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EFFECTS OF TEMPERATURE AND HUMIDITY ON STUDENT ACADEMIC PERFORMANCE IN FEDERAL POLYTECHNIC, DAMATURU

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ABSTRACT

This research investigates the impact of temperature and humidity on student academic performance in The Federal Polytechnic Damaturu. The research focuses on the relationship between environmental factors and Grade Point Average (GPA) from 2020 to 2023, incorporating academic records from the institution and weather data provided by the Nigerian Meteorological Agency. A regression analysis quantified the effect of temperature and humidity on GPA, revealing that for every 1°C increase in temperature, GPA dropped by approximately 0.03 points, and for every 1% rise in humidity, GPA decreased by about 0.01 points. The regression model had an adjusted R-squared value of 0.41, indicating that 41% of GPA variation could be explained by these environmental factors. The study confirmed negative correlations between GPA and both temperature and humidity. The average temperature ranged from 26.75°C to 32.71°C, with the highest recorded on 2023-06-07, while humidity ranged from 36.30% to 57.88%, peaking on 2022-07-20. A time series analysis demonstrated that semesters with higher temperatures and humidity, such as 2022-07 and 2023-04, were associated with lower GPA averages, further supporting the negative trend. The heat index, a combined measure of temperature and humidity, peaked at 34.77°C on 2023-06-07, reinforcing the link between extreme weather and reduced academic performance. These findings highlight the need for implementing strategies in educational institutions like Federal Polytechnic Damaturu to mitigate the effects of adverse weather, such as improving classroom conditions and adjusting academic schedules.

Keywords: *Temperature, Humidity, Academic Performance, GPA, Students*

INTRODUCTION

Environmental factors, particularly temperature and humidity, significantly impact human comfort and cognitive performance. In regions with extreme climatic conditions, such as Damaturu, Nigeria, where temperature often exceed 38°C during the hot season and humidity can rise above 70%, these environmental factors are not only a matter of daily discomfort but also pose challenges to productivity, including academic performance. Research has demonstrated that high temperatures can impair concentration, reduce work output, and diminish cognitive performance. Similarly, high humidity exacerbates discomfort and hampers the body's natural cooling mechanisms, further reducing cognitive efficiency (Zhang et al., 2024). High temperatures, particularly above 35°C, have been shown to impair advanced cognitive functions such as working memory and situation awareness (Zhang et al., 2024). Studies reveal a significant negative correlation between cognitive performance and heart rate variability (HRV), indicating that as temperature rises, cognitive performance declines (Zhu et al., 2023)(Zhu et al., 2022).

Research by (Cen et al., 2023) suggests that maintaining thermal comfort is essential; cognitive performance declines when thermal comfort is compromised, even at slightly elevated temperatures. While the detrimental effects of extreme heat and humidity on cognitive performance are well-documented, some studies suggest that under certain conditions, individuals may temporarily adapt, showcasing resilience in cognitive tasks (Zhang et al., 2024). However, the overall trend indicates that prolonged exposure to such environmental stressors is detrimental to productivity. The Federal Polytechnic, Damaturu, is located in a semi-arid region with pronounced wet and dry seasons, provides a valuable case study for exploring the impact of environmental conditions on academic performance. This study aims to quantify the effect of varying temperatures and humidity levels on student GPAs over a three-year period (2020–2022), from historical meteorological and academic data. The aim is to uncover actionable insights that can help institutions mitigate the adverse effects of climate conditions on student success. Previous research has demonstrated that higher temperatures can impair cognitive function, reduce attention, and increase fatigue, while elevated humidity levels often exacerbate discomfort and heat-related stress. Indoor temperature from 26°C to 39°C significantly

decreased cognitive test accuracy, but reducing humidity from 70% to 50% at 39°C improved performance (Tian et al., 2021). Another study highlighted that thermal discomfort in lecture theatres, with temperatures averaging 29-32°C and relative humidity of 78%, led to stress behaviours that negatively impacted learning (Amasuomo & Amasuomo, 2016). Analyzing historical meteorological data alongside academic performance metrics can reveal patterns that inform strategies to mitigate adverse effects (Almazroui et al., 2017).

