

Real-Time IoT-Based Lecture Room Occupancy and Indoor Air Quality Monitoring System

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Abstract

A comfortable and healthy lecture room environment is essential for supporting student well-being and enhancing learning performance. However, manual monitoring of student attendance and indoor air quality is often inadequate. Unstable temperatures, poor ventilation, and elevated carbon dioxide (CO₂) levels can negatively impact comfort, health, and energy efficiency. To address this issue, this project proposes an IoT-based system that continuously monitors student presence and key environmental parameters like temperature, humidity, and CO₂ levels. The system provides a low-cost, automated solution that can be integrated into existing facility management tools. It uses an ESP32 microcontroller with PIR sensors, an SHT40 sensor for temperature and humidity, and an MQ135 sensor for gas detection. Real-time data is visualized through the Blynk mobile app and logged in Google Sheets for analysis. Target users include facility managers and university administrators seeking data-driven approaches to optimize indoor conditions. Two lecture rooms were monitored concurrently to evaluate performance. Results indicated that Bilik Kuliah 5 maintained acceptable environmental conditions, while Bilik Kuliah 6 exhibited higher temperatures and gas levels exceeding comfort thresholds. These findings highlight the system's ability to identify areas needing improved ventilation. In conclusion, the system successfully achieved its objectives by promoting safer, healthier, and more energy-efficient learning environments. This project showcases the practical potential of IoT in improving educational facility management.

1. Introduction

Indoor environmental quality has emerged as a significant concern in recent years, particularly within educational institutions, where both students and lecturers spend substantial time in enclosed spaces. Among the various aspects of indoor comfort and safety, indoor air quality (IAQ) is one of the most critical components. Poor IAQ, often characterized by elevated carbon dioxide (CO₂) levels, temperature fluctuations, and insufficient ventilation, has been linked to a range of adverse outcomes, including fatigue, lower concentration, diminished academic performance, and increased absenteeism among students [1][2]. As individuals increasingly spend time indoors, particularly in learning environments, the imperative to create safe and comfortable settings has become even more critical.

Monitoring and managing indoor air quality and room occupancy in real time is vital for fostering healthy, productive, and energy-efficient learning environments. Research indicates that factors such as temperature, humidity, ventilation rate, and CO₂ concentration are directly related to learning efficiency and cognitive performance [3][4][5]. Overcrowded classrooms and prolonged class durations can lead to elevated CO₂ levels and thermal discomfort, both of which adversely affect student well-being [6][7]. As educational institutions strive to achieve sustainable development goals and enhance academic outcomes, the integration of Internet of Things (IoT) technologies offers a timely and effective solution to these challenges through smart, real-time monitoring.

Despite advancements in IoT and environmental sensing technologies, many schools and universities, particularly in developing regions, continue to rely on manual attendance tracking and outdated HVAC systems that lack real-time responsiveness and precision. These conventional systems are incapable of adapting to the dynamic conditions of classrooms and fail to provide actionable data necessary for optimizing ventilation and occupancy [8][9]. Consequently, poorly ventilated and overcrowded classrooms persist as a significant issue [10].

Currently, there exists a gap in the implementation of integrated systems capable of simultaneously monitoring both room occupancy and IAQ, allowing for real-time analysis and interventions [9]. If this gap remains unaddressed, students and educators may continue to experience discomfort, health risks, and compromised learning experiences [8][10]. Conversely, if successfully implemented, such a system could empower universities to proactively manage classroom environments, resulting in improved health standards and enhanced energy efficiency across campuses [9].

The objective of this study is to design and evaluate a real-time IoT-based monitoring system that detects lecture room occupancy and measures essential environmental parameters, including temperature, humidity, and CO₂ concentration. This system aims to deliver reliable data for assessing indoor air quality and space utilization, facilitating timely interventions that enhance classroom comfort, safety, and energy management

2. Methodology

This section outlines the systematic process used to develop and implement the real-time IoT-based monitoring system. The methodology consists of four main components: materials selection, sensor integration and programming, IoT cloud configuration for real-time visualization, and system characterization for performance evaluation.

2.1 Methods and Materials

The main hardware components used in this project include the ESP32 microcontroller, PIR motion sensors, an SHT40 temperature and humidity sensor, and the MQ135 gas sensor for detecting carbon dioxide levels. The ESP32 acts as the central processing unit, chosen for its built-in Wi-Fi capabilities and efficient power management [11]. A stable 5V power supply powers the sensors. Sensor data is wirelessly sent to the Blynk IoT cloud platform for real-time monitoring via a mobile app [11]. At the same time, the data is saved in Google Sheets over Wi-Fi for long-term storage and analysis [12].

The system architecture depicted in Fig. 1 provides a comprehensive overview of the workflow for the IoT-based lecture room monitoring system. At the heart of this innovative system is the versatile ESP32 microcontroller, which functions as the central processing unit, efficiently gathering data from three distinct types of sensors: a carbon dioxide sensor (MQ135) [13], a sophisticated humidity and temperature sensor (SHT40) [14], and a PIR motion sensor designed to detect occupancy.

Each sensor is powered through a regulated power supply, ensuring stable operation, and is directly connected to the ESP32 microcontroller, enabling real-time data acquisition. The ESP32 diligently collects environmental data from these sensors and processes it for subsequent transmission. Leveraging its integrated Wi-Fi capabilities, the microcontroller transmits the gathered information to the Blynk IoT cloud platform [11]. This connectivity allows users to effortlessly monitor critical environmental conditions and occupancy status through an intuitive mobile application interface.

