Enhancing Air Quality Policies at the Creative Computing Institute

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GitHub repository

Data People and Society: Essay 2

MSc Data Science & Artificial Intelligence

University of the Arts London

June 2024

Introduction

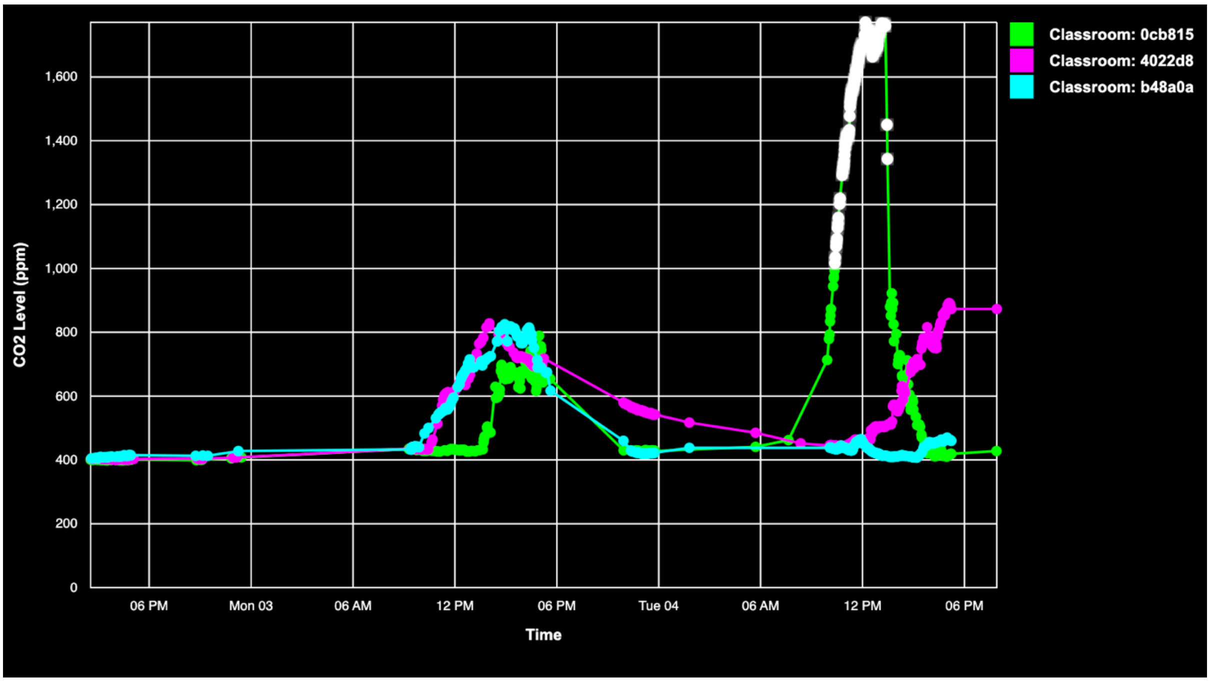
Air quality is a critical factor in ensuring a healthy and productive environment, especially in educational settings such as the Creative Computing Institute (CCI). Poor air quality can have significant adverse effects on both health and cognitive function, which in turn can impact student performance and well-being. This essay aims to **analyse the air quality data collected by CCI's sensors through MQTT data** between the period of the second to the fourth of June of 2024 across five different classrooms. It also aims to visualize the data to **understand trends and anomalies, critically analyse the findings, and recommend policies** to improve air quality at CCI.

Visualization of Collected Data

The data collected by CCI's air quality sensors include various parameters such as **Carbon Dioxide (CO2) levels, temperature, relative humidity, Total Volatile Organic Compounds (TVOC), Nitrogen Oxides (NOx), and particulate matter (PM1, PM2.5, PM10).** Visualizing these data helps in understanding the temporal variations and interrelationships between different parameters.

