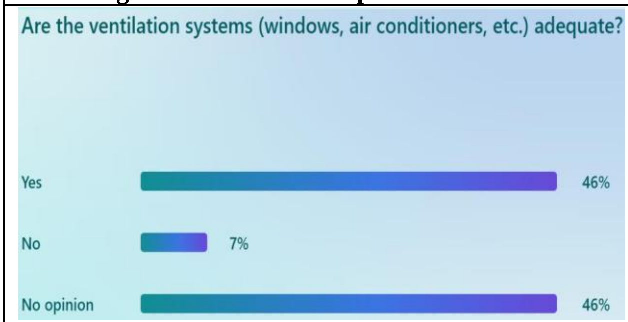

Figure 9: Ventilation Adequacy

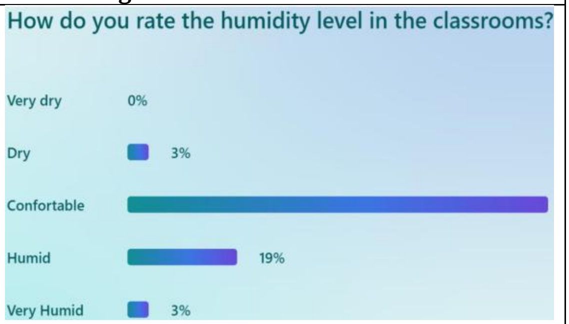

Figure 10: Humidity Level Rating

Figure 11: Discomfort Related to Humidity

Based on the collected responses, several thermal comfort issues have been identified in the classrooms, particularly regarding temperature and humidity levels. Some students specifically requested a temperature reduction and a change to the ventilation system to enhance their comfort during classes. This feedback highlights the importance of addressing these factors to improve the overall learning environment. Building on the insights gained from the survey responses, the measurement phase to obtain quantitative data regarding the classroom environment proceeded. This involved assessing the physical parameters of temperature, humidity, and particulate matter in the classrooms. Employing two specialised instruments, a Particle Counter and a Heat Stress Tracker, aims to gather precise data that corroborates student feedback and identifies specific areas for improvement.

The survey results indicated that classroom temperature was generally stable during classes (92% Yes). However, 23% of students reported often experiencing temperature variations throughout the day, and 65% reported experiencing them sometimes. Subjective student feedback indicates severe systemic overcooling, with occupants perceiving the environment as "very cold". This operational error leads directly to massive energy waste and paradoxical occupant behaviour, such as opening windows to introduce warm air.

4.4 Environmental Measurement Results

The measurements revealed significant variations in particulate matter and thermal comfort across classrooms and seating areas. For the analysis of Classroom B009A, it is important to note that this room is the largest of the six studied, nearly double the size of a regular classroom. It also has the most windows 7 in total, allowing for greater air circulation. This explains why the fine particle emissions in this room were the lowest. Specifically, the average concentration for 2.5 µm particles was 62.67 µg/m³, and for 10 µm particles, the average was 2.67 µg/m³ (see Table 1).

Table 1: Analysis of Classroom B009A

Classeroom B009A	Heat Stress Tracker		Particle Counter					
	Temperature	**Humidity**	**0.3µm**	**0.5µm**	**1µm**	**2.5µm**	**5.0µm**	**10µm**
Right 1st rang	25.5	66.6	14662	3847	647	47	3	1
Middel 1st rang	25.7	60.3	13450	3481	531	58	5	3
Left 1st rang	25.8	65.8	13756	3360	540	79	5	3
Right 2nd rang	25.2	63.7	14523	3743	484	45	1	1
Middel 2nd rang	26.2	57.8	1427	3659	500	73	7	2
Left 2nd rang	24.8	59.6	13965	3585	512	83	11	3
Right 3th rang	24.3	61.5	13494	3874	534	74	11	7
Middel 3th rang	24.2	57.5	15055	3856	505	36	4	2
Left 3th rang	24.1	60.2	14036	3520	358	47	11	7
moyenne B009A	Temperature	Humidity	0.3µm	0.5µm	1µm	2.5µm	5.0µm	10µm
1st rang	25.75	63.05	13956.00	3562.67	572.67	61.33	4.33	2.33
2nd rang	25.40	60.37	9971.67	3662.33	498.67	67.00	6.33	2.00
3th rang	24.20	59.73	12083.33	3706.17	482.17	59.67	7.50	3.67

