Environmental Monitoring in CAED, Kent State University

Course Name: CMGT 40095/50095 Advanced Technology Applications in Construction

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Abstract

Environmental monitoring is a critical aspect of optimizing indoor environmental quality, ensuring occupant comfort, and improving energy efficiency in buildings. This study employs an Internet of Things (IoT)-based approach, integrating Raspberry Pi-enabled sensors to systematically measure and analyze temperature and humidity fluctuations within two distinct spaces in Kent State University's College of Architecture and Environmental Design (CAED): the Cafeteria and the Studio. These locations were strategically selected due to their contrasting environmental characteristics, allowing for an in-depth comparative assessment of how occupancy levels, ventilation efficiency, and heat sources influence indoor climate stability.

The cafeteria experiences high variability in environmental conditions due to continuous foot traffic, frequent door openings, and the presence of heat-generating cooking equipment. These factors contribute to significant fluctuations in temperature and humidity. On the other hand, the Studio, designed as a structured academic workspace, is equipped with a regulated HVAC system and experiences minimal external disturbances, leading to a more stable indoor climate. Given these fundamental differences, this study hypothesizes that the cafeteria will exhibit greater environmental fluctuations compared to the Studio.

By leveraging real-time sensor data, this research provides quantifiable insights into the impact of human activity, spatial design, and ventilation efficiency on indoor environmental conditions. The findings contribute to the development of data-driven strategies aimed at enhancing HVAC performance, optimizing thermal comfort, and promoting sustainable building management. Future research can extend this work by incorporating additional environmental parameters, such as CO_2 levels, airflow patterns, and lighting conditions, to establish a more holistic understanding of indoor climate control. Furthermore, the integration of sensor-driven HVAC automation presents a promising avenue for creating energy-efficient and adaptive climate control systems in both academic and commercial environments.

Introduction

Environmental monitoring is essential for optimizing indoor environmental quality, ensuring occupant comfort, and improving energy efficiency. This study employs an IoT-based approach using Raspberry Pi-enabled sensors to measure temperature and humidity fluctuations in two distinct locations within Kent State University's College of Architecture and Environmental Design (CAED): the Cafeteria and the Studio. With the growing emphasis on energy efficiency and improved indoor comfort, smart building technologies have become essential. Smart sensing technology, a key component of this transformation, enables the collection, analysis, and transmission of environmental data, allowing for dynamic, responsive building operations.

Raspberry Pi is a compact, affordable, and versatile computing platform widely used for various applications, including environmental monitoring. By connecting sensors like DHT22, Raspberry Pi can continuously measure key environmental parameters such as temperature and humidity. The collected data can be analyzed to optimize HVAC systems, enhance occupant comfort, and promote energy-efficient practices. The Cafeteria and Studio were selected due to their contrasting environmental conditions, making them ideal for comparative analysis. The cafeteria, a high-traffic area with frequent door openings, cooking appliances, and varied occupancy levels, leads to significant temperature and humidity variations. In contrast, the Studio, a structured workspace with regulated HVAC settings and minimal external disturbances, offers a stable indoor climate for comparison.

By analyzing real-time sensor data from these locations, this study aims to provide insights into the factors influencing indoor environmental quality and inform future building management practices. The results support strategies for improving HVAC performance, optimizing thermal comfort, and promoting sustainable building management. Future studies could include additional environmental parameters like CO_2 levels, airflow, and lighting to enhance indoor climate control and develop data-driven solutions for energy-efficient indoor environments.

Team Members and Contributions

Our project was a team effort, and each member was given specific tasks to do in order to guarantee a thorough and well-rounded execution. The individual contributions are broken as follows:

	Member	Role	Responsibilities
1	Shiva Kumar Miryala	Team Leader (Title Page & Final Compilation)	Led coordination, compiled final report, formatted title page
2	Javeed Shaik	Abstract	Summarized objectives, methodology, findings, and conclusions
3	Gnana Jagadeesh Gangula	Introduction	Provided background on Raspberry Pi, stated objectives, significance of locations
4	Ozaswi Acharya & Shivani Patel	Team Members & Contributions & Location Selection & Justification	Documented team roles, ensured equal representation, identified data collection locations, and provided justifications
5	Bishnu Adhikari	Experimental Procedure	Outlined step-by-step methodology, described equipment and workflow
6	Neha Pillanagrovi	Data Collection & Analysis	Collected data, performed analysis, created visualizations
7	Mehraneh Aladini	Conclusion	Summarized findings, discussed challenges and improvements
8	Reshma Ananthaneni	Appendices	Compiled raw data, Python code, experimental data, and additional materials

Location Selection and Justification

For this project, we have carefully selected two distinct locations within the College of Architecture and Engineering Department at Kent State University for collecting temperature and humidity data using Raspberry Pi Model 4. These locations, the cafeteria and the student work studio—were chosen based on their unique environmental conditions, human occupancy patterns, and potential sources of temperature and humidity variation. By analyzing data from these two areas, we aim to understand how different factors such as human activity, equipment usage, ventilation, and material properties influence indoor climate conditions.

1. Cafeteria

The cafeteria is a dynamic environment where students, faculty, and staff gather to eat, socialize, and take breaks between academic activities. This location is particularly relevant for data collection due to:

- **High Occupancy:** The cafeteria experiences fluctuating occupancy levels throughout the day, impacting factors like temperature, humidity, and CO_2 levels.
- **Heat Sources:** The presence of food preparation areas, hot meals, and numerous individuals in a confined space contributes to variations in thermal conditions and air quality.
- **Ventilation & Airflow Variations:** With frequent opening and closing of doors and the presence of ventilation systems, this space offers an excellent opportunity to study air circulation and environmental stability.
- **Potential for Indoor Comfort Analysis:** Understanding environmental conditions in the cafeteria can provide insights into how well the space accommodates its occupants in terms of thermal comfort and air quality.

Figure 1 CAED Cafeteria

2. Studio

The studio is a core workspace within the CAED building, where students spend long hours working on architectural projects, engaging in discussions, and participating in critiques. We selected this location for data collection because:

- **Extended Occupancy Durations:** Unlike transient spaces, studios are occupied for prolonged periods, making it crucial to analyze temperature and humidity variations over time.
- **High Energy Usage:** The use of laptops, desktop computers, and projectors generates heat, potentially affecting indoor climate conditions.

Figure 2 CAED Studio

- **Minimal Airflow Compared to Open Spaces:** Since students often work in groups in fixed seating arrangements, ventilation efficiency and indoor air quality become key concerns.
- **Impact on Productivity:** Comfortable environmental conditions are crucial for enhancing student concentration and productivity. Analyzing this space can help evaluate whether the current ventilation and climate control systems support an optimal working environment.

Justification for Selection

These locations were chosen because they represent two distinct types of environments within CAED—one focused on social and relaxation activities (cafeteria) and the other on academic and creative work (studio). By collecting and analyzing data from both spaces, we can compare how environmental factors vary between areas with high interaction and movement versus those designed for focused, long-term engagement.

This study will help us better understand environmental comfort in the CAED building by offering useful details on how occupancy levels, indoor temperature, humidity, and air quality vary in various circumstances.

Experimental Procedure

This section explains the steps followed to set up and use the **Raspberry Pi Model 4** and **DHT22 sensor** to collect temperature and humidity data in the **CAED Studio** and **Cafeteria**.

1. Setup of Equipment

The first step in the experimental procedure was setting up the necessary equipment for data collection. This involved assembling the components and configuring the Raspberry Pi to collect environmental data continuously.

- **Raspberry Pi Setup**:
  The Raspberry Pi **Model 4** was selected for its compact size, low cost, and ability to interface with sensors. It was set up with the Raspbian operating system, a user-friendly Linux distribution optimized for the Raspberry Pi. The operating system was updated to ensure it had the latest software.
- **Sensor Installation**:
  The **DHT22** sensor, known for its accuracy and reliability in measuring both temperature and humidity, was connected to the Raspberry Pi via its GPIO pins. The sensor was placed in a location that would be representative of the environmental conditions (one in the **CAED Studio** and one in the **Cafeteria**).
- **Power Supply**:
  A stable power supply was connected to the Raspberry Pi to ensure continuous operation during data collection. The power supply was chosen to support Raspberry Pi's voltage and current requirements.