1. **Line Charts**: Line charts are used to track the variation of CO2 levels, temperature, and humidity over time. These charts help in identifying trends and fluctuations in the data, which are critical for assessing the indoor air quality during different periods, such as before and during class times.
2. **Heatmaps**: Heatmaps are used to visualize the relationship between temperature and humidity over time. By using colour intensity to represent humidity levels, heatmaps can help in identifying patterns and anomalies in the data, such as periods of high humidity that might require intervention.
3. **3D visualizations**: This are used to mostly be more interactive, eye-catching and dramatic to generate awareness of the identified data

Air Quality Visualization by Classroom (d3 visualization)

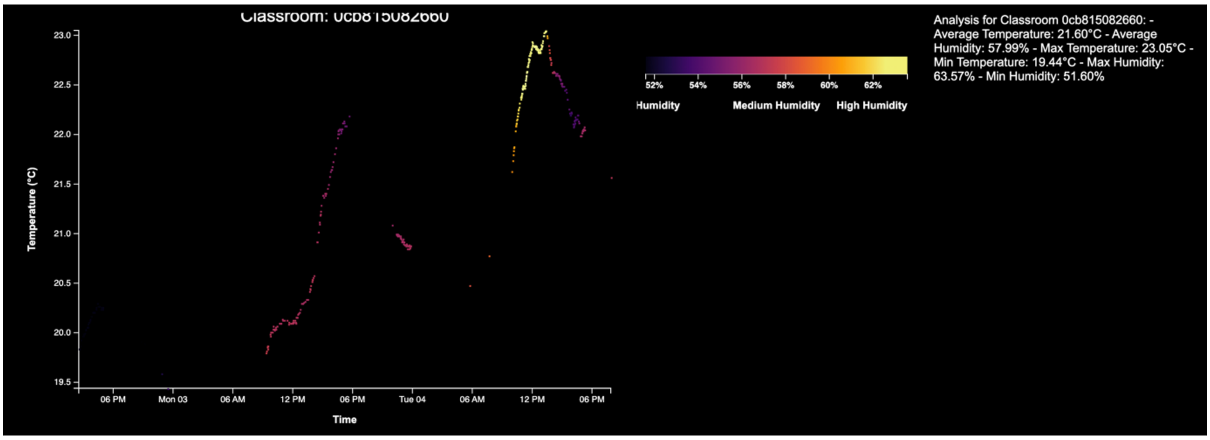


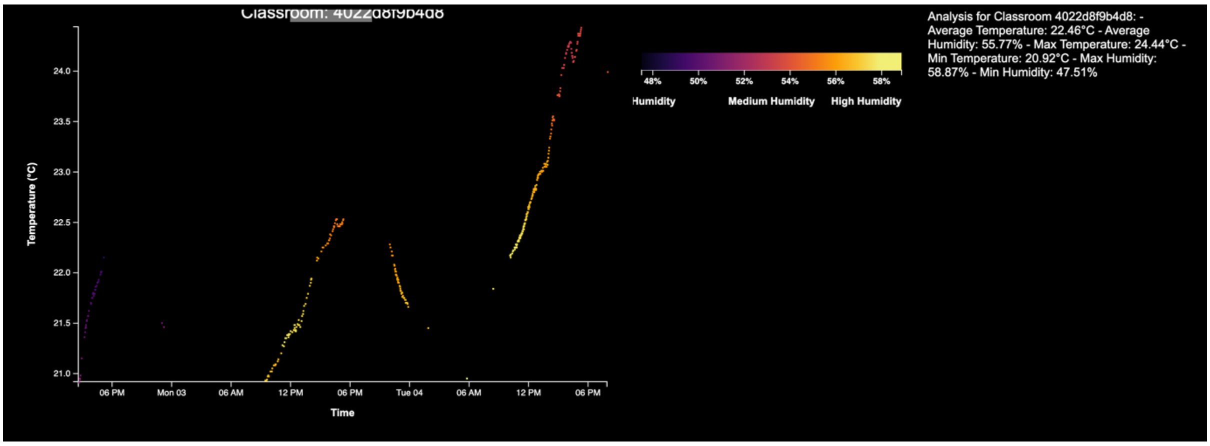
Through this graph, we can identify and highlight all the CO2 values that exceed the recommended safety threshold of 1000 ppm (UK, 2023). Notably, the "Green" classroom, representing the High Holborn classroom used by the MSc Data Science and BSc Data Science programs, shows different safety levels based on class sizes.

