Smart Environmental Monitoring Pilot: Effects on Student Productivity via Surveys and Sensors

Estefania Orjuela Parra[1], Sam Saleh[1], Kobe Mendoza[1], Gabriel Paguio[1], Cassidy J Rucker[2], Sarahana Shrestha[2,3], Pankaj Lal[2,3] and Michelle Zhu[1]
1. School of Computing, 2. Clean Energy & Sustainability Analytics Center, 3. Earth and Environmental Studies
Montclair State University, Montclair, NJ USA
orjuelaparre1, salehs7, mendozak1, paguiog1, ruckerc, shresthas1, lalp, zhumi@montclair.edu

Abstract - **This study investigates the impact of temperature and humidity on student well-being and productivity using a Raspberry Pi-based environmental monitoring system. Conducted as a pilot project within a single semester, this research deployed sensor kits across six different campus locations to collect real-time data on ambient temperature and humidity conditions. Simultaneously, a survey was administered to gather self-reported data on students' feelings and productivity in relation to the recorded environmental conditions. Utilizing chi-square tests to explore the relationships between these environmental factors and students' self-reported feelings and productivity, our findings indicate that while there are trends suggesting optimal environmental conditions, the results were not statistically significant due to the limited sample size and the brief data collection period. The study highlights the importance of moderate environmental conditions, with preliminary data suggesting that certain temperature and humidity levels may influence student comfort and cognitive performance. However, the lack of significant findings underscores the need for extended data collection over multiple seasons and with a larger cohort to enhance the reliability and generalizability of the results. This pilot project lays the groundwork for more comprehensive studies aimed at optimizing learning environments to support student success, emphasizing the importance of automating data collection processes and expanding the sample size to better understand the impacts of environmental variables on educational outcomes.**

Index Terms - Campus Climate, Raspberry Pi Sensors, Student Productivity, Student Well-being

INTRODUCTION

Maintaining optimal indoor environmental conditions is critical for enhancing comfort, productivity, and overall well-being—particularly in educational settings. Research has consistently shown that factors such as temperature and humidity can significantly influence productivity and comfort levels among students [1, 2]. Moderately elevated classroom temperatures have been associated with reduced academic performance, emphasizing the need for continuous environmental monitoring in schools and universities [3]. Ventilation, thermal conditions, and occupants' health are linked with the productivity in commercial and educational buildings [4,5]. With increasing concerns over climate change and its impact on academic environments, understanding the temperature and humidity levels on college campuses has become crucial.

Recent technological advances have made low-cost, Internet of Things (IoT) solutions increasingly accessible for monitoring indoor environmental parameters [6]. Single-board computers such as the Raspberry Pi now offer powerful yet affordable platforms capable of collecting, processing, and transmitting sensor data in real time. Moreover, add-on sensors (e.g., DHT11, DHT22) can measure temperature and humidity with reasonable accuracy, making them ideal for small-scale pilot projects [7,9]. By leveraging open-source software ecosystems and cloud storage services, these systems can facilitate automated data collection and analysis, enabling stakeholders to make informed decisions about improving classroom or laboratory conditions.

However, while the technology is readily available, studies focusing on integrating quantitative environmental measurements with student self-reported well-being and productivity remain less common. Most existing research tends to either measure environmental data or survey occupants, but not together. Bridging this gap can provide a holistic picture of how environmental factors interact with students' subjective experiences. It is especially relevant in higher education, where environmental conditions can influence classroom engagement, study habits, and academic outcomes.

This research leverages Raspberry Pi sensor kits to gather real-time temperature and humidity data across multiple campus locations, laying the groundwork for understanding how these environmental factors influence student comfort and learning conditions. We describe the pilot environmental monitoring system, including hardware setup, software configuration, and data collection protocols, alongside chi-square analyses that assess the relationships between measured variables (temperature and humidity) and student well-being and productivity. Integrating qualitative and quantitative data, the objectives of this study are:

- Develop a pilot environmental monitoring system using low-cost Raspberry Pi sensors.
- Identify patterns and fluctuations in temperature and humidity across different campus locations.

- Examine the impact of environmental conditions on student comfort, well-being, and academic performance.
- Establish a scalable architecture that can be expanded to larger sample sizes and extended timeframes.

