



ANALYZING THE IMPACT OF MAHALANOBIS D2 STATISTICS ON ACHIEVEMENT OF GROUP OF SUBJECTS OF TENTH GRADE STUDENT: A COMPARATIVE STUDY BEFORE AND DURING THE COVID-19 PANDEMIC

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RESEARCH ARTICLE



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Abstract

Education stands as a cornerstone for both individual development and a nation's socioeconomic prosperity. Yet, the COVID-19 pandemic has disrupted the education landscape, necessitating a transition from traditional offline methods to online learning. However, the inherent disparities within society present a formidable obstacle to the sustainability of India's education system through e-learning. In this investigation, our primary focus lies in the realm of education, specifically in comparing the academic achievement of tenth-grade students in subjects such as General Mathematics, English, General Science, and Social Science, both before and during the COVID-19 pandemic, across various dichotomous variables. Utilizing Mahalanobis Distance (MD), we assess the nature of achievement fluctuations amidst the pandemic. This study was conducted among 10th-grade students in the Bodoland Territorial Region (BTR) of Assam, India, with sample collection considering dichotomous variables such as rural vs urban and tribal vs non-tribal backgrounds. Employing a stratified random sampling technique ensured data collection integrity. When analysing the combined performance in these four subjects, MD serves as a metric to gauge the dynamic shift in achievement patterns. Interestingly, the analysis reveals predominantly insignificant differences in academic achievement between the pre-pandemic and pandemic periods across most cases.

Keywords: *Mahalanobis Distance, Tenth Grade, General Mathematics, General Science, Social Science, English, BTR, Assam, COVID-19 Pandemic*

Introduction

The global ecosystem underwent a profound transformation due to the corona virus disease (COVID-19) pandemic, prompting various sectors of society to adapt to novel strategies to fulfil their potential. Notably, many government and corporate sectors shifted their work standards to online platforms, embracing remote work programs commonly referred to as "work from home." Similarly, the educational system embraced a fresh approach to teaching and learning, departing from traditional face-to-face methods to embrace blended learning, primarily modular and online. Students emerge as some of the most profoundly affected stakeholders in this transition, as they navigate the complexities of this new educational landscape. This substantial shift in the educational paradigm necessitates both educators and students to familiarize themselves with new learning platforms, adapting to the "new normal." Consequently, educators and students alike must acclimate to these changes, embracing the evolution of learning methods. Additionally, this shift towards blended learning establishes a new normal for students' learning habits and their overall way of life.

Despite the current curfew, Agarwal and Kaushik (2020) concluded that online education is feasible and cost-effective, advocating for its integration into postgraduate education in India. However, not all children have internet access at home, and some institutions lack the necessary resources to provide educational opportunities to students (Hani, 2020). Moreover, many students reside in remote areas with poor internet connectivity. In response, higher education has embraced flexible learning, which offers adaptability in terms of time, location, and audience, leveraging technology among other resources (Commission on Higher Education, 2020). This approach empowers educators and learners to choose from a diverse array of affordable and easily accessible learning materials and platforms.

Joan (2013) posited that flexible learning fosters learners' ability to organize activities based on their passions and interests while maintaining a relaxed, fearless state of mind. He concluded that flexible learning in the classroom contributes to the promotion of high-quality education. Additionally, Amir et al. (2020) advocated for blended learning, which combines in-person and online

instruction, as a future pedagogical approach. Despite challenges, dental students successfully adapted to new fully online learning methodologies.

The on-going COVID-19 pandemic has influenced future pedagogical initiatives and the integration of technology in education. However, significant differences exist in students' behaviors and learning patterns before and during the pandemic. Typically, student activity and learning patterns decline during a pandemic due to various limitations, including connectivity issues, changes in assignment approaches, delivery methods, and time management constraints (Noviyanti et al., 2020). Moreover, the pandemic has significantly disrupted students' daily schedules and instructional methods, potentially negatively impacting their sleep patterns and routines (Deutsch & Ehsan, 2021). Ahrberg et al. (2012) highlighted the close relationship between poor sleep, high stress levels, and academic performance, underscoring the detrimental impact on student achievement.

Ali et al. (2013) discovered no correlation between sleep habits and the academic performance of medical students. Similarly, Jalali et al. (2020) found that sleep quality indices did not significantly differ between pupils with good and low grades. However, eating habits and study time demonstrated a clear correlation with academic success, as reported by Dubuc et al. (2020). Moreover, the importance of effective study techniques in fostering academic achievement cannot be overstated. The approach a person takes towards their studies can profoundly influence both their academic success and overall personality development (Lone, 2021).

During the epidemic, there was a surge in demand for social media platforms, accessible to individuals of all ages. Teachers, for example, utilized social media to engage with their students. According to Ali et al. (2021), there is a significant positive correlation between students' use of social media and their academic success. Both boys and girls utilize social media for communication and educational purposes. However, despite its benefits for the learning process, Atteh et al. (2020) suggest that social media can have adverse effects on students' grades and academic performance.