In addition to real-time monitoring, the data collected is simultaneously logged to Google Sheets via cloud integration. This dual-storage approach not only facilitates immediate visualization of conditions but also ensures long-term data retention for in-depth analysis and evaluation. The reliable Wi-Fi connectivity maintains continuous communication between the monitoring system and the cloud, enabling seamless and remote oversight of multiple lecture rooms. This integrated setup equips facility managers and educators with the tools to accurately determine room occupancy and assess whether the indoor environmental conditions align with established safety and comfort benchmarks. Ultimately, this system fosters improved ventilation practices and optimizes energy consumption, contributing to a healthier and more responsible learning environment.

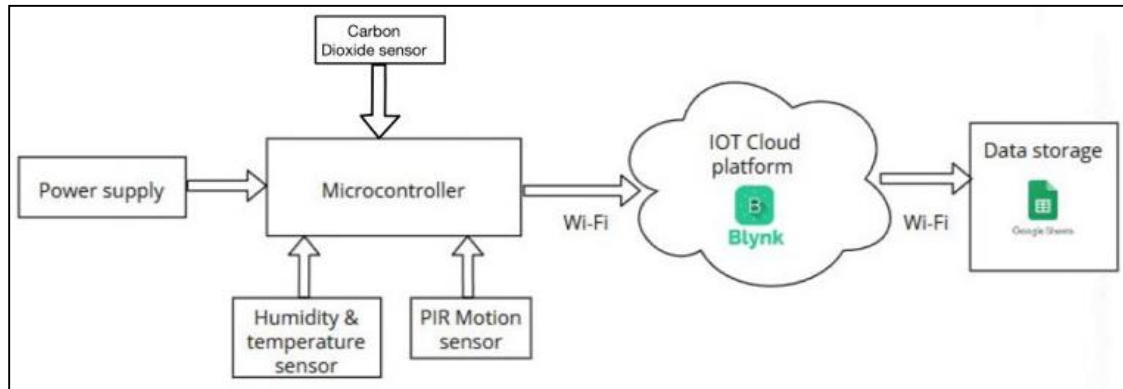


Fig. 1 Project Block Diagram

For a better grasp of the working of the system, Fig. 2 shows the process flow along with the system architecture. The flowchart in part (a) summarizes the basic steps in system operation which starts with capturing temperature, humidity, and CO₂ in two classrooms. The sensor information is collected, processed and uploaded into a cloud system, which feeds it to Blynk and Google Sheets. This flow aids in automated control of the system and also assists in determining the room occupancy in real time.

As an addition, part (b) presents the operational diagram where the system's physical configuration and the monitoring system's data transmission framework are shown. The ESP32 microcontroller acts as the main controller and receives information from an infrared (IR) proximity sensor, a CO₂ sensor, and a temperature and humidity sensor. These sensors gather data related to the environment as well as occupancy, which the ESP32 processes and transmits wirelessly. Data is sent to two cloud platforms; one for real-time visualization via mobile application is Blynk, and the other is Google Sheets where data is logged every five minutes. Having data on two platforms provides valuable instant feedback and allows an in-depth analysis of data trends over an extended period. The system components and data flow are illustrated in the operating diagram showing the multi-functionality of software and hardware which rely on each other.

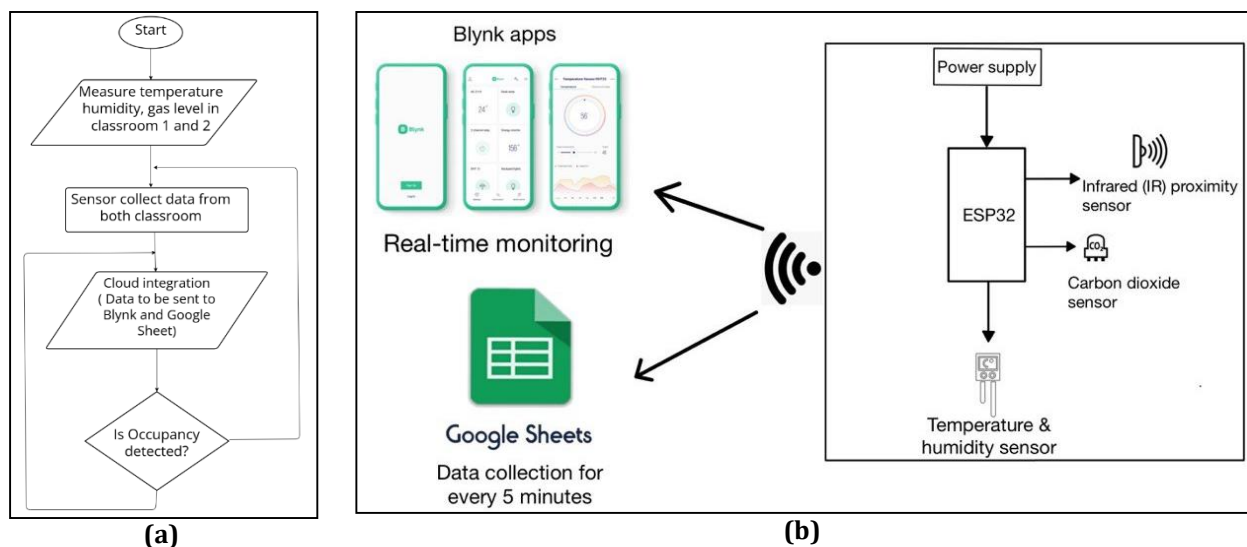


Fig. 2 System (a) Flowchart; (b) Operating Diagram

The final prototype, as shown in Fig. 3, was built on a compact baseboard with all sensors securely fixed and properly aligned. An LCD was added to the unit for on-site readings, while colored LEDs provided visual indicators of air quality status. The entire system was enclosed in a protective casing to prevent damage and ensure portability. This prototype was designed not only to demonstrate functionality but also to simulate a real-world classroom application where both environmental and occupancy data can be continuously and accurately monitored.