The relationships between the environmental factors and GPA was investigated in a structured manner by examining historical weather data and student performance records of the Federal Polytechnic, Damaturu from 2020 to 2023, and analyses the correlations between temperature, humidity, and GPA to determine if adverse weather conditions correspond with declines in academic performance. Previous research has shown that classroom temperatures significantly affect children's performance, with optimal performance occurring at temperatures lower than 22°C (Wargocki et al., 2019). Additionally, environmental factors such as temperature, lighting, and noise have been found to significantly impact academic performance during online classes (Realyvásquez-Vargas et al., 2020). This research seeks to provide insights into how climate affects student outcomes in The Federal Polytechnic, Damaturu by using detailed statistical analysis, and offers practical recommendations for mitigating these effects. Understanding the role of environmental factors on student's overall performance will enable educational institutions to implement strategies to improve learning environments, in every climatic conditions. For example, increasing the temperature set point in air-conditioning systems without affecting thermal comfort has been suggested as a viable strategy (Balbis-Morejón et al., 2020). Moreover, ensuring adequate thermal comfort in naturally ventilated classrooms has been identified as a key requirement for good classroom performance (Talukdar et al., 2020).

MATERIALS AND METHODS

Data Collection

The study employs two key datasets, Student academic records from 2020 to 2023 collected from The Federal Polytechnic, Damaturu, this dataset includes the following fields: student registration number, school, department, academic level, semester, semester duration, and GPA.

The dataset covers three academic sessions and four semesters per session. The second dataset is Weather Data from 2020 to 2023 sourced from the Nigerian Meteorological Agency (NMA), this dataset includes daily meteorological data for Damaturu, with fields such as average, maximum, and minimum temperature and humidity levels recorded throughout the year.

Data Preprocessing

A range of preprocessing steps were applied to prepare the data for analysis. Missing weather or academic records were handled using imputation techniques. For weather data, missing values were interpolated, while missing academic records were excluded to maintain dataset integrity. GPA outliers, specifically those with values below 1.0 or above 4.0, were flagged and analyzed separately. These outliers indicate of extraordinary circumstances (e.g., illness, absenteeism) or errors in data entry. Outliers were removed for the main analysis but were later revisited for contextual understanding.

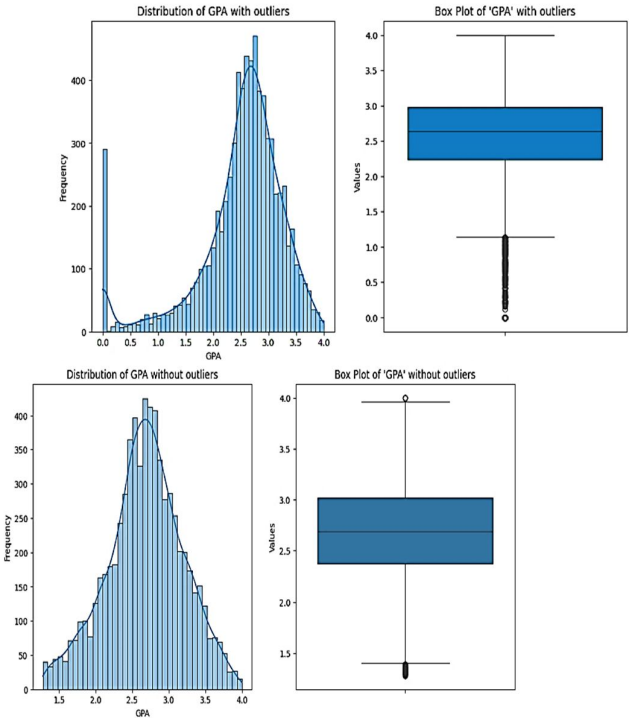

Figure 1: Histogram and Boxplot Showing Distribution of Student GPAs (with and without outliers)

The student GPA distribution exhibited a left skew, (Figure 1) with the mean GPA around 2.68, and the majority of students falling within a 2.5–3.0 GPA range. Only a small number of students had GPAs above 3.5 or below 2.0. The weather data revealed seasonal fluctuations in temperature and humidity, with average temperatures ranging from 24°C to 36°C and humidity levels spanning from 20% to 70%. To ensure accurate alignment between the academic semesters and weather conditions, the semester start and end dates were synchronized with the daily weather data. This process enabled precise matching of academic performance with the corresponding weather conditions during each semester. Temperature data was standardized to degrees Celsius, while humidity data was converted to percentages for consistency across all observations.