In classroom B207 (lab5), there are six windows, most of which are on the right side of the room. This results in better airflow and lower fine particle emissions in that area. However, at the front and back rows, the concentration of fine particles is higher, reaching 111 µg/m³ and 103 µg/m³ for 2.5 µm particles, and four µg/m³ and six µg/m³ for 10 µm particles. This is due to direct exposure to ventilation systems. In contrast, particle levels are lower in the middle, with 89 µg/m³ for 2.5 µm particles and about three µg/m³ for 10 µm particles, as the area is farther from the air vents (see Table 2).

Table 2: Analysis of Classroom B207

Classroom B207 (lab5)	Heat Stress Tracker		Particle Counter					
	Temperature	**Humidity**	**0.3µm**	**0.5µm**	**1µm**	**2.5µm**	**5.0µm**	**10µm**
Right 1st rang	23.9	55.3	20039	5559	685	94	7	2
Middel 1st rang	23.2	53.5	21246	5767	848	111	15	4
Left 1st rang	23	56.5	20837	5763	748	107	8	3
Right 2nd rang	22.8	58	20751	5928	691	85	7	2
Middel 2nd rang	22.4	55.6	19994	6196	791	89	11	3
Left 2nd rang	22.3	56.3	19731	5839	764	120	10	6
Right 3th rang	23.3	60.7	19302	5729	886	75	9	4
Middel 3th rang	23.2	52.9	20277	5670	761	103	10	6
Left 3th rang	23	57.4	20090	5321	781	81	9	4
moyenne B207	Temperature	Humidity	0.3µm	0.5µm	1µm	2.5µm	5.0µm	10µm
1st rang	23.37	55.10	20707.33	5696.33	760.33	104.00	10.00	3.00
2nd rang	22.50	56.63	20158.67	5987.67	748.67	98.00	9.33	3.67
3th rang	23.17	57.00	19889.67	5573.33	809.33	86.33	9.33	4.67

In classroom B004A, the highest humidity is observed, averaging 72%. This can be explained by the fact that it has the fewest windows and the smallest surface area, which means humidity builds up more easily due to the heat and limited air circulation. Additionally, the concentration of fine particles is relatively high in this room, likely due to the reduced airflow and ventilation (see Table 3).

Table 3: Analysis of Classroom B004A

Classeroom B004A	Heat Stress Tracker		Particle Counter					
	Temperature	**Humidity**	**0.3µm**	**0.5µm**	**1µm**	**2.5µm**	**5.0µm**	**10µm**
Right 1st rang	24.8	72.4	23334	6850	1092	154	25	15
Middel 1st rang	24.8	71.7	25442	7219	1167	109	20	16
Left 1st rang	24.8	71.5	22556	6391	1021	108	16	6
Right 2nd rang	25	70.9	23194	6473	1093	115	22	6
Middel 2nd rang	24.9	72.7	24970	6801	995	140	18	8
Left 2nd rang	25	75.1	24802	6815	885	114	18	10
Right 3th rang	25	70.9	23802	6932	1079	116	23	7
Middel 3th rang	25.1	73	23107	6366	1040	137	15	7
Left 3th rang	25	70	22996	6669	1051	106	19	9
moyenne B004A	Temperature	Humidity	0.3µm	0.5µm	1µm	2.5µm	5.0µm	10µm
1st rang	24.80	71.87	23777.33	6820.00	1093.33	123.67	20.33	12.33
2nd rang	24.97	72.90	24322.00	6696.33	991.00	123.00	19.33	8.00
3th rang	25.03	71.30	23301.67	6655.67	1056.67	119.67	19.00	7.67

For Classroom B101B, it is clear that the area with the most windows is where there are the lowest emissions of fine particles. It can also be observed that the middle of the room has lower results because it is farther from the air inlets. Generally, it is warmer in the front row, averaging 26.93°C, because the wall in front of it connects directly to another classroom, retaining heat. In contrast, the wall near the back row, which typically averages 23.77°C, faces the outside, allowing greater heat loss through thermal transmittance, especially around the windows (see Table 4).