Ultimately, this pilot study serves as a steppingstone toward more comprehensive, long-term monitoring efforts, providing insights that can help optimize campus environments, promote better learning conditions, and enhance overall student satisfaction.

RELATED WORK

The Raspberry Pi system, when attached to a DHT11 sensor offers a cost-effective and portable monitoring hardware system, in which users can design its function and use. This system is ideal for monitoring the temperature and humidity of indoor environments and has been used in smart homes and other controlled spaces [6]. The system also allows for data collected to be transferred through wireless internet or ethernet to a cloud-based storage and file system of the user's choice, through the python software, enabling continuous logging and remote access to environmental measurements.

The framework of the Raspberry Pi can be divided into two components: hardware and software. The hardware is included in the purchased Raspberry Pi kit, which consists of a DHT11 sensor, LCD display, breadboard and wire components. When assembled correctly with the added software, this can continuously record temperature and humidity measurements. The software is provided via the Raspberry Pi's website, which can be downloaded and installed onto the hardware. Xie et al outlined their design of the Raspberry Pi and sensor with its capabilities of connecting to an online cloud-based platform called OneNet. This allowed the system to give access to the collected data on an android mobile app [6]. Our pilot project aims to use this outlined design but due to time constraints and product availability, Google Drive and Rclone were used for exporting the data. The Raspberry Pi system can also be connected to external batteries and other power sources, as done by Adiono et al in an experiment monitoring the temperature and humidity measurements collected over a 24-hour period [7]. For this pilot research, data does not need to be collected continuously in that larger time frame, but between 2-4 hours within each sampling location. The potential for monitoring and collecting data in real time over in both shorter and longer time periods further supports the flexibility and capacity of the Raspberry Pi system.

Environmental monitoring in classrooms and academic settings have impacts on learning and student comfort, which have been the subject of study for many years. Accurate temperature and humidity monitoring can help optimize classrooms increasing student engagement, comfort, and performance. Jiang et al. conducted a study observing the relationship between the temperature of student environments and thermal comfort and noted the impacts on student performance. They identified a quantitative relationship between temperature and thermal comfort of the students and their results indicated that higher temperatures led to more efficient and engaging learning. Their findings concluded schools should take action to create a more holistic classroom heating and cooling design to promote higher learning achievements and increase student comfort [10].

Humidity control is another factor that impacts student learning and comfort as well as their health. Schools have the complicated task of designing the building and HVAC structures and to set safe temperature and humidity settings within the facilities. This can be difficult at times where there are high numbers of people in the buildings. Humidity can lead to poor air quality which results in higher numbers of respiratory illnesses like asthma (such as with mold growth) and allergies, which greatly harms student health and wellbeing and causes interruptions in class [10]. This pilot project does not incorporate the building heating and cooling systems into the analysis due to time constraints however, the survey data from students at each of the locations on campus provides an insight into the students' wellbeing which was compared to the continuous humidity measurement captured by the Raspberry Pi system. This allowed for an analysis of the potential relationship between humidity and wellbeing reported.

Using Raspberry Pi with multiple sensors in one classroom location, has been achieved by Navarrete-Sanchez et al. in their Internet of Things (IoT) study which developed a simple and scalable system for real-time environmental monitoring in a classroom. This supports the potential use of the Raspberry Pi system in academic settings, its range from one classroom to many and collecting continuous temperature data [9]. An observational study conducted by Fretes et al. over a four-week period in a secondary classroom in Spain recorded the temperature and other environmental variables in ten-minute intervals while simultaneously documenting students' emotions using emotional recognition technology. The results suggested that the temperature and humidity variables were associated with an emotional response from the students but note that other factors influencing their emotions could not be omitted [12].

Our research expands on the use of the Raspberry Pi system by utilizing our DHT11 sensor in multiple locations on the main college campus where students aggregate to learn and study outside the classrooms. Each location is unique in terms of building layout, student gathering (sitting versus standing and sitting alone versus in groups of two or more) and shifting occupancy density. While this study does have limitations, including shorter time intervals for testing and small data sets, our focus is on capturing the students' wellbeing and emotions in real time while observing the temperature and humidity variables in different areas with fluctuating activity levels.