Weather Patterns

Seasonal trends in temperature and humidity were analyzed, revealing significant variability. The highest temperatures were recorded between March and May (hot season), with humidity peaking during the rainy season in August. These fluctuations were critical for understanding their impact on student academic performance.

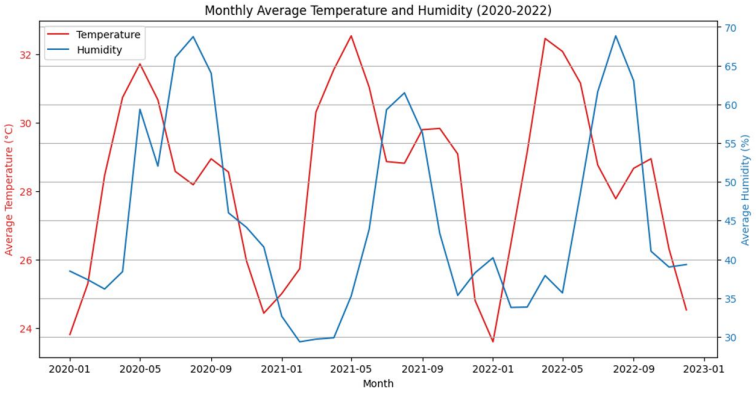

Figure 2: Monthly Distribution of Average Temperature and Humidity (2020–2023)

RESULT AND DISCUSSION

Correlation Matrix

The correlation matrix in table 1 shows the relationships between Average Temperature, Average Humidity, and GPA (Grade Point Average).

Table 1: correlation matrix of Average Temperature, Average Humidity, and GPA (Grade Point Average).

	AVERAGE TEMPERATURE	AVERAGE HUMIDITY	GPA
AVERAGE HUMIDITY	0.38	1.0	-0.44
AVERAGE TEMPERATURE	1.0	0.38	-0.45
GPA	-0.45	-0.44	1.0

According to table 1, average temperature and GPA has a correlation Coefficient of -0.45, this shows a moderate negative correlation between average temperature and GPA. This suggests that as the average temperature increases, GPA tends to decrease. In other words, higher temperatures are associated with lower student performance(Larson et al., 2016). Average humidity and GPA has Correlation Coefficient of -0.44, this also indicates a moderate negative correlation between average humidity and GPA. This indicates that as humidity increases, student GPA tends to decline. High humidity seems to have a negative impact on student performance(Tian et al., 2021; Watson et al., 2011). Average Temperature and Average Humidity has a Correlation Coefficient of 0.38 showing a moderate positive correlation between average temperature and average humidity. This means that as the temperature increases, humidity tends to increase as well. These two environmental factors are positively related, which is common in many climates.

This implies that both average temperature and average humidity have negative effects on GPA, with correlation coefficients of -0.45 and -0.44 respectively. This indicates that higher temperatures and humidity levels are associated with lower student performance, and addressing these environmental conditions could potentially improve academic outcomes. Meanwhile, the positive relationship between temperature and humidity (r = 0.38) suggests that these two variables often rise together, which may amplify their combined negative impact on student performance.

Plot of GPA vs. Average Temperature and Average Humidity

The scatter plot in figure 3 shows the relationship between average temperature, average humidity and student's GPA