Table 4: Analysis of Classroom B101B

Classroom B004A	Heat Stress Tracker		Particle Counter					
	Temperature	**Humidity**	**0.3µm**	**0.5µm**	**1µm**	**2.5µm**	**5.0µm**	**10µm**
Right 1st rang	24.8	72.4	23334	6850	1092	154	25	15
Middel 1st rang	24.8	71.7	25442	7219	1167	109	20	16
Left 1st rang	24.8	71.5	22556	6391	1021	108	16	6
Right 2nd rang	25	70.9	23194	6473	1093	115	22	6
Middel 2nd rang	24.9	72.7	24970	6801	995	140	18	8
Left 2nd rang	25	75.1	24802	6815	885	114	18	10
Right 3th rang	25	70.9	23802	6932	1079	116	23	7
Middel 3th rang	25.1	73	23107	6366	1040	137	15	7
Left 3th rang	25	70	22996	6669	1051	106	19	9
moyenne B004A	Temperature	Humidity	0.3µm	0.5µm	1µm	2.5µm	5.0µm	10µm
1st rang	24.80	71.87	23777.33	6820.00	1093.33	123.67	20.33	12.33
2nd rang	24.97	72.90	24322.00	6696.33	991.00	123.00	19.33	8.00
3th rang	25.03	71.30	23301.67	6655.67	1056.67	119.67	19.00	7.67

In room B209A, measurements indicated the highest levels of fine particle emissions among the classrooms studied. The average concentration of particles measuring 2.5 µm was 170.67 µg/m³, while that of particles measuring 10 µm was 9.33 µg/m³. This elevated level of emissions could be attributed to poor ventilation and insufficient airflow, underscoring the need to address these issues to improve classroom air quality (see Table 5).

Table 5: Analysis of Classroom B209A

Classeroom B209A	Heat Stress Tracker		Particle Counter					
	Temperature	**Humidity**	**0.3µm**	**0.5µm**	**1µm**	**2.5µm**	**5.0µm**	**10µm**
Right 1st rang	25.6	59.4	34661	10285	1557	197	32	7
Middel 1st rang	24.9	59	34962	10246	1753	200	21	12
Left 1st rang	24.1	61.3	33305	9749	1697	153	15	7
Right 2nd rang	23.3	64.3	33839	9147	1340	148	19	6
Middel 2nd rang	23.3	61.5	33507	9531	1651	154	16	15
Left 2nd rang	23.7	61	34528	10104	1652	209	30	12
Right 3th rang	23.6	62	28679	8856	1489	153	15	4
Middel 3th rang	23.1	64.5	31844	9279	1374	163	14	9
Left 3th rang	23.3	64.5	31344	8967	1482	159	21	12
moyenne B209A	Temperature	Humidity	0.3µm	0.5µm	1µm	2.5µm	5.0µm	10µm
1st rang	24.87	59.90	34309.33	10093.33	1669.00	183.33	22.67	8.67
2nd rang	23.43	62.27	33958.00	9594.00	1547.67	170.33	21.67	11.00
3th rang	23.33	63.67	30622.33	9034.00	1448.33	158.33	16.67	8.33

The observations revealed significant variations in indoor air quality across different classrooms in the Learning Complex. Classroom B207 (lab5), the largest with seven windows, had the lowest particulate emissions, while B209A exhibited the highest emissions at 170.67 µg/m³ for 2.5 µm particles. Additionally, B004A showed an average humidity level of 72% due to limited air circulation. These results highlight the need for improved ventilation and further investigation into sources of indoor pollution.

Based on survey results and classroom fine particle emission measurements, it been observed that PM2.5 emissions are abnormally high, exceeding the WHO (World Health Organisation) recommended threshold of 35 µg/m³. In fact, we found an average level of 60-130 µg/m³ in the UTAR classrooms, with an average of 108.63 µg/m³ per classroom, which is more than three times the recommended limit.