DATA AND METHODS

I. Data Collection

This study was conducted at Montclair State University, New Jersey, USA. Both quantitative environmental measurements and qualitative survey responses (n = 29) were collected. Temperature and humidity data were recorded in real-time using Raspberry Pi devices equipped with DHT22 sensors at ten different locations across six buildings while students were simultaneously surveyed. A Google Forms survey was administered comprising 16 questions: 6 demographical and 10 assessing productivity and well-being in relation to ambient temperature. The survey was conducted in person at these buildings:

1. Center of Environmental and Life Sciences (CELS)
2. Feliciano School of Business (SBUS)
3. Susan A. Cole Hall (COLE)
4. Richardson Hall (RICH)
5. Schmitt Hall (SCHM)
6. Center for Computing and Information Science (CCIS)

During each site visit, participants were briefed on the study's purpose and given the option to participate. Survey responses were automatically saved in Google Forms for later analysis. Simultaneously, the Raspberry Pi system was deployed at each site to capture corresponding temperature and humidity readings. This enabled us to correlate environmental conditions with student responses, providing accurate readings that could be directly correlated with student feedback. After the data collection phase, both datasets were merged for further analysis, enabling a correlation study between environmental conditions and reported well-being/productivity.

II. Equipment Set Up (Hardware)

A Canakit Raspberry Pi 5 was assembled with DHT11 temperature and humidity sensor to collect data, and an LCD screen to display the readings, alongside a breadboard, GPIO extension board, 40-pin ribbon cable, various jumper wires (female-to-male and male-to-male), and 10k pull-up resistors. The sensor was connected to the Raspberry Pi through a GPIO extension board using a 40-pin ribbon cable, serving as a bridge, to reduced clutter and minimize accidental disconnects. This allowed the DHT11 sensor, and the LCD display to easily communicate with the Raspberry Pi.

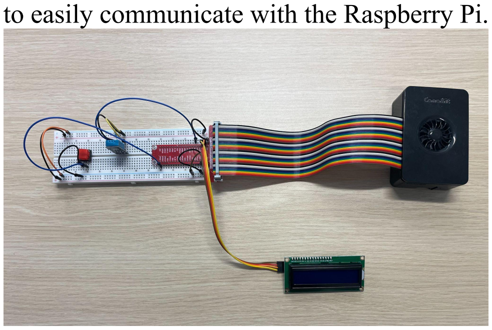

FIGURE I

RASPBERRY PI SYSTEM SET-UP

The DHT11 temperature and humidity sensor was mounted on a breadboard which provided a stable platform for the wire connections. The breadboard served as the central hub for all the wired connections. This approach made it simple to adjust components during the development and testing phases. Female-to-male wires and jumper wires were used to link the sensor to the GPIO pins on the Raspberry Pi. The sensor was powered with a 3.3V supply from the Raspberry Pi and was grounded using a shared ground line on the breadboard. The DHT11 temperature and humidity sensor requires a 10k pull-up resistor for stable communication between the sensor and the Raspberry Pi. The 10k value is optimal because it has a strong pull-up without drawing excessive current.

The LCD's power and ground pins were also routed to the breadboard, ensuring the correct voltage and current levels, to prevent overloading the system. For cooling purposes, the Raspberry Pi was housed in a Caha Kit case equipped with a fan which provided ventilation to prevent overheating, as well as adding durability, protection and portability for relocation and testing. Once assembled, the system was powered on and tested to confirm the DHT11 sensor readings were accurately transmitted and displayed on the LCD.

III. Software Development

The software development hinged on the DHT11 sensor functionality library, and a singular python file within to read and display the temperature and humidity continuously on both Thonny's output, and the LCD screen. A subsequent modification enabled the script to generate an html file consisting of a three-column table for the temperature, humidity, and time recorded. The script updates continuously, extracting and saving data into the html file as long as it runs. Figure II shows an example of said table of results from the School of Business (SBUS) building, one of the six locations where the data was collected.