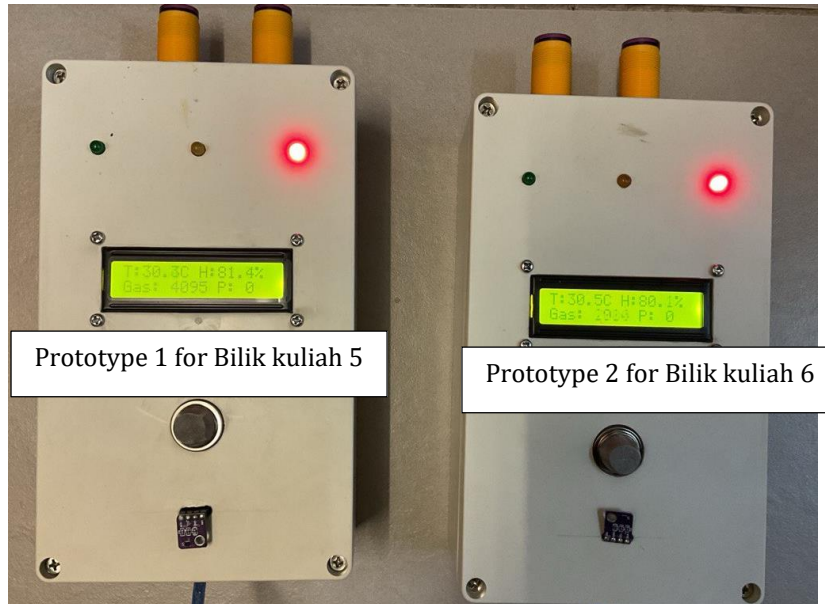


Fig. 3 Final Prototype deployed in Bilik Kuliah 5 and Bilik Kuliah 6

2.2 Sensor Integration and Programming

The integration process began by configuring the ESP32 microcontroller to serve as the central unit for handling input from all environmental and motion sensors. PIR motion sensors were installed to detect movement within the lecture rooms and were used to estimate occupancy status based on activity. The SHT40 sensor was implemented to accurately measure temperature and humidity, while the MQ135 gas sensor was selected to monitor changes in carbon dioxide levels, providing essential insight into indoor air quality. All programming was done using the Arduino IDE, and sensor-specific libraries were used to ensure stable communication and accurate data readings. The ESP32 was programmed to gather data at five-second intervals, and the collected information was transmitted over Wi-Fi to the Blynk IoT platform for real-time monitoring. At the same time, data was logged to Google Sheets for further analysis and record-keeping [15].

The entire wiring configuration includes the ESP32 microcontroller with all peripherals – sensors, LCD display, and indicator LEDs. As shown in Fig. 4, each component is attached to its corresponding GPIO pins and the power and data flow lines are organized. For ease of use, the LCD1602 I2C interfaces so that sensor data can be displayed and viewed on the device in real-time. The environmental status prompts such as air quality or occupancy detection are signaled through light-emitting diodes. To guarantee proper measure sensor data is collected, each sensor modules like E18-D80NK infrared proximity sensor, MQ135 air quality sensor, SHT40 temperature and humidity sensor are connected neatly; this ensures smooth and reliable communication. The circuit aids in the uninterrupted acquisition of data signals as well as the wireless transmission, the system continuously monitors and supplies real-time information on the environment and occupancy.

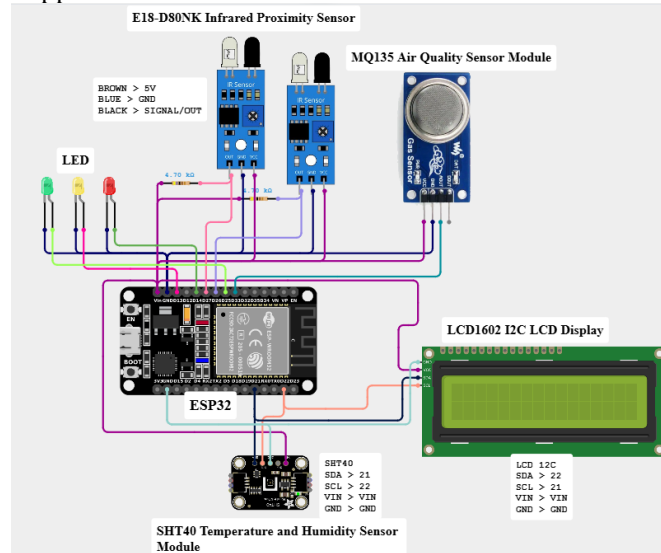


Fig. 4 Project Circuit Diagram

2.3 IoT Cloud Setup and Real-Time Visualization

The Blynk IoT platform was selected for its user-friendly interface and seamless integration with the ESP32 microcontroller, making it an ideal choice for real-time monitoring applications [16]. A dedicated dashboard was created within the platform to visualize live data from sensors installed in both Lecture Room 5 and Lecture Room 6. As illustrated in Fig. 4, the Blynk Web Dashboard, the layout features interactive widgets, including digital gauges, labeled indicators, and real-time graphs [17]. These widgets are linked to specific virtual pins on the ESP32, enabling them to receive and display sensor readings such as temperature, humidity, gas concentration, and occupancy status. The dashboards were independently configured for each room, facilitating easy comparison and assessment of environmental conditions side by side.