2. Calibration of the Sensor

Before initiating data collection, it was important to calibrate the DHT22 sensor to ensure the accuracy of the data. Calibration involved the following steps:

- **Test Runs**:
  The DHT22 sensor was placed in a controlled environment to test its readings. Any discrepancies between the actual conditions and sensor readings were noted.
- **Adjustment of Code**:
  The Raspberry Pi was programmed with code that utilized a Python library specifically designed for the DHT22 sensor.

- **Validation of Readings**:
  During test runs, readings from the sensor were cross-checked with a known reliable thermometer and hygrometer to ensure consistency and to eliminate any calibration issues.

3. Data Collection

Once the sensor was calibrated and verified, the next step was data collection. This process involved monitoring environmental conditions continuously at both selected locations, namely the **CAED Studio** and **Cafeteria**.

- **Location Setup**:
  The DHT22 sensors were strategically placed in locations where temperature and humidity changes were most likely to occur:
  - **CAED Studio**: The sensor was positioned on a desk or workspace where students regularly used electronic devices.

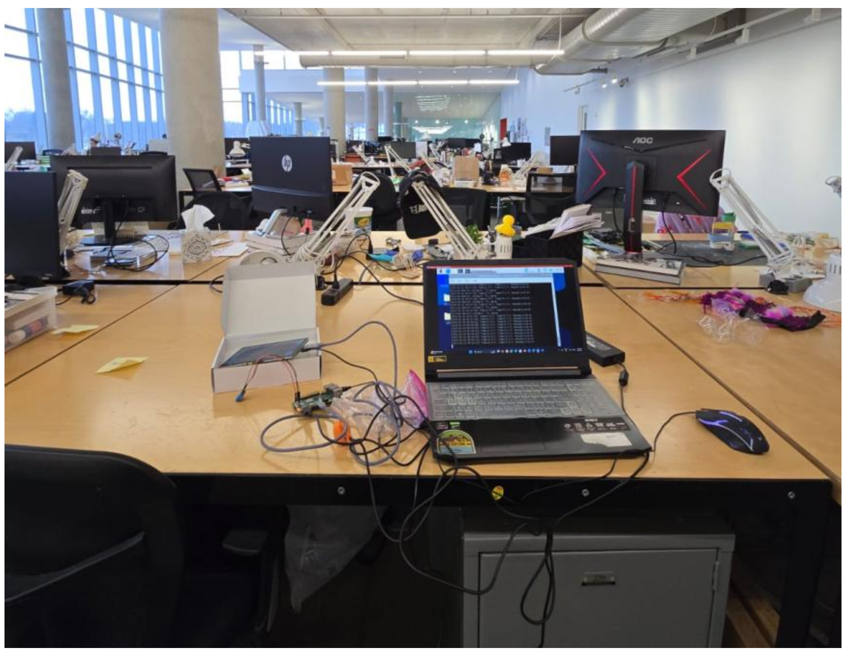
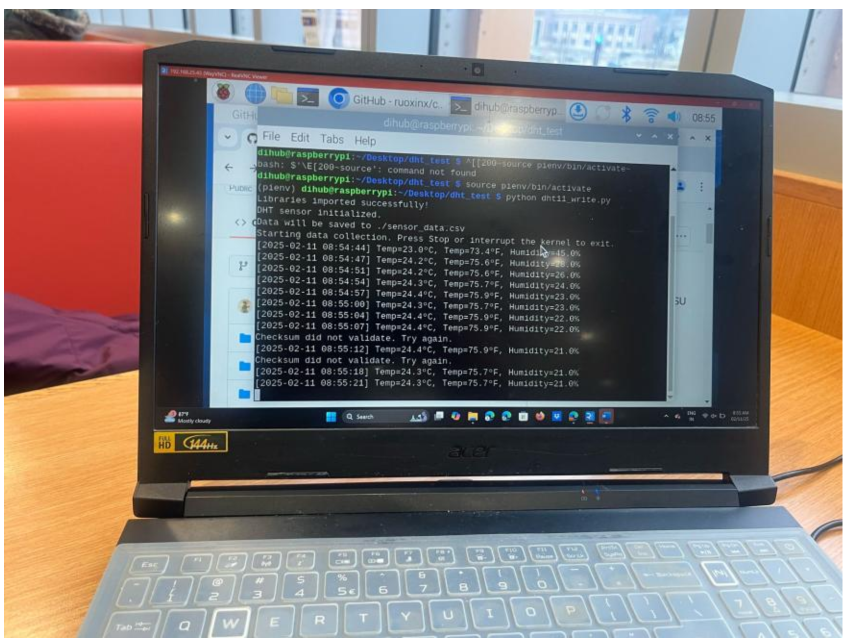