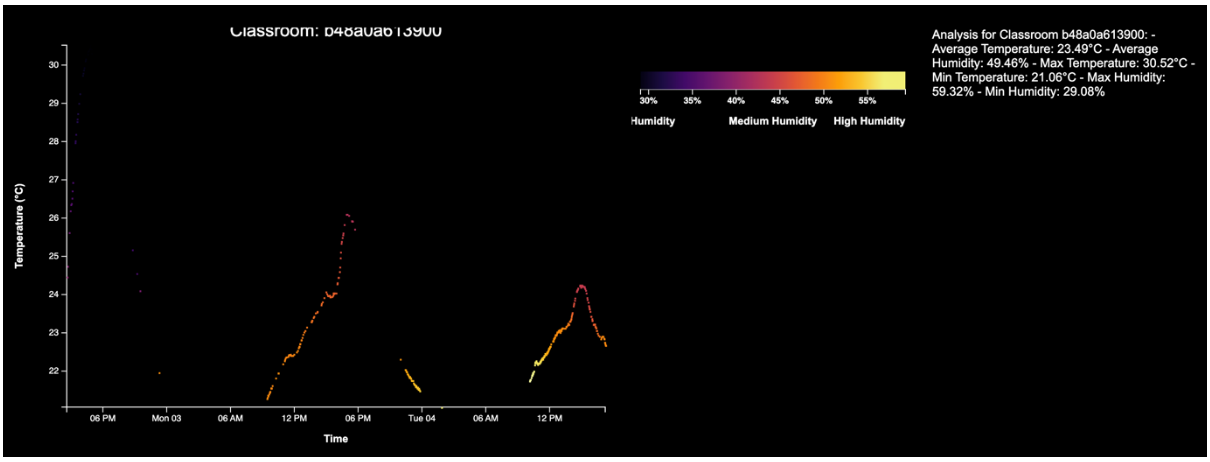
For the MSc students' class, held from 2 pm to 6 pm on "Mon 03", the data indicates that the classroom can safely accommodate up to 10-12 students under the current configuration. However, the BSc class, with around 25 students attending from 11 am to 2 pm on "Tue 04", clearly exceeds the recommended safety limits.

Although the classroom is designed to hold approximately 50 students, the **data demonstrates that, given the current air configuration, it should not exceed 16-18 students to maintain safe CO2 levels** unless other CO2 mitigation strategies are implemented.

Temperature and Humidity Heatmap by Classroom (d3 visualization)

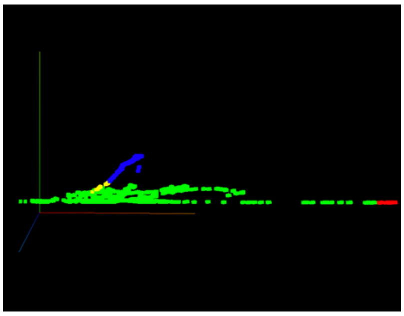
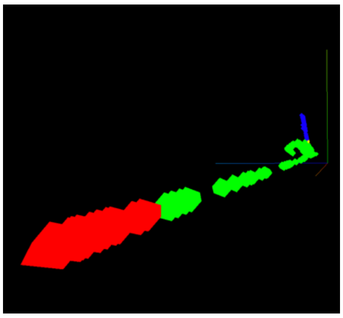
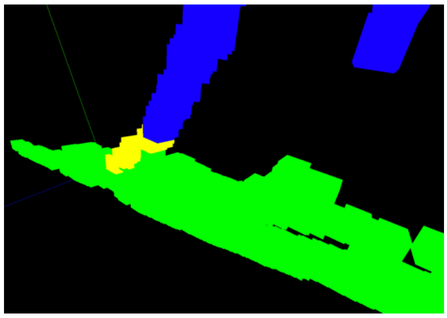