The system permits real-time feedback which is illustrated in Fig. 5 which shows data from the Blynk web dashboard. Each pane displays four important environmental metrics: temperature, humidity, occupancy, and gas concentration with visual symbols showing green (ideal), yellow (borderline), or red (dangerous) levels. Users can easily tell whether the situation is within the pre-defined acceptable safety limits or not. In the interface, Room 1 refers to Bilik Kuliah 5 and Room 2 refers to Bilik Kuliah 6. As described in this interface, green indicators confirm all monitored values are within safe ranges, yellow signifies caution of possible rising levels, and red points out that immediate action is necessary. This approach allows for very quick, actionable decisions for ventilation or usage changes. Fig 5. Blynk web dashboard displaying real-time monitoring and assessment of temperature, humidity, occupancy, and gas concentration in (a) Bilik Kuliah 5 and (b) Bilik Kuliah 6.

This real-time alert mechanism empowers users to respond promptly and effectively, whether by increasing ventilation or modifying room usage to ensure a healthier environment. Together, the web and mobile dashboards offer comprehensive access to live environmental data, significantly enhancing user awareness and enabling proactive management of classroom conditions.

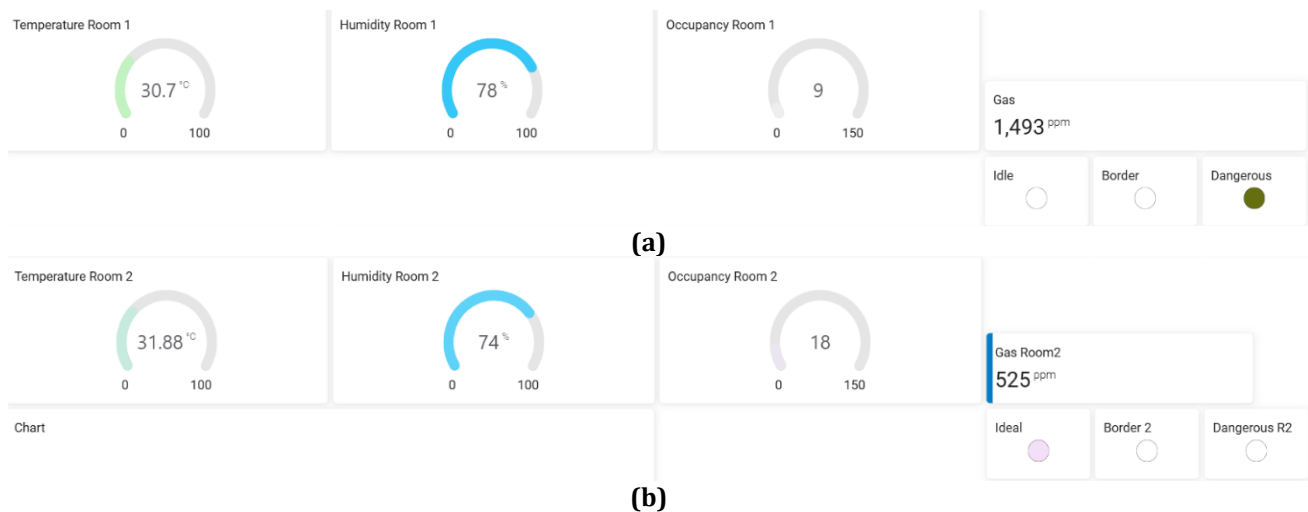


Fig. 5 Blynk Web Dashboard (a) Bilik Kuliah 5; (b) Bilik Kuliah 6

In addition to the web dashboard, the system also supports Blynk's mobile application, shown in Fig. 6, which provides real-time access to the same data through a smartphone or tablet. The mobile interface mirrors the functionality of the web dashboard but is optimized for portable devices, allowing users to monitor room conditions from anywhere with an internet connection. Together, the Blynk web dashboard and mobile application offer a flexible, real-time monitoring system that ensures both accessibility and convenience. The integration of live data visualization and immediate alerts supports proactive environmental management and contributes to healthier, more energy-efficient classroom conditions.