Figure 3 Instrument Setup at CAED

  - **Cafeteria**: The sensor was placed in a common area, near the food preparation area where heat from cooking appliances and variations in occupancy would cause fluctuations in temperature and humidity.
- **Data Logging**:
  The Raspberry Pi was programmed to log data from the DHT22 sensor at regular intervals. The data was recorded in **CSV format** for easy analysis. Each data point included the following:
  - **Timestamp**: The exact time the data was collected.

- ○ **Temperature**: The measured temperature in degrees Celsius.
- ○ **Humidity**: The measured humidity in percentage.

Figure 4 Data Capturing



4. Data Backup and Storage

- **Data Storage**:
  All the raw data collected from both the **Studio** and **Cafeteria** were stored in CSV files on the Raspberry Pi's **MicroSD card**. This ensured the data was available for further analysis.

The MicroSD card had a capacity of **32GB**, which was sufficient to store data for an extended period.

- **Backup Process**:
Regular backups of the data were made to prevent data loss. Backups were stored on external storage devices or cloud platforms, allowing easy access and further processing.

5. Data Analysis

- After collecting the data over the course of the experiment, the next step was to analyze the environmental conditions in both the Studio and Cafeteria. The raw data in CSV format was imported into a data analysis tool (Excel) for more advanced analysis.

The temperature and humidity data were analyzed for trends and fluctuations. Key points analyzed included:

  - The average temperature and humidity for each location.
  - The range and variability of the data.
  - Correlation between foot traffic and fluctuations in temperature or humidity.

Code Implementation

Python Code for Producing Temperature and Humidity Data Using a Sensor and a Raspberry Pi

```
import time
import board
import adafruit_dht
import csv

print("Libraries imported successfully!")

# Sensor data pin is connected to GPIO 4
# sensor = adafruit_dht.DHT22(board.D4)
# Uncomment for DHT11
sensor = adafruit_dht.DHT11(board.D4)

print("DHT sensor initialized.")

# CSV file to save data
csv_file = "./sensor_data.csv"

# Write the CSV header
with open(csv_file, mode='w', newline='') as file:
    writer = csv.writer(file)
```

```
    writer.writerow(["Time", "Temperature (°C)", "Temperature (°F)", "Humidity (%)"])

print(f"Data will be saved to {csv_file}")

print("Starting data collection. Press Stop or interrupt the kernel to exit.")

while True:
    try:
        # Get the current time
        measurement_time = time.strftime("%Y-%m-%d %H:%M:%S", time.localtime())

        # Read temperature and humidity
        temperature_c = sensor.temperature
        temperature_f = temperature_c * (9 / 5) + 32
        humidity = sensor.humidity

        # Print the values to the console
        print("[{0}] Temp={1:0.1f}ºC, Temp={2:0.1f}ºF, Humidity={3:0.1f}%".format(
            measurement_time, temperature_c, temperature_f, humidity))

        # Save the data to the CSV file
        with open(csv_file, mode='a', newline='') as file:
            writer = csv.writer(file)
            writer.writerow([measurement_time, temperature_c, temperature_f, humidity])

    except RuntimeError as error:
        # Errors happen fairly often, DHT's are hard to read, just keep going
        print(error.args[0])
        time.sleep(2.0)
        continue
    except Exception as error:
        sensor.exit()
        raise error

    time.sleep(3.0)
```

Data Collection

Here, code was used to generate the data, which was then stored in CSV format.