Regarding PM10, to comply with the WHO-recommended threshold of 18 µg/m³, with an average of 5.95 µg/m³ and a maximum of 15 µg/m³ in the classrooms. This means there are fewer particles of 10 µm in the classrooms, suggesting that ventilation filters block them more easily. In contrast, the 2.5 µm particles can pass more easily through filtration systems, contributing to higher PM2.5 levels in indoor air.

4.5 Fine Particulate Matter (PM2.5 and PM10)

The average concentration of (PM2.5) across the studied classrooms ranged from 60 to 130µg/m³, with a high average of 108.63µg/m³ per classroom. This average is more than three times the World Health Organisation (WHO)- recommended threshold of 35 µg/m³ for PM2.5. The highest (PM2.5) concentration was recorded in Classroom B209A at 170.6µg/m³.

The largest room, B009A, with seven windows, had the lowest (PM2.5) emissions at 62.67µg/m³. In contrast, (PM10) levels complied with the WHO-recommended threshold of 18 µg/m³, with an average of 5.95 µg/m³. This suggests that ventilation filters more easily block 10µg/m³ particles, while the smaller 2.5 µg/m³ particles pass through, contributing to higher indoor (PM2.5) levels.

4.6 Humidity and Thermal Comfort

Classroom B004A had the highest humidity, averaging 72%, attributed to its small size and limited air circulation (fewest windows). In Classroom B101B, the front row was warmer (26.93°C) due to heat retention from a neighbouring classroom wall, while the back row was cooler (23.77°C) due to the wall facing the outside.

The alarmingly high (PM2.5) levels pose serious health risks, as fine particles can penetrate deep into the lungs and bloodstream, potentially causing respiratory and cardiovascular issues. Given UTAR's location in a natural setting, the source of these high emissions is likely internal, stemming from the ventilation systems and their filters.

5. Conclusion and Recommendations

The study successfully combined student perception data with objective environmental measurements to evaluate the classroom environment in the UTAR Learning Complex. While most students rated the air quality as acceptable, the objective measurements of fine particulate matter, especially PM2.5, revealed a significant, alarming issue with indoor air quality. The average PM2.5 concentration of 108.63µg/m³ substantially exceeds WHO guidelines.

Based on these initial results, several recommendations can be proposed to improve the environmental conditions in the Learning Complex. These include improving the ventilation systems, regularly servicing air filters, and reconfiguring seating arrangements to enhance both air quality and thermal comfort throughout the classrooms. Ongoing data analysis will provide further insights, but early findings already highlight the importance of maintaining proper indoor air quality and thermal regulation to support students' comfort and performance.

The high levels of fine particles observed in the classrooms can be attributed to the ventilation systems and their filters. Since the university in Kampar is located in a natural setting, surrounded by lakes and vegetation, airborne particle emissions are likely to originate mainly within the buildings. Therefore, it is essential to examine the quality and efficiency of ventilation systems to identify the source of the fine particles in classrooms.

Based on these findings, the following recommendations are proposed to improve the learning environment. Urgent examination and upgrade of the ventilation systems are necessary to address the high PM2.5 levels and optimise ventilation. Air filters must be regularly serviced or replaced to ensure they effectively block fine particles, particularly PM2.5. The improvements to air circulation are needed to mitigate high humidity in rooms like B004A.

Additionally, implement measures to ensure uniform thermal comfort across all seating areas, such as adjusting the air conditioning to mitigate temperature differences between the front and back rows. Consider reconfiguring seating in specific classrooms to improve air quality and thermal comfort for all students.

Addressing these issues is critical for improving student comfort, satisfaction, and ultimately, academic performance. These concerning values are primarily attributed to inadequate ventilation systems, particularly given that the university is situated in a pristine natural environment. The findings underscore the need to optimise ventilation systems to ensure a healthy, comfortable learning environment. This research emphasised environmental health issues and the potential health impacts on building occupants.

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Conflict of Interest Statement
The authors declare no conflicts of interest regarding the publication of this study.

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