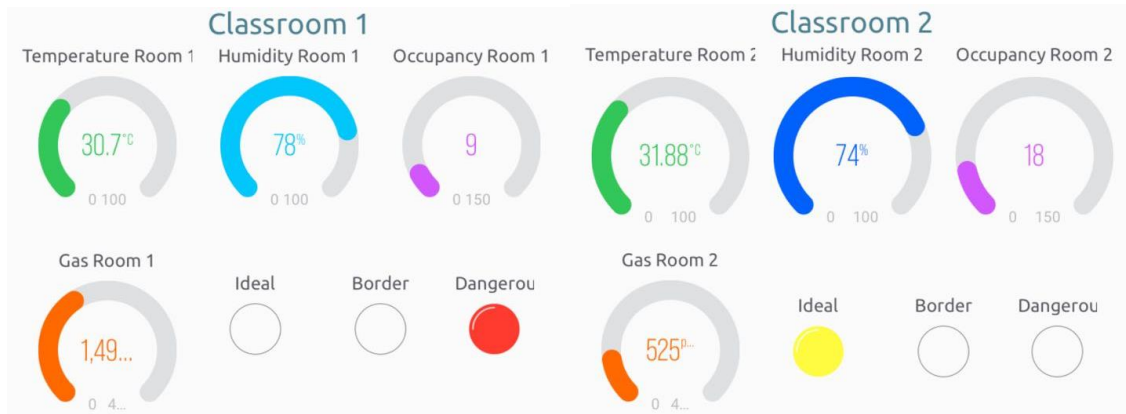


Fig. 6 Blynk Mobile Application

2.4 Data Logging

To ensure precise tracking and thorough long-term analysis, the system was designed to automatically log all sensor data into Google Sheets through Google Apps Script. Data was recorded at consistent five-minute intervals, facilitating detailed monitoring of temperature, humidity, occupancy levels, and gas concentrations over time.

As illustrated in Fig. 7, the spreadsheet captures multiple columns, including the exact date and time, alongside sensor readings for environmental conditions and the number of individuals present in the room. This structured format provides a reliable way to observe changes and trends throughout the day. The collected data offers valuable insights into the dynamic relationship between room occupancy and indoor air quality. For instance, as the number of occupants increased, there was a corresponding rise in gas concentration and temperature. Between 9:20 AM and 9:40 AM, with a consistent occupancy of 45 individuals, gas levels exceeded 1600 parts per million, while humidity began to decline. This suggests that higher occupancy levels can influence ventilation and air freshness, indicating the need for adjustments in airflow or air conditioning.

	A	B	C	D	E	F
1	Date	Time	Temperature	Humidity	Current People	Gas Value
73	April-24-2025	9:09:07	24.86	76.79	28	1602
74	April-24-2025	9:12:51	28.32	59.75	45	1515
75	April-24-2025	9:14:07	24.93	75.28	31	1595
76	April-24-2025	9:17:51	28.22	59.78	45	1590
77	April-24-2025	9:19:07	24.94	74.38	31	1587
78	April-24-2025	9:22:51	28.63	58.97	45	1587
79	April-24-2025	9:24:07	25.02	73.58	31	1576
80	April-24-2025	9:27:51	28.42	59.35	45	1584
81	April-24-2025	9:29:07	25.08	73.04	31	1590
82	April-24-2025	9:32:51	28.39	59.16	45	1498
83	April-24-2025	9:34:07	25.07	72.77	31	1581
84	April-24-2025	9:37:51	28.39	59.21	45	1591
85	April-24-2025	9:39:07	25.05	72.29	31	1583
86	April-24-2025	9:42:51	28.34	58.93	45	1596
87	April-24-2025	9:44:08	25.07	71.95	31	1603
88	April-24-2025	9:47:51	28.54	58.77	45	1604

Fig. 7 Google Excel Data Spreadsheet

3. Result

For the experimental setup, the complete system was deployed in two actual lecture rooms at Universiti Tun Hussein Onn Malaysia (UTHM), specifically Bilik Kuliah 5 and Bilik Kuliah 6. The devices were strategically installed in well-ventilated areas and mounted at an appropriate height to ensure accurate air sampling and reliable motion detection. Sensors were placed away from doors, windows, and direct airflow sources to reduce false readings caused by sudden environmental changes. Extra care was taken to maintain a consistent power supply, secure wiring, and stable Wi-Fi connectivity throughout the testing period. These controlled conditions were designed to ensure that the data collected accurately represented real classroom usage with minimal external interference.

The first phase of the testing focused on collecting indoor air quality (IAQ) data from two lecture rooms. The parameters measured included temperature, humidity, and gas concentration, with a specific focus on monitoring

carbon dioxide levels. The system recorded data at five-minute intervals, displayed real-time trends on the Blynk dashboard, and stored the information in Google Sheets for further analysis. In Lecture Room 5, environmental conditions remained largely within acceptable limits. The temperature varied between 24°C and 26°C, while gas concentration readings stayed below 1000 ppm, indicating adequate ventilation. Humidity levels ranged from 50% to 60%, which is within the thermal comfort zone. These results are summarized in Table 1, while Figure 8 provides a comparative graph illustrating the variation in temperature, humidity, gas concentration, and occupancy levels in Bilik Kuliah 5 throughout the testing period.

Table 1 Data collection summary for Bilik Kuliah 5

Lecture Room Bilik Kuliah 5 in Block A, Campus Pagoh Universiti Tun Hussein Onn Malaysia (UTHM)				
Time	Classroom Occupancy (Person)	Temperature (°C)	Relative Humidity (rh%)	Carbon Dioxide (ppm)
Acceptable Range	66	23 – 26	40-70	1000
9:02:51	5	24.59	78.43	471
9:07:51	6	25.09	79.5	481
9:12:51	8	24.86	76.79	504
9:17:51	9	24.93	75.28	518
9:22:51	11	24.94	74.38	536
9:27:51	13	25.02	73.58	557
9:32:51	14	25.08	73.04	573
9:37:51	16	25.07	72.77	593
9:42:51	18	25.05	72.29	612
9:47:51	19	25.07	71.95	626
9:52:51	21	25.13	71.93	645
9:57:51	22	25.1	71.78	657
10:02:51	24	25.11	71.48	680
10:07:52	26	25.12	71.37	697
10:12:52	27	25.23	71.2	709
10:17:52	29	25.14	71.17	733
10:22:52	31	25.11	71.11	754
10:27:52	32	25.19	70.94	768
10:32:53	34	25.17	70.56	788
10:37:53	35	25.1	70.66	798
10:42:53	37	25.11	70.7	826
10:47:53	39	25.15	70.59	844
10:52:53	40	25.21	70.34	856
10:57:53	42	25.22	70.31	875
11:02:53	44	25.37	73.1	898