Results of School of Business First Floor

Temperature	Humidity	Time
62.6	22%	11:17:04.093124
62.6	22%	11:17:06.365885
62.6	22%	11:17:08.637355
62.6	22%	11:17:10.905800
62.6	22%	11:17:13.174897
62.6	22%	11:17:15.444609
62.6	22%	11:17:17.720449
62.6	22%	11:17:19.996785
62.6	22%	11:17:22.267595
62.6	22%	11:17:24.539278
62.6	22%	11:17:26.814584

FIGURE II

EXAMPLE OF HTML FILE WITH THE TABLE PRODUCED BY THE PROGRAM IN RASPBERRY PI FOR SBUS FIRST FLOOR LOUNGE

After installing and configuring the DHT11 module on a virtual machine, the necessary files were copied into the Raspberry Pi's working folder. Accessing the DHT11 sensor from the python file was done using the dtoverlay driver. DTOVERLAY DHT11 was installed by modifying the config.txt file in the Raspberry Pi. By navigating to the "/sys/bus/iio/devices" folder from the terminal, the DHT11 was successfully confirmed to be recognized, and its readings were programmatically accessed at one-second intervals. The readings were converted to Fahrenheit and stored in a newly created html file.

To store data remotely, the Raspberry Pi was mounted to Google Drive using Rclone. After installing

Rclone via a Debian package and creating a client ID and secret on the Google Developer Console, the user authenticated the device, granting it file system access to a dedicated project folder on Google Drive. The Client ID and secret were used for configuring rclone. All files in the top-level directory of the Google Drive are listed and can be accessed from the Raspberry Pi.

IV. Analysis using Chi-square

For the purpose of the analysis, a chi-square test was used. Despite the temperature and humidity readings being numerical variables, they had a limited range of distinct values due to the nature of our data collection. Because the chi-square test is specifically designed for categorical data, treating temperature and humidity as a categorical variable allowed us to analyze its relationship with the students' feelings and their perceived productivity. Students were surveyed on how they were feeling on a Likert scale (0-5), with 0 representing "Feeling stressed, low energy, or just not my day" and 5 representing "Feeling excited, energized, and productive". Figure III shows the Likert Scale that was used in the survey for students to select what best described how they were feeling at that moment. Additionally, students were asked about their current productivity, categorized into three levels: 1 for "Alert (productive and engaged)," 0 for "Neutral," and -1 for "Tired (fatigued, burned out, distracted)." The Chi-Square test was used to test for independence to examine potential associations between temperature and humidity with students' feelings and productivity. Data analysis was performed using Python's scipy.stats library, focusing on Chi-Square statistics, degrees of freedom (DoF), and p-values. A significance threshold of 0.05 was used for all tests.

FIGURE III
LIKERT SCALE FOR STUDENTS TO SELECT WHAT DESCRIBES BEST HOW THEY WERE FEELING AT THE MOMENT OF THE SURVEY

RESULTS AND DISCUSSION

I. Descriptive Findings

We surveyed 29 undergraduate students (n = 29). Among the respondents, 37.9% were seniors, 6.9% juniors, 20.7% sophomores, and 34.5% freshmen (Figure IV). The gender distribution was 58.6% female and 41.4% male. Participants ranged in age from 18 to 28, with 79.3% falling between the ages of 18 and 21. Regarding temperature preferences while studying, 55.2% preferred a warmer environment, 27.6% preferred cooler conditions, and 17.2% had no preference.

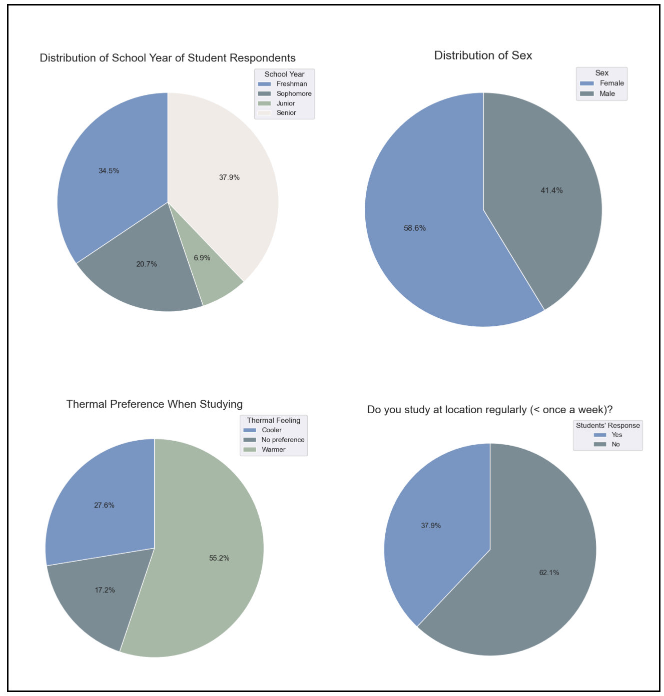

FIGURE IV
PIE CHARTS ILLUSTRATING THE DISTRIBUTION OF ACADEMIC STANDING, GENDER, AGE, AND TEMPERATURE PREFERENCES AMONG SURVEYED STUDENTS