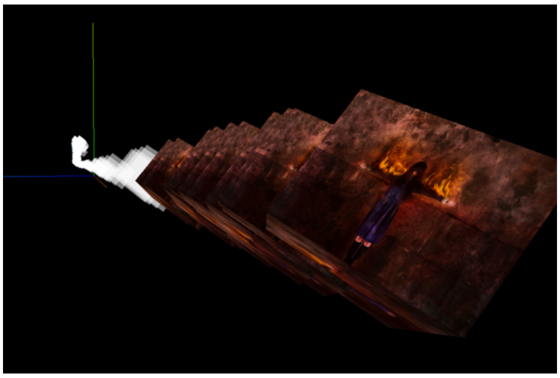
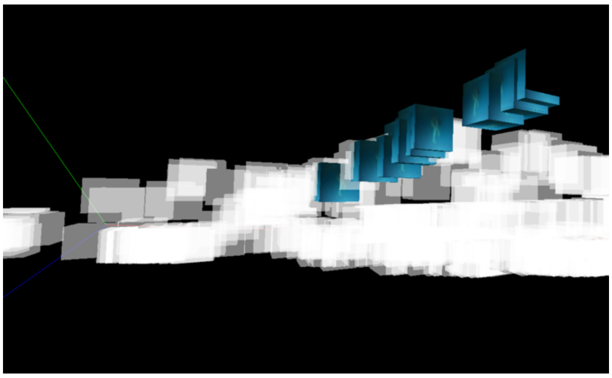




The calculated correlation coefficient is approximately -0.63, indicating a moderate to strong negative correlation between temperature and humidity. This means that **as the temperature increases, the humidity tends to decrease**. Nonetheless. Some inconsistencies are shown in the first chart showing that the highest humidity was also positively correlated with the highest temperature reached, it would be relevant to **assess which other causes could be altering humidity** in the environment since that can present a threat for students safety and because rationally it does not make sense and could be the effect of a leakage or other concerns. (Union, 2023)

3D Environmental Data Visualization: Correlating Temperature, CO2 Levels, and Humidity (d3 and ThreeJS visualization)