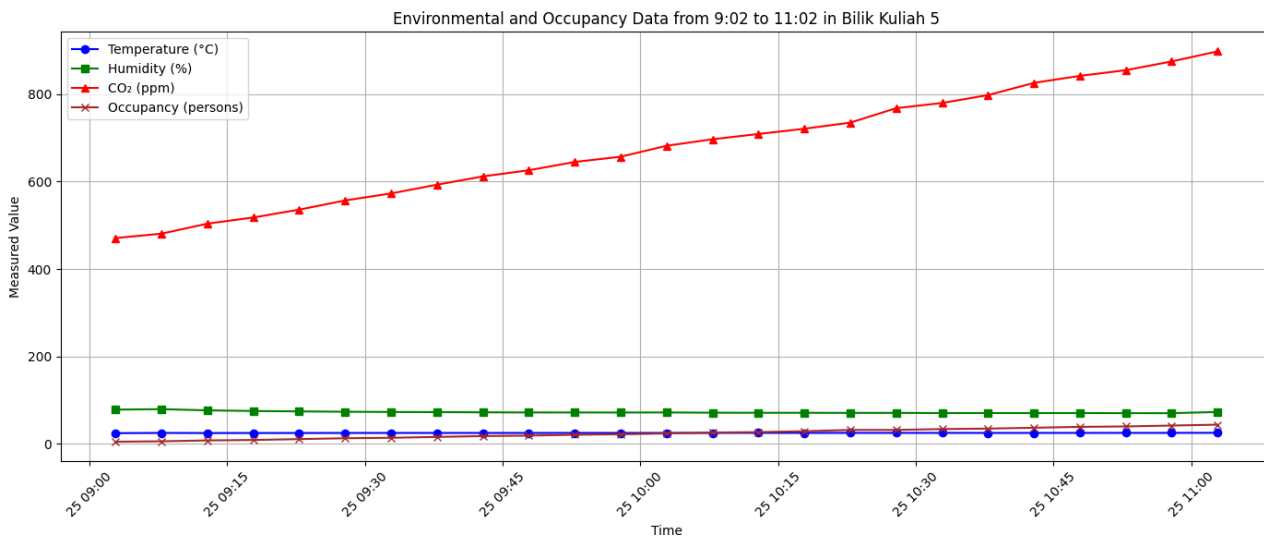


Fig. 8 Graph of Environmental Data in Bilik Kuliah 5

In clear contrast, Bilik Kuliah 6 showcased significantly poorer air quality than Bilik Kuliah 5. Temperature measurements reached an alarming 30°C, creating an excessively warm learning environment. Additionally, gas levels, particularly carbon dioxide, consistently exceeded 1500 ppm, especially during peak occupancy hours when student attendance was at its highest. These elevated readings unequivocally indicate a serious deficiency in ventilation, leading to conditions that are not only uncomfortable but potentially detrimental to the health of both students and instructors. Table 2 confirms these findings, illustrating that Bilik Kuliah 6 consistently recorded higher average values across all monitored parameters. This stark difference is further visualized in Fig. 9, which presents a line graph summarizing the data from the table. The graph highlights a clear upward trend in temperature, CO₂ levels, and occupancy over time, with significantly higher peaks in Bilik Kuliah 6 compared to Bilik Kuliah 5.

Table 2 Data collection obtained in Bilik Kuliah 6

Lecture Room Bilik Kuliah 6 in Block A, Campus Pagoh				
Universiti Tun Hussein Onn Malaysia (UTHM)				
Time	Classroom Occupancy (Person)	Temperature (°C)	Relative Humidity (rh%)	Carbon Dioxide (ppm)
Acceptable Range	69	23 – 26	40-70	1000
9:02:51	20	28.36	59.34	744
9:07:51	21	28.27	59.74	752
9:12:51	23	28.32	59.75	775
9:17:51	24	28.22	59.78	784
9:22:51	26	28.63	58.97	805
9:27:51	28	28.42	59.35	824
9:32:51	29	28.39	59.16	840
9:37:51	31	28.39	59.21	856
9:42:51	33	28.34	58.93	875
9:47:51	34	28.54	58.77	889
9:52:51	36	28.27	59.51	905
9:57:51	37	28.58	58.55	919
10:02:51	39	28.65	58.24	935
10:07:52	41	28.61	58.6	956
10:12:52	42	28.38	59.07	970
10:17:52	44	28.33	59.52	991
10:22:52	46	28.55	58.96	1010
10:27:52	47	28.6	58.73	1020
10:32:53	49	28.29	59.93	1040
10:37:53	50	28.2	58.39	1048
10:42:53	52	28.19	59.55	1070
10:47:53	54	28.38	58.42	1091
10:52:53	55	27.93	60.61	1105
10:57:53	57	28.35	59.06	1124
11:02:53	59	28.38	59.3	1140