II. Chi-Square Test Findings

The results of the chi-square test are shown in Table I, which shows the relationship between temperature and humidity with how the students were feeling and their productivity level. The chi-square shows that relationship between how students' were feeling to be not statistically significant with temperature ($\chi^2(16)$ =24.86, p= 0.07), as well as with the humidity ($\chi^2(16)$ = 19.03, p = 0.27) as the p-values for both the tests were more than 0.05, which is the significance threshold set. Our results also show no significant statistical relationship between students' productivity with temperature ($\chi^2(16)$ = 8.96, p = 0.35) and humidity ($\chi^2(8)$ = 10.98, p = 0.20). This analysis was limited by a small sample size of only 29 participants. This small dataset reduces the statistical power of the Chi-Square tests, potentially masking meaningful correlations. To improve the reliability and validity of these findings, additional data collection is necessary. A larger sample size will allow for a more robust analysis and a deeper understanding of the relationships between temperature, humidity, student well-being, and productivity.

TABLE I

CHI-SQUARE TEST RESULTS

	Variable Pair	Chi-Square Statistic	Degrees of Freedom	p-value
1	Temperature vs Students' Feelings	24.86	16	0.07
2	Humidity vs Students' Feelings	19.03	16	0.27
3	Temperature vs Students' Productivity	8.96	8	0.35
4	Humidity vs Students' Productivity	10.98	8	0.20

Box Plot Visualization: To visualize the relationships examined in our chi-square tests, we generated four box plots (Figures V.I-V.IV) corresponding to Students' Feelings vs Temperature, Students' Feelings vs Humidity, Productivity vs Temperature, Productivity vs Humidity.

Each box plot displays the median (red line), the interquartile range (IQR) (the box's upper and lower hinges at the 75th and 25th percentiles), and any data outliers (points beyond the whiskers). In cases where the box collapses to a single line (e.g., at 62.6°F in Figure V.I), it indicates that all or the vast majority of responses for that temperature were the same (in this instance, a feeling rating of 4). Although a few data points appear as outliers, these are likely due to normal variability given the small sample size.

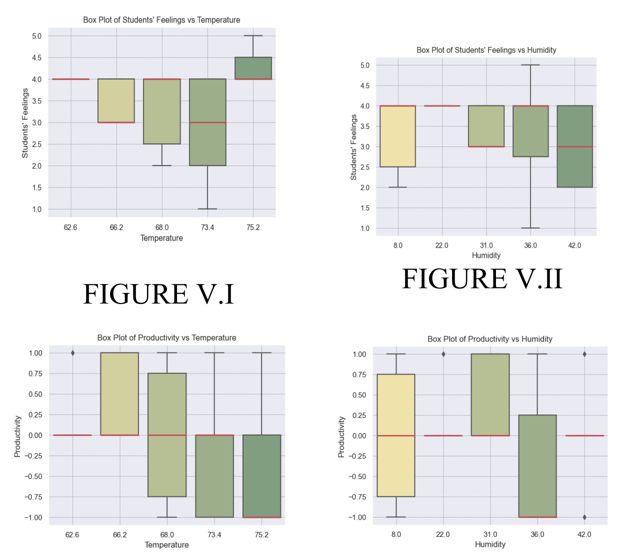

FIGURE V.I

FIGURE V.II

FIGURE V.III

FIGURE V.IV

FIGURE V

BOX PLOTS (V.I-V.IV) ILLUSTRATING THE DISTRIBUTION OF DATA FOR THE FOUR RELATIONSHIPS EXAMINED IN THE CHI-SQUARE ANALYSES: (V.I) STUDENTS' FEELINGS VS. TEMPERATURE (°F), (V.II) STUDENTS' FEELINGS VS. HUMIDITY (%), (V.III) PRODUCTIVITY VS. TEMPERATURE (°F), AND (V.IV) PRODUCTIVITY VS. HUMIDITY (%)

Temperature and Students' Feeling: Students' feelings generally remained neutral to positive across temperatures ranging from 62.6°F to 75.2°F (Figure V.I). The median ratings consistently exceeded a score of 3. Notably, temperatures of 62.6°F, 66.2°F, and 73.4°F each had a median feeling rating of 4, indicative of comfort. However, the widest IQR at 73.4°F suggests the greatest variability in feelings at this temperature, possibly due to a larger data set contributing to this point.