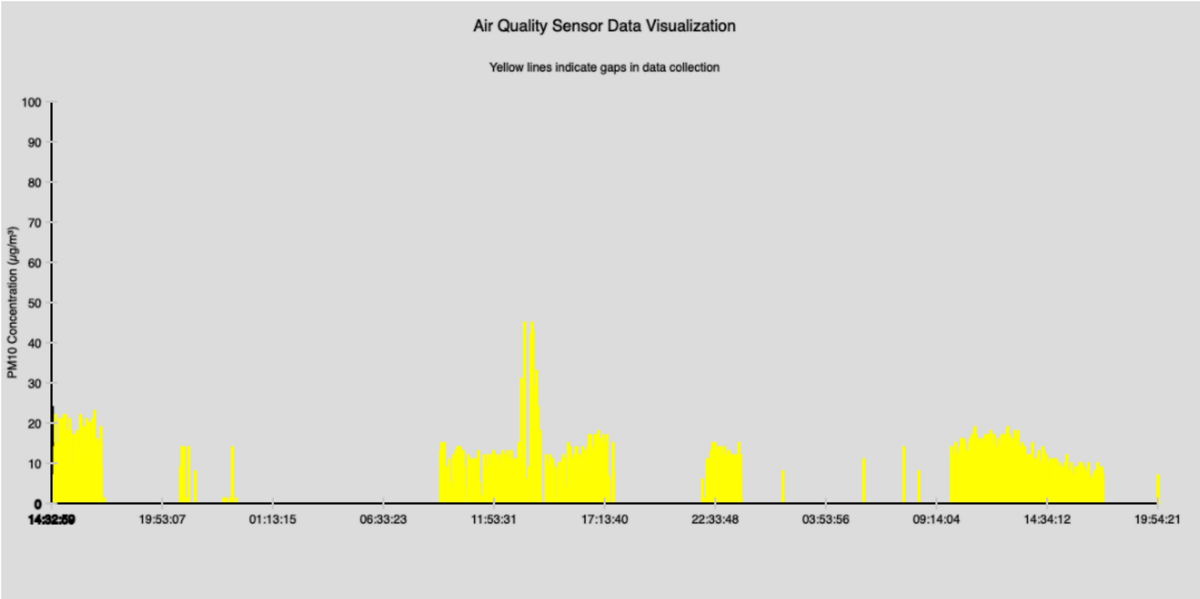
Live Video of the Visualization

The 3D visualization displays environmental data from the log file, mapping **temperature** (atmp) to the X-axis, **CO2** levels (rco2) to the Y-axis, and **humidity** (rhum) to the Z-axis. Each data point is represented by a cube positioned based on these three parameters. Axis labels help identify the dimensions, enhancing interpretability.

This visualization reveals interesting patterns and potential areas of concern, such as **cubes changing "texture" when exceeding recommended thresholds**: "burning silhouette" for temperatures above 30°C, "asphyxiating person" for CO2 levels above 1000 ppm, and "drowning body" for humidity levels above 60% RH. (AlicexLiddell, n.d.) (Bretoe, n.d.) (Condair, n.d.)

While this 3D visualization might not be as easy to interpret as traditional 2D plots, it can be highly effective for **data awareness** by the presentation of a more eye-catching and dynamic representation. It allows for simultaneous analysis of multiple variables, providing a comprehensive understanding of the data and highlighting outliers and extreme values in environmental monitoring data.

P5 Visualization on gaps of Data Recordings and Sensors Misreading



Despite the model to collect MQTT data was on for around 3 consecutive days, some gaps or misread data (e.g., negative values) were identified in collection. Hypothesis to be analysed consider that some sensors might break / stop for some periods because of maintenance requirements. This observation is relevant to take into consideration since the lack of data collection might affect the ability of CCI to take measures to ensure student's safety. Nonetheless, it is also worth it to have a look at the model to see potential errors that are causing it to stop storing the right data.

Use of Data to Affect Policy at the CCI

Data insights from air quality sensors can inform several policy changes at CCI to improve indoor air quality. **Optimizing HVAC settings** based on temperature and humidity data is crucial. **Regular maintenance schedules** should be established to ensure the sensors and HVAC systems function efficiently. **Real-time monitoring systems** can enable dynamic adjustments to maintain optimal air quality. **Educational policies** should promote healthy behaviours among staff and students, such as keeping windows closed during high pollution periods and reporting any discomfort promptly. **Space utilization strategies**, such as avoiding overcrowding and implementing staggered schedules, can also help manage indoor environmental conditions effectively.

Critical Analysis of the Data

The air quality data collected by CCI's sensors reveal several important trends and patterns:

1. **Trends and Patterns:**

   CO_2 Levels: The CO_2 levels are significantly higher during class periods compared to before, indicating increased human activity. High CO_2 levels can lead to reduced cognitive function and should be managed through improved ventilation.

   Temperature: The temperature is slightly higher during class periods, likely due to the presence of students and equipment. This increase, while not drastic, could affect comfort levels.

   Humidity: The relative humidity is slightly lower during class periods, which can be due to increased temperature and the operation of HVAC systems. Maintaining optimal humidity levels is essential for comfort and health.