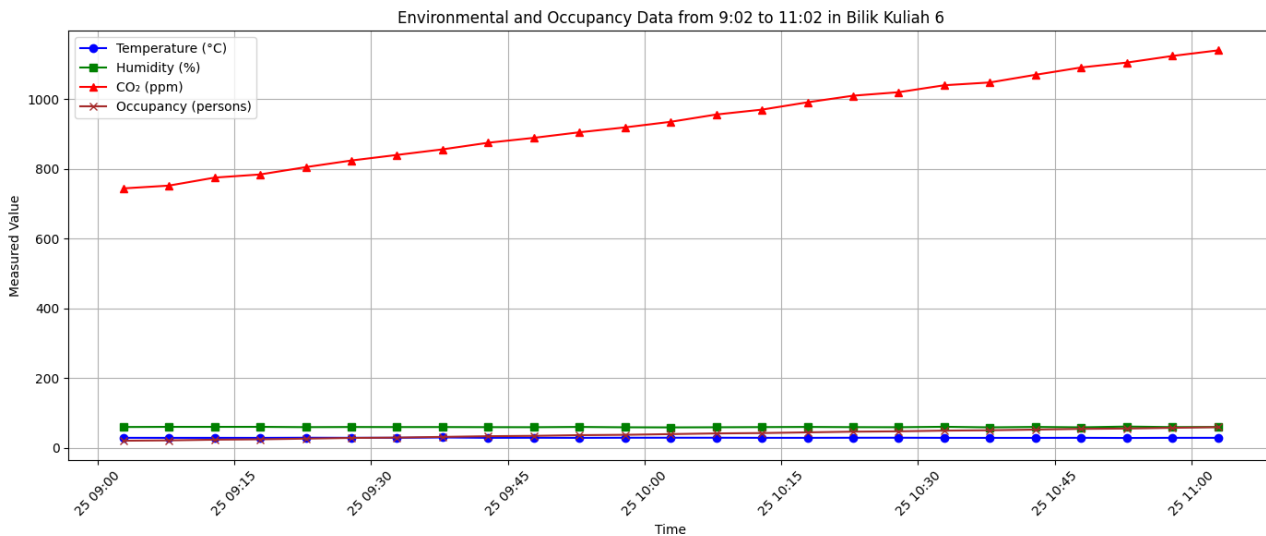


Fig. 9 Graph of Environmental Data in Bilik Kuliah 6

Occupancy levels were meticulously monitored using passive infrared (PIR) motion sensors, strategically positioned near key seating areas and entry points in both lecture rooms. These advanced sensors recorded motion data at five-second intervals, providing a comprehensive estimation of the number of occupants present. This data was visualized on the Blynk platform, allowing for real-time monitoring, and was also logged for in-depth analysis.

The findings revealed a notable difference in occupancy between the two lecture rooms, with Bilik Kuliah 6 consistently accommodating a larger number of occupants compared to Bilik Kuliah 5. For instance, during one busy morning session, Bilik Kuliah 6 experienced a peak occupancy of 45 individuals, while Bilik Kuliah 5 remained below 30. This significant disparity in attendance directly correlated with the heightened temperature and gas readings observed in Bilik Kuliah 6. These observations support the hypothesis that an increased presence of people, combined with insufficient ventilation, severely compromises indoor air quality, creating an uncomfortable environment for those present.

4. Discussions

The findings from this study demonstrate that the real-time IoT-based monitoring system effectively captured variations in indoor air quality and occupancy across two different lecture rooms. The observed patterns support the primary research question: Can a low-cost IoT system effectively monitor and differentiate environmental conditions in active classroom settings?

The interpretation of the results reveals a strong correlation between occupancy and air quality levels. Bilik Kuliah 6, which frequently hosted a larger number of students, recorded significantly higher temperatures and

gas concentration values compared to Bilik Kuliah 5. This supports the hypothesis that increased human presence without adequate ventilation leads to a measurable decline in indoor air quality. In Bilik Kuliah 6, the temperature peaked at 30°C, and gas levels exceeded 1500 ppm, conditions known to contribute to discomfort, reduced cognitive function, and health risks. In contrast, Bilik Kuliah 5 maintained more stable conditions, with temperature and gas values well within the recommended limits. These results align with prior research linking classroom overcrowding and insufficient airflow to poor indoor environments.

The contrasts between the two rooms are strikingly illustrated in Fig. 10, which meticulously details the temperature, relative humidity, and gas concentration levels. In these graphs, Bilik Kuliah 6 consistently reveals elevated temperature and gas readings, showcasing a concerning trend. Additionally, as occupancy rises, there is a substantial decline in humidity levels that is both noticeable and alarming. These visual representations not only reinforce the patterns observed in the data but also align with previous studies highlighting the detrimental effects of classroom overcrowding and inadequate airflow on indoor air quality. This convergence of findings underscores the importance of maintaining a healthy classroom environment for optimal learning.