Humidity and Feelings*:* Similarly, feelings were relatively stable across varying humidity levels from 8% to 42%, with slight increases in variability at the highest tested humidity (Figure V.II). Despite varying humidity, the sentiment generally remained positive, with a consistently narrow spread indicating uniform responses.

Temperature and Productivity: Productivity ratings across temperatures were mostly neutral, centered around a score of 0 (Figure V.III). However, cooler temperatures, specifically 62.3°F and 68°F, displayed higher upper hinges, suggesting that these conditions may be more conducive to productivity.

Humidity and Productivity: Across the humidity spectrum, productivity similarly centered around neutral, with a slight variation at 36% humidity showing the highest proportion of negative productivity responses, implying that this level may hinder concentration (Figure V.IV)

. These findings show that while students can adapt to a range of environmental conditions, extremes in temperature and humidity may challenge their comfort and productivity. Our analysis suggests a need for moderate environmental control in educational settings to optimize both comfort and learning outcomes.

Histogram Visualization: Additionally, we also created 4 stacked histograms, Figures VI.I to V.IV, that illustrate the distribution of students' feelings (rated on a scale of 1 to 5) at the five distinct temperature levels. The x-axis represents temperature, while the y-axis indicates the total count of responses. Each bar is segmented into color-coded sections that correspond to the amount of students that chose each answer for how they were feeling. The colors allow for easy differentiation of the contributions of each rating to the total count within each distinct temperature.

. Our analysis of the histograms (Figures VI.I to VI.IV) reveals significant insights into how temperature and humidity affect students' feelings and productivity. Figure VI.I indicates a preference for moderate temperatures, with students expressing the most positive feelings at 68.0°F. In contrast, higher temperatures, such as 75.2°F, resulted in less comfort, suggesting an optimal temperature range that maximizes student comfort [13]. Humidity levels showed a similar pattern in Figure VI.II, where mid-range humidity levels (31% to 36%) were associated with more favorable feelings. This indicates a comfort zone in mid-range humidity that is ideal for maintaining cognitive clarity and reducing the physiological stress caused by either too high or too low humidity levels [14].

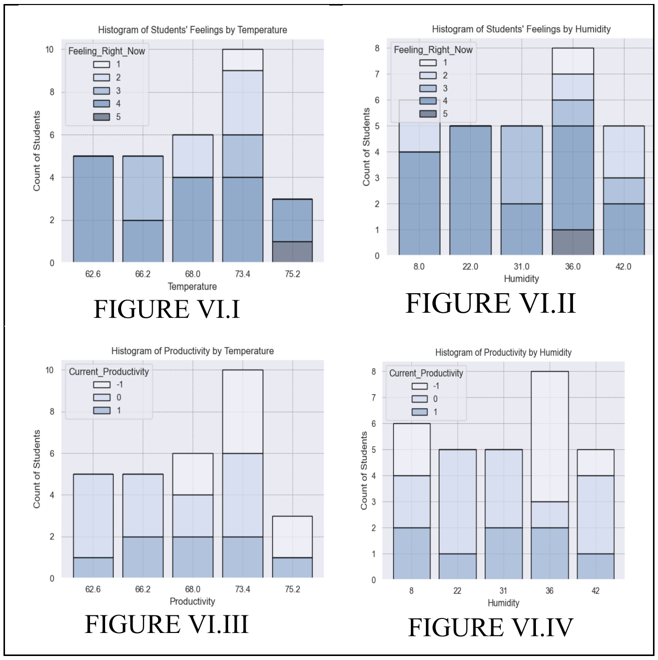

FIGURE VI

STACKED HISTOGRAMS (VI.I-VI.IV) DISPLAYING THE DISTRIBUTION OF STUDENTS' FEELING RATINGS AND CURRENT PRODUCTIVITY (ON A 1–5 SCALE) ACROSS DISTINCT TEMPERATURE LEVELS (°F) AND HUMIDITY (%)