   TVOC and NO_x: The TVOC index is lower during class periods, suggesting effective ventilation. The NO_x index remains relatively stable, indicating consistent external conditions.

2. **Implications:**

   Health and Comfort: Variations in CO_2, temperature, and humidity directly impact the comfort and health of students and staff. High CO_2 levels and temperatures can reduce cognitive performance and lead to discomfort.
   Effectiveness of HVAC Systems: The data suggest that the current HVAC systems may not be fully effective in maintaining stable indoor conditions, especially during peak occupancy times. This indicates a need for system optimization and regular maintenance.

3. **Limitations:**

   Sensor Accuracy: Potential inaccuracies in sensor data, such as negative or inconsistent readings, could affect the analysis. Regular calibration and maintenance of sensors are necessary to ensure data reliability.

   Incomplete Data: Missing or negative values can limit the comprehensiveness of the analysis. Ensuring complete and accurate data collection is essential for effective monitoring and policy-making.

4. **Addressing Limitations:**

   Calibration and Maintenance: Regular sensor calibration and maintenance are crucial to ensure accurate data collection. This includes checking for sensor drift and replacing faulty components.

Cross-referencing with External Data: Comparing indoor sensor data with external weather data can help in understanding the broader context and identifying external factors influencing indoor air quality.

Recommendations

Based on the data analysis, the following recommendations are proposed to improve air quality at CCI:

1. **HVAC Settings:**
   Adjust Temperature and Humidity Set Points: Set appropriate temperature and humidity levels to maintain a comfortable indoor environment. Use dehumidifiers to control humidity levels during high occupancy periods.

   Improve Air Circulation: Enhance air circulation through the use of fans and open windows during suitable weather conditions.

2. **Maintenance:**

   Regular Maintenance Schedules: Establish regular maintenance schedules for HVAC systems and sensors. This includes cleaning filters, checking for leaks, and ensuring all components are functioning correctly.

   Ensure Sensor Functionality: Regularly check and calibrate sensors to ensure accurate data collection. Address any issues with negative or inconsistent readings promptly.

3. **Monitoring:**

   Consider the installation of Advanced Monitoring Systems: Implement advanced monitoring systems to track air quality parameters in real-time. Use this data to make dynamic adjustments to HVAC settings based on occupancy and external weather conditions.

   Use Real-time Data for Adjustments: Leverage real-time data to make immediate adjustments to air quality settings, ensuring a stable and healthy indoor environment.

4. **Energy Efficiency:**

   Implement Energy-saving Practices: Use programmable thermostats and optimize the use of natural ventilation to save energy while maintaining air quality.
   Optimize Natural Ventilation: When weather permits, use natural ventilation to improve air quality and reduce the load on HVAC systems.

5. **Educational Policies:**
   Educate Staff and Students: Raise awareness about the importance of maintaining good air quality. Encourage behaviours that support healthy indoor environments,

such as reporting discomfort and keeping windows closed during high pollution periods.

Promote Healthy Behaviors: Implement policies that promote healthy behaviors among staff and students, such as reducing the use of personal air fresheners and maintaining clean and uncluttered spaces.

6. **Space Utilization:**

   Avoid Overcrowding: Avoid overcrowding in classrooms to reduce the impact on air quality. Implement staggered schedules to manage occupancy levels effectively.

   Implement Staggered Schedules: Use staggered schedules to ensure that classrooms are not overcrowded and that air quality can be maintained at optimal levels.

Potential Research

1. **Optimal Standards:**

   Indoor Air Quality Standards: Refer to guidelines from the World Health Organization (WHO) and Environmental Protection Agency (EPA) for recommended levels of CO2, TVOC, particulate matter, and other pollutants.

   Recommended Levels: Ensure that indoor air quality meets or exceeds these standards to provide a safe and comfortable environment for students and staff.