Date	Time	Temperature (Â°C)	Temperature (Â°F)	Humidity (%)
02/11/25	8:54:44	23	73.4	45
02/11/25	8:54:47	24.2	75.56	28
02/11/25	8:54:51	24.2	75.56	26
02/11/25	8:54:54	24.3	75.74	24
02/11/25	8:54:57	24.4	75.92	23
02/11/25	8:55:00	24.3	75.74	23
02/11/25	8:55:04	24.4	75.92	22
02/11/25	8:55:07	24.4	75.92	22
02/11/25	8:55:12	24.4	75.92	21
02/11/25	8:55:18	24.3	75.74	21
02/11/25	8:55:21	24.3	75.74	21

Table 1 Data Collection format and Stored in CSV format

Data Analysis and Visualization

The data was collected from the sensors using Raspberry Pi, and a thorough analysis was conducted to identify patterns and variations in temperature and humidity levels. By analyzing real-time sensor data from these locations, this study aims to provide insights into the factors influencing indoor environmental quality and inform future building management practices.

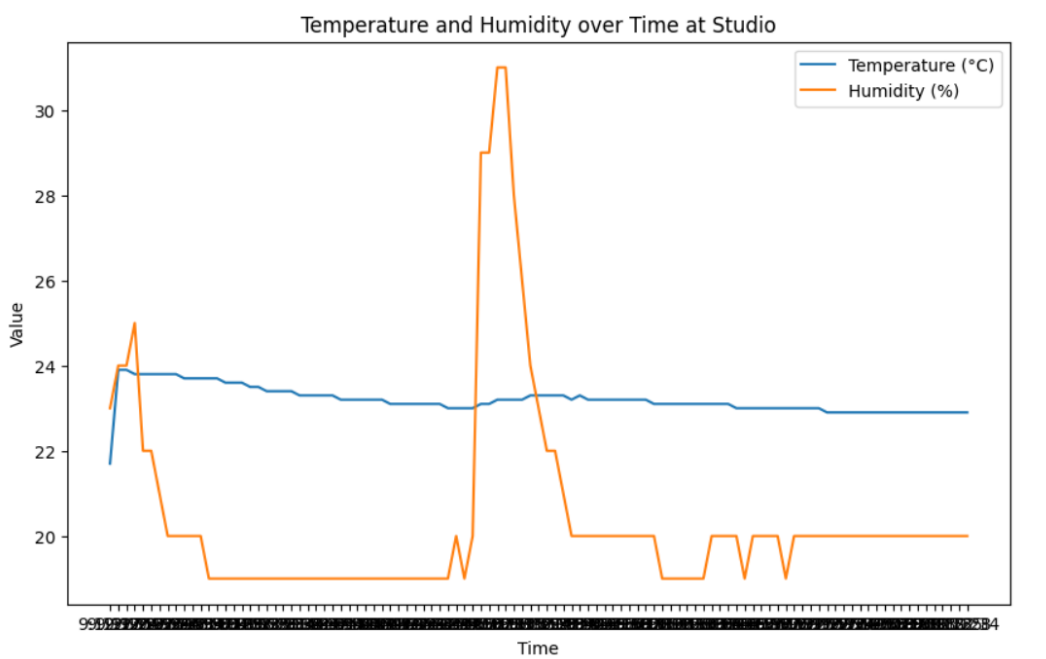


Figure 5 Temperature and Humidity Over time at Studio

The temperature in the studio stayed stable throughout the observation period, with values between 22.9°C (73.22°F) and 23.9°C (75.02°F). This provided a comfortable setting for indoor tasks, as there were no notable temperature changes that could lead to discomfort. In contrast, humidity levels exhibited some fluctuations. They varied from 19% to 31%, with most measurements leaning toward the lower range of 19%-20%. The occasional peaks in humidity reaching 29%-31% were short-lived, suggesting some moisture in the air, but not enough to raise any alarms. Overall, the studio upheld a relatively dry atmosphere, with moderate humidity changes. These conditions were typically adequate for various studio activities, although it is advisable to keep an eye on the humidity to prevent it from reaching levels that could impact comfort or equipment performance.