Regarding productivity, as depicted in Figure VI.III, cooler temperatures were associated with higher productivity, with peaks at 62.6°F and 68.0°F. This trend suggests that cooler, but not overly cold, temperatures might be conducive to better concentration and learning outcomes. Figure VI.IV further supports the notion that humidity has a nuanced impact on productivity; while moderate humidity levels (22% to 36%) were mostly neutral in their effects, higher humidity at 42% led to a decrease in productivity [15-20]. This observation aligns with the temperature data, underscoring the importance of maintaining moderate environmental conditions within educational settings to foster optimal student performance and well-being. This concurrence between the histogram and box plot data underscores the nuanced impacts of environmental variables on student performance and well-being, highlighting the necessity for maintaining moderate conditions to optimize academic outcomes and comfort within educational settings.

CONCLUSION AND FUTURE WORKS

This study has established a foundational framework for assessing the impact of temperature and humidity on student well-being and productivity using Raspberry Pi sensor kits. The analysis conducted in this study explored potential relationships between indoor environmental conditions, specifically temperature and humidity and student well-being and productivity. While the results are not statistically significant, most likely due to the limited sample size and the brief data collection period within a single semester [21-22], they highlight potential trends that call for further research in this area. The use of Raspberry Pi sensors has shown their effectiveness in capturing environmental data in educational settings, offering preliminary insights into optimal conditions for student performance and comfort. This study also emphasizes the importance of adequate sample sizes and extended data collection periods to achieve reliable and generalizable results.

Recognizing the limitations of this pilot project, particularly its scope and the duration of data collection, future efforts will focus on expanding the research in several key areas:

- Prolonged study spanning at least one full academic semester, allowing us to gather a larger dataset, improving the statistical power and reliability of the results. By capturing data across different seasons, we can also assess the impact of seasonal variations on student responses, providing a more comprehensive understanding of environmental influences.
- Automating the data transfer process to upload temperature and humidity readings directly to cloud services to streamline data management and facilitate real-time analysis.
- Deploying sensors in various classroom settings and possibly across different campus buildings to analyze how different architectural environments affect student comfort and productivity.

In conclusion, this pilot study serves as a stepping stone for more extensive research into the environmental conditions of educational spaces. By addressing the limitations noted and employing the proposed enhancements, future studies can provide more definitive evidence on how to optimize learning environments to support educational success and student well-being.

ACKNOWLEDGMENT

We would like to acknowledge the Clean Energy and Sustainability Analytics Center (CESAC) and Montclair State University's School of Computing for the use of the Raspberry Pi kit and equipment for this research. We also express our gratitude to the Montclair students for their participation in our survey from this project.

REFERENCES

[1] Bakó-Bíró, Zs, Clements-Croome, Derek J., Kochhar, Neena, Awbi, Hazim B., and Williams, Marilyn J. 2012. "Ventilation Rates in Schools and Pupils' Performance." *Building and Environment*, vol. 48, pp. 215–223.

[2] Sadrizadeh, Sasan, Runming, Yao, Feng Yuan, Hazim Awbi, William, Bahnfleth, Yang, Bi, and Guangyu, Cao, et al. 2022. "Indoor Air Quality and Health in Schools: A Critical Review for Developing the Roadmap for the Future School Environment." *Journal of Building Engineering*, vol. 57, p. 104908.

[3] Wargocki, Pawel and Wyon, David P. 2013. "Providing Better Thermal and Air Quality Conditions in School Classrooms Would Be Cost-Effective." *Building and Environment*, vol. 59, pp. 581–589.

[4] Liu, Chao, Zhang, Yalin, Sun, Limei, Gao, Weijun, Jing, Xiaotong, and Ye, Weirui. 2021. "Influence of Indoor Air Temperature and Relative Humidity on

Learning Performance of Undergraduates." *Case Studies in Thermal Engineering*, vol. 28, p. 101458.

[5] Wang, Chao, Fan, Zhang, Wang, Julian, Doyle, James K., Hancock, Peter A., Mak, Minkg, Cheuk, and Liu, Shichao. 2021. "How indoor environmental quality affects occupants' cognitive functions: A systematic review." *Building and environment*, vol. 193 pp. 107647.

[6] Vatsal, Shah, and Mehta, Bhavin. 2017. "Using raspberry pi to sense temperature and relative humidity." *Int. Res. J. Eng. Technol* 4, no. 2, pp. 380-385.