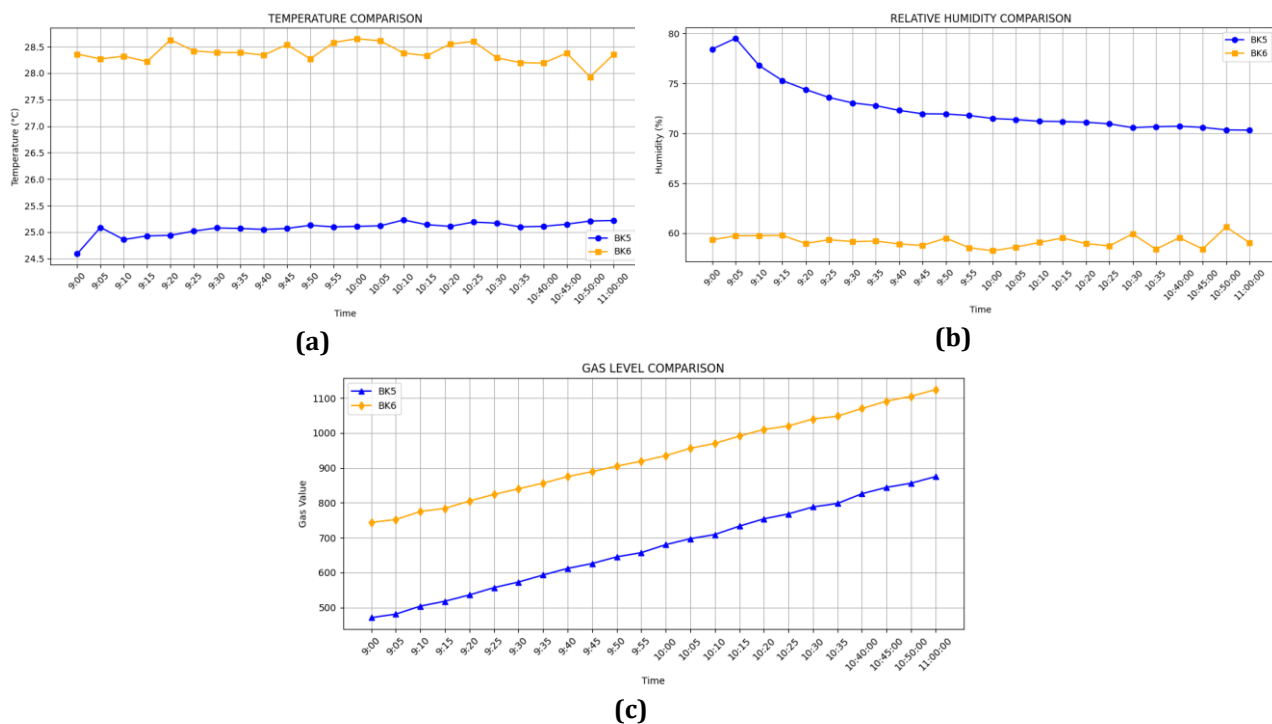


Fig. 10 Plot of Comparison (a) Temperature; (b) Relative Humidity; (c) Gas Level

One of the strengths of this study is its use of real-time visualization combined with cloud data logging, which provides users with both immediate and historical insights. The Blynk platform, available in both web and mobile formats, offered intuitive dashboards equipped with alert mechanisms. The system's visual indicators transition from green (ideal condition) to yellow (borderline) and red (out-of-range), allowing users to take prompt action when environmental values deviate from safe thresholds. This user-friendly interface enhances the system's practical value beyond academic observation. Furthermore, the real-world deployment in two active lecture rooms provided meaningful and applicable data under realistic conditions, reinforcing the credibility of the findings.

However, there are limitations to consider. The PIR motion sensors, while effective for general occupancy detection, are motion-based and do not directly count people. This may lead to inaccuracies when students remain stationary or move unpredictably, potentially causing the system to undercount or overcount occupants. The MQ135 sensor, although commonly used in academic prototypes, detects a range of gases but does not specifically measure CO₂. Consequently, gas concentration readings provide general indicators of air quality rather than precise CO₂ values. Additionally, the system's reliance on a stable Wi-Fi connection introduces potential challenges in locations with poor or inconsistent network coverage, which could affect data transmission and the reliability of real-time monitoring.

Despite these limitations, the system presents a valuable and scalable solution. Its integration into classroom environments fits within the broader context of smart campus initiatives. Previous research often suggested costly HVAC upgrades to improve indoor air quality (IAQ). In contrast, this study demonstrates that a compact and affordable IoT setup can deliver timely, actionable data to support ventilation decisions, enhance student comfort,

and improve energy efficiency. By monitoring gas, temperature, and humidity levels with occupancy patterns, the system contributes to informed classroom management.

The implications of this work are both practical and educational. Campus administrators can use the system to identify problem areas, adjust scheduling, or activate ventilation protocols based on actual environmental data. From a research perspective, the project lays the groundwork for expanded studies that could incorporate additional sensors, machine learning for trend prediction, or automated environmental controls. Future iterations may benefit from more advanced people-counting technologies and the integration of precise NDIR CO₂ sensors to improve accuracy.

In summary, the project provides a compelling and valuable answer to its research question. It not only confirms established relationships between IAQ and occupancy but also delivers a working prototype that can be effectively applied in real-world educational settings.

5. Conclusion

In conclusion, this project successfully developed and implemented a real-time IoT-based monitoring system designed to track indoor air quality and occupancy in lecture rooms at Universiti Tun Hussein Onn Malaysia. By integrating the ESP32 microcontroller with temperature, humidity, gas, and motion sensors, the system delivered reliable real-time data visualization through the Blynk platform and facilitated long-term data storage via Google Sheets. Experimental findings from Bilik Kuliah 5 and Bilik Kuliah 6 demonstrated that increased occupancy levels, coupled with inadequate ventilation, significantly diminished indoor air quality, thereby validating the system's effectiveness and relevance. Although there were limitations concerning sensor specificity and occupancy estimation, the system emerged as a low-cost, scalable solution that aligns with existing research while providing practical advantages for smart campus management. Overall, the project not only achieved its objectives but also underscored the potential of IoT technologies to enhance indoor environmental conditions and improve energy efficiency in educational settings.

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