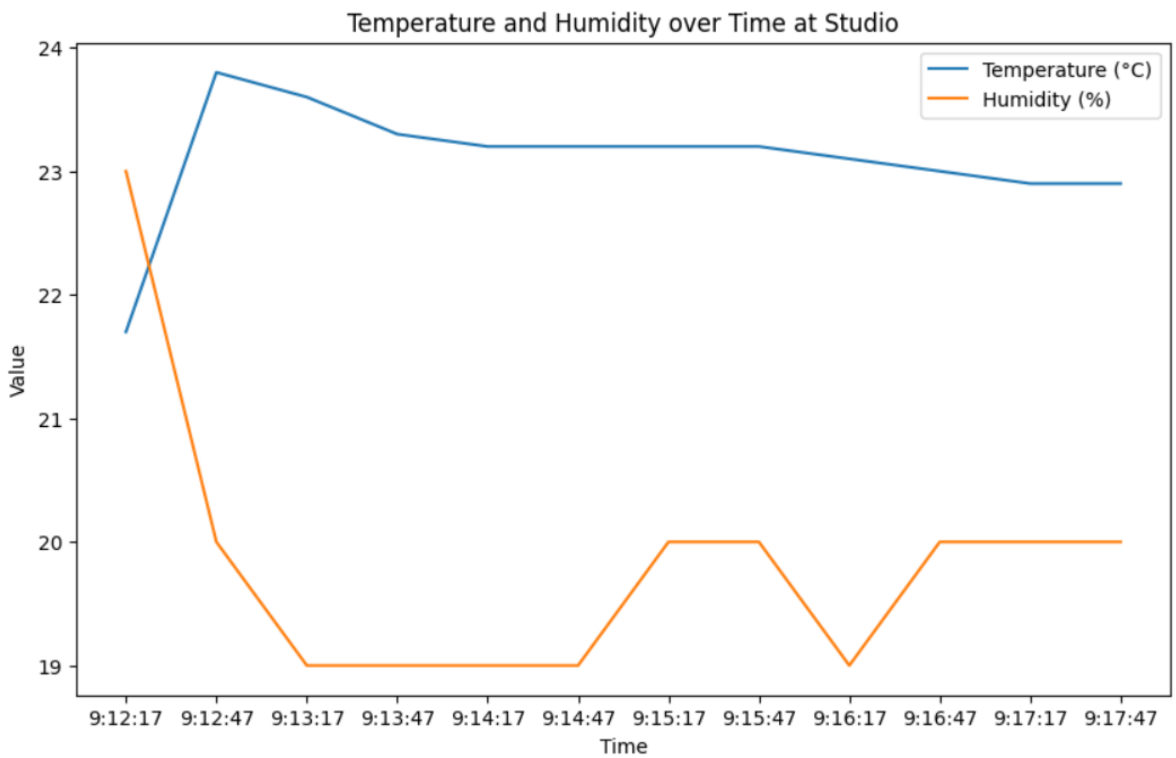


Figure 6 Temperature and Humidity Over Time at Studio

In contrast to the earlier data, the updated data from February 11, 2025, depicts a more stable and marginally warmer atmosphere. With a smaller swing than the previous record, which showed temperatures as low as 21.7°C (71.06°F), the temperature ranged from 22.9°C (73.22°F) to 23.8°C (74.84°F). In contrast to the earlier range of 19% to 31%, the humidity levels were likewise continuously lower, remaining between 19% and 23%. According to the updated statistics, the atmosphere is drier and more stable, with fewer variations in temperature and humidity, providing a more regulated and cozy setting overall.