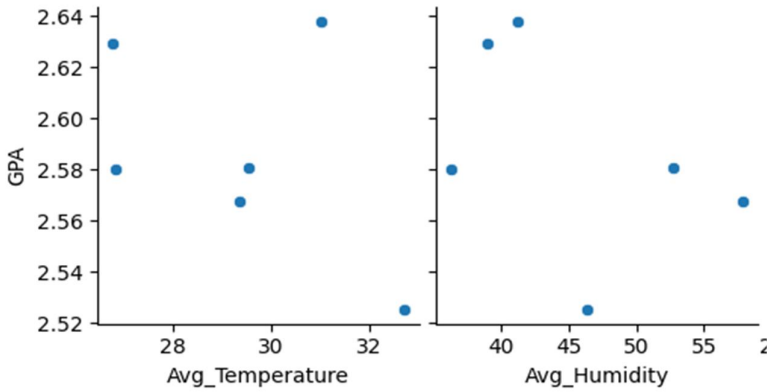

Figure 3: Scatter Plot of GPA vs. Average Temperature and Humidity

As can be seen from figure 3 above, the scatter plot indicates a negative trend, where higher temperatures are associated with lower GPAs, supporting the negative correlation observed earlier. The plot also shows a negative trend, indicating that higher humidity levels are associated with lower GPAs, reinforcing the earlier findings. This indicates the chart visually confirms the negative correlations between GPA and both environmental factors (temperature and humidity). The temperatures recorded range from 26.75°C to 32.71°C, with the highest average temperature recorded on 2023-06-07 (32.71°C). High temperatures, particularly those above 30°C, are expected to impact students' comfort and cognitive performance negatively. The humidity levels range from 36.30% to 57.88%, with the highest average humidity on 2022-07-20 (57.88%). Higher humidity, especially above 50%, can lead to discomfort by impeding the body's ability to cool through sweating, which could further contribute to cognitive fatigue.

Regression Analysis

To further explore the relationship between GPA and environmental factors, a linear regression model was developed.

$$GPA = 3.10 - 0.03 \times T_{avg} - 0.01 \times H_{avg} \quad (1)$$

Where: T_{avg} = Average Temperature and

H_{avg} = Average Humidity

The model revealed that both temperature and humidity have a negative impact on students' GPA. For every 1°C increase in temperature, GPA

dropped by approximately 0.03 points. Likewise, a 1% rise in humidity resulted in a 0.01-point decrease in GPA, as noted by (Lin et al., 2024). The model had an adjusted R-squared value of 0.41, indicating that 41% of the variation in GPA could be explained by temperature and humidity(Li et al., 2023; Lin et al., 2024).

Time Series Analysis

A time series analysis was conducted to investigate seasonal trends in academic performance. Figure 4 is a plot GPA data for each semester against the corresponding temperature and humidity levels.

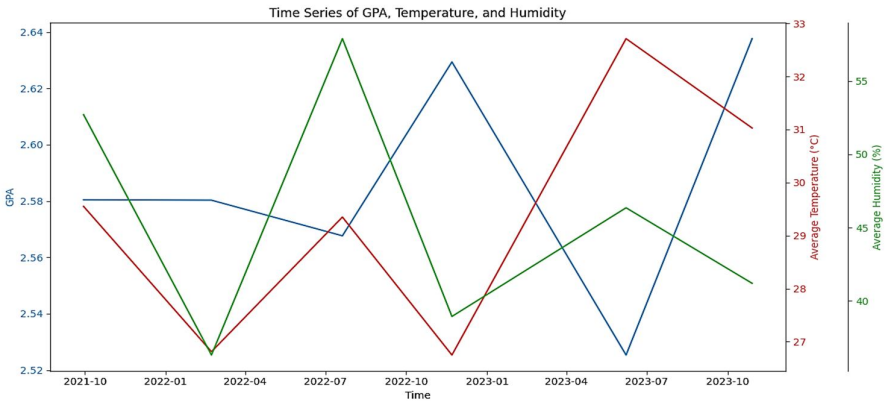

Figure 4: Time Series of GPA, Temperature, and Humidity Across Semesters (2020–2022)

Blue Line (GPA) - Represents the average GPA of students per semester. The y-axis on the left side (in blue) shows the GPA scale ranging from 2.52 to 2.64. Red Line (Temperature) - represents the average temperature per semester in degrees Celsius. The right-side y-axis (in red) shows the temperature scale, ranging from 27°C to 33°C. Green Line (Humidity) - represents the average humidity per semester in percentages. The right-side y-axis (in green) shows the humidity scale, ranging from 40% to 55%. As can be seen from the chart, GPA is relatively stable but fluctuates between semesters. There is a clear drop in GPA during semesters corresponding to higher temperatures and humidity (e.g., around the middle of 2022 and 2023-04). A significant drop occurs in early 2023 (2023-04 semester), where GPA falls to its lowest point (2.52) while temperature rises to over 32°C. In contrast, during the semester of 2023-10, when GPA rises to its highest (2.64), the temperature also peaks.

Temperature exhibits a cyclical pattern, peaking in the semesters around 2022-07, 2023-04, and 2023-10. This suggests that these semesters align with the hotter seasons of the region (likely the hot dry season). There is a strong inverse relationship between temperature and GPA, where higher temperatures tend to coincide with lower GPAs.