[7] Yongsheng, Xie, Hong, Ding, and Fendong, Huang. 2019. "Design of Temperature and Humidity Measuring System Based on Raspberry Pie" *Association for Computing Machinery, New York, NY, USA*, pp. 610–615.

[8] Adiono, T., Fathany, M.Y., Fuada, S., Purwanda, I.G, and Anindya S.F. "A portable node of humidity and temperature sensor for indoor environment monitoring,". *2018 3rd International Conference on Intelligent Green Building and Smart Grid (IGBSG)*, Yilan, Taiwan, 2018, pp. 1-5.

[9] M.A. Navarrete-Sanchez1, Re. Olivera-Reyna, Ro. Olivera-Reyna,R. J. Perez-Chimal, and J. U. Munoz-Minjares. 2025. "IoT-Based Classroom Temperature Monitoring andMissing Data Prediction Using Raspberry Pi and ESP3", *Journal of Robotics and Control (JRC*), 2024, vol. 6, pp. 234-245.

[10] Jing, Jiang, Dengjia, Wang, Yanfeng, Liu, Yuhui, Di, and Jiaping, Liu. 2021. "A holistic approach to the evaluation of the indoor temperature based on thermal comfort and learning performance," *Building and Environment*, vol. 196, pp. 107803.

[11] Fischer, John C., and Bayer, Charlene W. 2003. "Humidity control in school facilities.", *Energy,* vol. 30.35, pp. 606-613.

[12] Fretes, G., Llurba C., and Palau, R. "Exploring classroom temperature and humidity on students' emotions through IoT and image processing", 2024. *Journal of Infrastructure, Policy and Development,* vol. 8.7, pp. 1-14.

[13] Fengyu, Lin, Qin, Tiffany, Tsuyuki, Miranda, Wang, Amy, and You, Shuhan . "No chill: Heat-related student stress in varied classroom occupancy."2023. *University of British Columbia*, pp. 1-24.

[14] Hamzah, Baharuddin, Zhonghua Gou, Rosady Mulyadi, and Samsuddin, Amin. 2018. "Thermal comfort analyses of secondary school students in the tropics." *Buildings 8*, no. 4, pp. 56.

[15] Bueno, Ana Maria, Antonio Augusto de Paula Xavier, and Evandro Eduardo Broday. 2021."Evaluating the connection between thermal comfort and productivity in buildings: A systematic literature review." *Buildings* 11.6 pp. 244.

[16] Voordt, Theo Van Der, and Per Anker Jensen. 2023 "The impact of healthy workplaces on employee satisfaction, productivity and costs." *Journal of Corporate Real Estate 25*, no. 1, pp. 29-49.

[17] Soto Munoz, Jaime, Trebilcock Kelly, Maureen, Flores-Alés, Vicente, and Ramírez-Vielma, Raúl. 2022. "Understanding the perceived productivity of office occupants in relation to workspace thermal environment." *Building Research & Information 50*, no. 1-2, pp. 152-170.

[18] Hamed, Sapiah Abdul, Mohd Ramzi Mohd, Hussain, Haza Hanurhaza Md, Jani, Syikh Sazlin Shah, Sabri, and Nazrul, Rusli. 2023. "The impacts of physical workplace environment (PWE) on employees productivity." *International Journal of Business and Technology Management 5*, no. 4, pp. 369-376.

[19] Lan, Li, Pawel, Wargocki, Peter Wyon, David, and Zhiwei, Lian. 2011. "Effects of thermal discomfort in an office on perceived air quality, SBS symptoms, physiological responses, and human performance." *Indoor air 21*, no. 5, pp. 376-390.

[20] Wolkoff, Peder, Kenichi, Azuma, and Paolo, Carrer. 2021. "Health, work performance, and risk of infection in office-like environments: The role of indoor temperature, air humidity, and ventilation." *International Journal of Hygiene and Environmental Health* vol. 233, pp. 113709.

[21] Mascha, Edward J., and Vetter, Thomas R. 2018."Significance, errors, power, and sample size: the blocking and tackling of statistics." *Anesthesia & Analgesia* vol. 126.2, pp. 691-698.

[22] Singh, Ajay S., and Masuku, Micah B. 2014. "Sampling techniques & determination of sample size in applied statistics research: An overview." *International Journal of economics, commerce and management* vol. 2.11 pp. 1-22 .