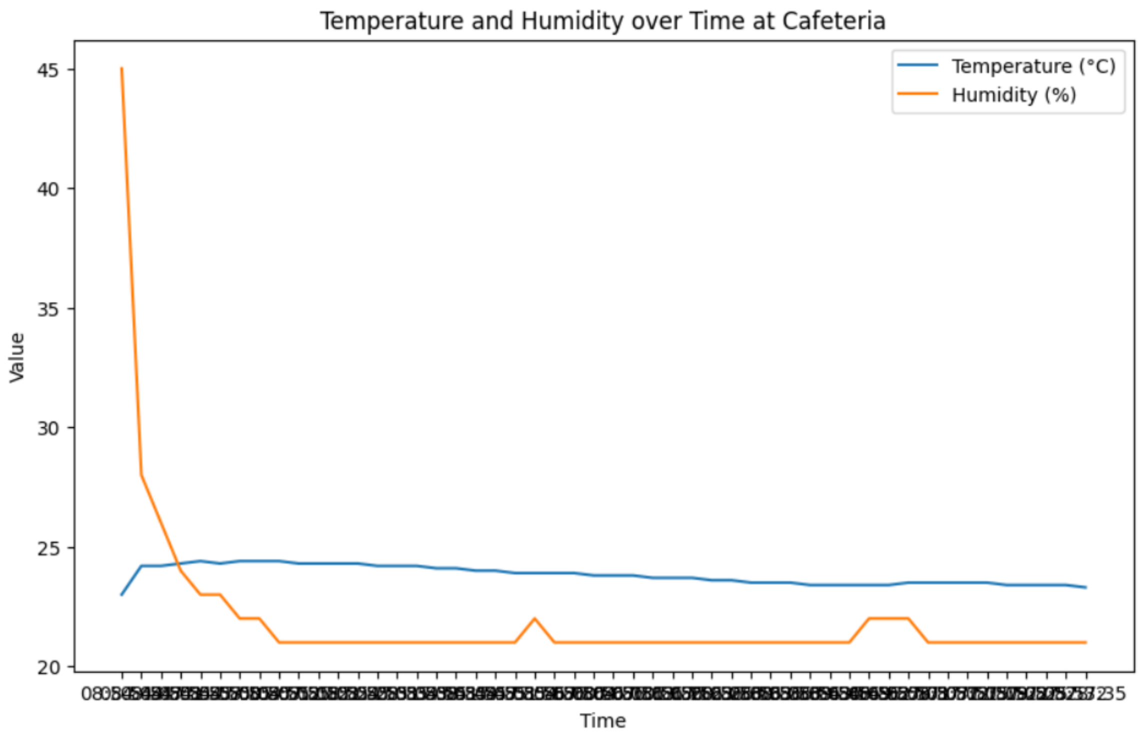


Figure 7 Temperature and Humidity over time at Cafeteria

The temperature in the café on February 11, 2025, varied between **23°C (73.4°F) and 24.4°C (75.92°F)** over the observation period, remaining comparatively constant. Early in the session, the temperature reached a peak of **24.4°C (75.92°F),** but by the end, it had progressively decreased to **23.3°C (73.94°F).** The humidity levels, however, were more inconsistent; they started off at 45% but gradually dropped to **21%–22%,** suggesting that the air was becoming less wet. Despite these variations, the cafeteria remained a pleasant place to be throughout this time, with a moderate level of warmth and a reasonable amount of dryness.