2. **Potential Risks:**

   Health Risks: High levels of CO2, TVOC, and particulate matter can have significant health impacts, including respiratory problems, cardiovascular issues, and reduced cognitive function.

   Impact on Performance: Poor air quality can negatively affect academic performance and overall well-being. Ensuring optimal air quality is essential for maintaining high performance levels.

3. **Additional Metrics:**

   Other Pollutants: Consider monitoring additional pollutants such as ozone, formaldehyde, and noise levels to provide a comprehensive assessment of indoor air quality.

   Environmental Factors: Monitor external environmental factors that may influence indoor air quality, such as outdoor pollution levels and weather conditions.

4. **Sensor Malfunctions:**

   Identifying Malfunctions: Develop protocols for identifying and addressing sensor malfunctions, such as negative readings or inconsistent data.

   Handling Errors: Ensure that faulty sensors are calibrated or replaced promptly to maintain the accuracy and reliability of air quality data.

<u>Strategy</u>

1. **Maximizing Performance:**

   Optimal Indoor Environments: Create indoor environments that support high academic performance by maintaining stable and comfortable temperature and humidity levels.

   Balancing Air Quality: Balance air quality parameters to ensure that classrooms are conducive to learning and free from pollutants that can hinder cognitive function.

2. **Minimizing Risks:**

   Reducing Exposure to Pollutants: Implement measures to reduce exposure to harmful pollutants, such as improving ventilation and using air purifiers.

   Ensuring Stability: Ensure that indoor environmental conditions remain stable during class times to minimize disruptions and maintain a conducive learning environment.

<u>Policies</u>

1. **Control**

   Quality of Hardware: Ensure that air quality sensors and HVAC systems are of high quality and reliable. This includes selecting reputable brands and regularly updating the technology used.

   Reports: Develop comprehensive reporting systems for air quality data. Regularly generate and review reports to monitor trends and identify any issues promptly.

2. **Maintenance**

   Regular Calibration and Upkeep: Schedule regular calibration and maintenance for all air quality sensors and HVAC systems. This includes cleaning, checking for wear and tear, and ensuring all components are functioning correctly.

   Timely Repairs and Replacements: Ensure that any faulty sensors or HVAC components are repaired or replaced promptly to maintain the accuracy and effectiveness of the air quality monitoring system.

3. **Communication**

   Raising Awareness: Educate staff and students about the importance of maintaining good air quality. Provide information on how they can contribute to a healthy indoor environment, such as by keeping windows closed during high pollution periods and reporting any discomfort promptly.

   Measures for Risky Situations: Establish clear protocols for addressing high-risk air quality situations. This includes procedures for evacuating classrooms if necessary and steps to improve air quality quickly.

4. **Product Development**

   Alerts and Recommendations: Develop an alert system that notifies staff and students when air quality parameters exceed safe levels. Provide recommendations for actions to take in these situations, such as increasing ventilation or reducing occupancy.

   Public Displays: Install public displays that show real-time air quality data in common areas. This transparency can help raise awareness and encourage proactive behaviours to maintain good air quality.

<u>Conclusion</u>

In conclusion, maintaining optimal air quality in educational environments like the Creative Computing Institute is crucial for the health, comfort, and performance of students and staff. The data collected by air quality sensors provide valuable insights that can inform policy changes to improve indoor air quality. By visualizing and analysing this data, we can identify trends, understand the impacts of different environmental parameters, and develop effective strategies to address any issues.

Implementing recommendations such as optimizing HVAC settings, establishing regular maintenance schedules, enhancing monitoring systems, promoting energy-efficient practices, and educating the community can significantly improve air quality. Additionally, developing clear policies for hardware control, maintenance, communication, and product development will ensure that these improvements are sustainable and effective.

By taking these steps, the Creative Computing Institute can create a healthier, more comfortable, and more productive learning environment, ultimately enhancing the overall educational experience for its students and staff.

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