Humidity follows a more moderate fluctuation pattern compared to temperature. The highest humidity (55%) occurs during the 2022-07 semester, which coincides with the rainy season in tropical regions. During this period, GPA also drops, suggesting a possible combined effect of both high temperature and humidity on academic performance. Humidity tends to drop when temperatures rise in later semesters (e.g., 2023-10). There is a notable negative correlation between GPA and temperature. As temperature rises (e.g., in 2022-07 and 2023-04), GPA tends to fall, indicating that high heat may impair academic performance. Similarly, an increase in humidity seems to negatively impact GPA, though the effect appears to be less pronounced compared to temperature.

Heat Index

The heat index is a measure that combines temperature and humidity to reflect the perceived temperature. figure 2 shows the heat index ranges from 26.56°C to 34.77°C as shown in figure 5 below. The highest heat index was on 2023-06-07 (34.77°C), which suggests that although the actual temperature was 32.71°C, it felt much hotter due to the humidity, likely contributing to the lowest GPA in the data(Lee & Brenner, 2015). The lowest heat index (26.56°C) was recorded on 2022-02-21, when both the temperature (26.81°C) and humidity (36.30%) were relatively low, resulting in a more comfortable environment, but GPA remained unchanged from other observations at 2.58.

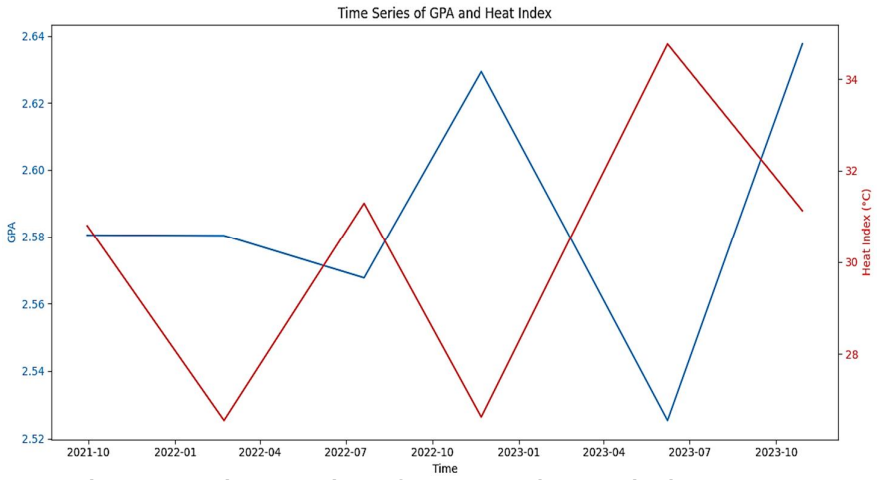

Figure 5: Time Series of GPA and Heat index

DISCUSSION

The findings are consistent with prior research suggesting that extreme temperatures and humidity negatively impact cognitive performance. Higher temperatures reduce concentration, increase fatigue, and contribute to psychological stress, all of which diminish academic performance. Similarly, elevated humidity levels disrupt the body's cooling mechanisms, exacerbating discomfort and impairing mental focus. These results have direct implications for educational institutions in the regions. Strategies such as improved classroom ventilation, air conditioning, and strategic scheduling of academic assessments during cooler months may mitigate the adverse effects of extreme environmental conditions on student performance.

RECOMMENDATIONS

Educational institutions should invest in air conditioning and ventilation systems to regulate classroom temperatures, especially during peak seasons. Exams and high-stakes assessments should be scheduled during cooler months to minimize the impact of extreme weather on student performance. Policymakers should explore infrastructure improvements and allocate resources to minimize the adverse impact of climatic conditions on education in educational institutions. While this study establishes significant correlations between temperature, humidity, and GPA, it is limited to a single institution in a specific region. Future studies should aim to generalize these findings by expanding to other institutions in similar climates. Additionally, factors such as

socioeconomic status, course difficulty, and cognitive load should be considered in future models. Moreover, climate adaptation strategies—such as long-term shifts in educational infrastructure and curriculum planning—should be investigated to understand how educational systems can better withstand the effects of climate change.

CONCLUSION

This study highlights the significant negative impact that temperature and humidity have on student academic performance at The Federal Polytechnic, Damaturu. The strong negative correlations between these environmental factors and GPA suggest that mitigating the effects of extreme weather conditions should be a priority for educational institutions in tropical regions. As global temperatures continue to rise, understanding and addressing the influence of climate on education will be crucial for fostering academic success.

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