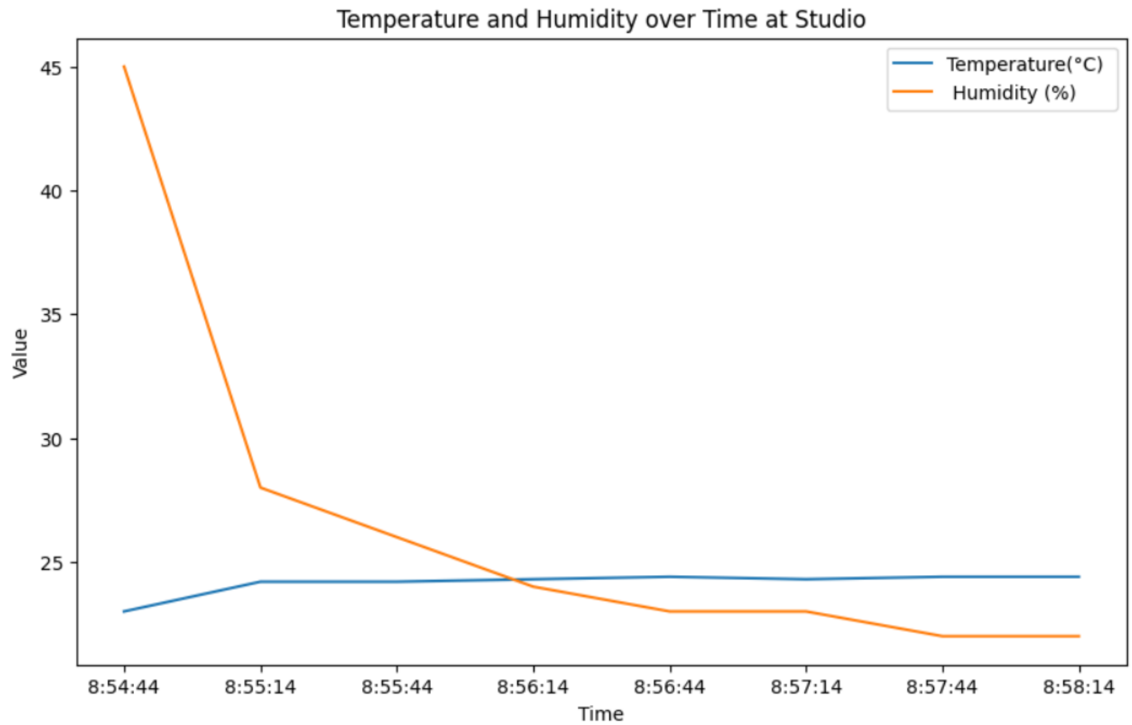


Figure 8 Temperature and Humidity over Time at Studio (Refined Data)

Data from the cafeteria as of February 11, 2025, indicates a steady rise in temperature and a slow drop in humidity. The temperature increased slightly from 8:54 AM, when it was 23°C (73.4°F), to 8:58 AM, when it was 24.4°C (75.92°F). In the meantime, the humidity gradually decreased from 45% at the start of the period to 22% at the end. This suggests a pattern of rising temperatures and falling moisture levels within the cafeteria over the period of the record.

Comparison and Findings

- Temperature Comparison: The studio exhibited a more stable temperature environment, whereas the cafeteria showed slight fluctuations due to dynamic occupancy and cooking activities.

- Humidity Trends: The studio maintained a drier environment with occasional peaks, while the cafeteria demonstrated a steady drop in moisture levels, likely influenced by ventilation and heat sources.

- Implications: The findings highlight the importance of space-specific environmental control. While the studio requires minimal adjustments, the cafeteria could benefit from optimized HVAC and moisture regulation to maintain comfort.

Conclusion

The Cafeteria and the Studio are two separate areas within Kent State University's College of Architecture and Environmental Design where this study effectively showed the efficiency of employing Raspberry Pi-based environmental sensors to monitor temperature and humidity changes. The results emphasize how indoor climate conditions are affected by occupancy levels, ventilation, and heat sources.

High foot traffic, food preparation activities, and changing ventilation defined the cafeteria, which also showed notable temperature and humidity changes. Frequent door movements, culinary activity, and the heat produced by appliances and food all helped to generate these variations. In contrast, through controlled HVAC settings, extended occupancy times, and low external air disturbance, the Studio offered a more consistent internal temperature.

The first Raspberry Pi unit failure during the trial presented one of the main difficulties; it called for troubleshooting and replacement of the gadget. Notwithstanding this challenge, the team effectively gathered and examined data to find trends that might guide policies meant to raise indoor environmental quality.

This research emphasizes how IoT-based environmental monitoring may boost occupant comfort, maximize HVAC performance, and enhance sustainable building operations. Future investigations might build on this work by including other environmental variables such as CO_2 levels, airflow rates, and illumination settings. Furthermore, improving indoor climate management and energy efficiency in commercial and educational environments could be achieved through real-time sensor-driven HVAC changes.

Appendices

1. Data analysis – Notebook

   Heatanalysis_cafe&studio.ipynb

2. Python code –

   Python code.py

3. Raspberry Pi – Notebook Setup.

   dht11_write.ipynb