According to Carlsson et al. (2015), regular school attendance contributes to improved memory retention among students. However, with school closures, overall student attendance decreases. The study suggests that for every day a school remains closed, there is a potential loss of 1% of the standard deviation of knowledge over the subsequent 10 days. This poses a significant challenge and obstacle for educational stakeholders striving to cultivate well-educated students, especially in times of intense competition. Insufficient time spent studying in the classroom may lead to a decline in students' knowledge.

Capinding (2021) conducted a study focusing on the analysis of education students' learning and academic performance both before and after the COVID-19 epidemic. In comparing students' sleep patterns, study habits, and social media usage before and after the epidemic, significant differences were observed. However, there was no discernible difference in the students' academic performance.

Based on the description provided, the study article addressed the following questions:

- What is the impact of the COVID-19 pandemic on students' academic performance across a group of subjects before and during the pandemic?
- How do students perceive the advantages and disadvantages of flexible learning during the pandemic?

Literature Review

Mahalanobis Distance is a measure used to determine the similarity between two data points in a multidimensional space. Unlike Euclidean distance, it accounts for correlations between variables and differences in their scales. It's particularly useful in clustering, classification, and outlier detection tasks.

Mahalanobis Distance (MD) serves as a crucial statistic for evaluating the separation or divergence between groups based on specific criteria. Proposed by P. C. Mahalanobis in 1936 during his research on racial similarities, this measure, also referred to as Mahalanobis D^2 statistics (Mahalanobis, 1936), has garnered significant attention and employment in the realms of statistics and data analysis. MD quantifies the distance between two data sets within the realm defined by pertinent characteristics. Its consideration of diverse character variances and correlations renders it adept at incorporating various key factors into the data point attributes, thereby enabling precise distance calculations. Leveraging such advantages can prove instrumental in addressing specific tasks within a given data set, provided an appropriate MD distance metric is available.

In scenarios involving classification with multiple groups and the focus on comparing group similarities (Mclachlan, 1999), Mahalanobis D^2 emerges as a valuable tool. The objective of such studies often revolves around clustering participants with similar attributes, potentially within a hierarchical framework. Furthermore, Mahalanobis D^2 finds applicability in pattern identification or discriminant analysis problems and in medical diagnosis contexts. According to Bedrick et al. (2000), Mahalanobis Distance (MD) stands as the preferred method for quantifying the distance between two populations when the observed data are quantitative. However, when dealing with a combination of qualitative and quantitative traits, there is a lack of universally accepted methods for distance calculation. Taguchi and Jugulum (2002) assert that MD serves as a discriminate analysis tool, particularly useful for forecasting changes in customer satisfaction corresponding to alterations in various technical characteristics across all levels of a hardware set (e.g., vehicle design).

Wu (2004) discussed the application of pattern recognition and medical diagnosis in assessing human health, particularly focusing on diagnosing liver function to predict major diseases in subsequent examinations. The study aimed to replace out dated double-blind testing with a more effective and humane approach. Similarly, Lande (2004) provided an analysis of different patterns that can be recognized and examined in relation to a reference point using Mahalanobis Distance (MD), a measure of

correlations between variables. This method allows for comparing an unknown group sample to a measured collection of known samples to determine the similarity of values from the unknown group. Marty et al. (2007) explored the use of MD in measuring multivariable effects when two research participant groups were assessed with two or more dependent variables. Their findings suggest that MD, serving as a multivariate measurement of efficacy, enhances investigations into hypnosis.

Xiang et al. (2008) argue that Mahalanobis Distance (MD) serves as a measure between two data sets within the realm defined by significant characteristics. By assigning various weights or significance to the attributes of data points, MD accurately evaluates distance, taking into account diverse variances and correlations between characters. Moreover, Xiang et al. demonstrated that MD can enhance the functionality of clustering or classification methods, such as the k-NN classifier, offering advantages that can be leveraged for specific tasks on a given dataset when suitable MD metrics are available.

Kritzman and Li (2010) utilized MD as a metric for assessing “financial turbulence,” a novel application within multidimensional financial market data. Positron Emission Tomography (PET), a field with applications in both medicine and research, benefits from MD by yielding higher image resolution and accuracy. Additionally, MD is instrumental in analyzing gamma quanta by reproducing signals at different energies, crucial for generating high-resolution images (Sharma et al., 2015).

Brereton (2015) explored the relationship between MD and Principal Components Analysis (PCA), revealing that Mahalanobis Squared Distance equals the sum of squares of the scores of all non-zero standardized principal components.

Ahmed et al. (2020; 2021) applied Mahalanobis D^2 statistics to assess mathematics achievement tests among senior secondary level students, revealing a comparable decline in mathematical achievement across two groups from various colleges. Additionally, they utilized MD to explore differences in academic performance among various student groups at the 12th-grade level across multiple subjects. Similarly, Sen and Pal (2020) utilized MD to investigate issues related to student achievement in science and math among different student groupings, revealing significant performance disparities across most instances.

In 2021, Mahato and Sen delved into the application of MD in the field of educational psychology. They compared two groups of higher secondary pupils using MD, examining the progressive properties of three dependent variables across different combinations of independent variables. Notably, no discernible differences were observed in the progressive properties of the three dependent variables between the various combinations of independent variables.

Gorain et al. (2021) explore the evolution of human reliance on the internet in the context of the globalized 21st century. Their study focuses on internet dependency, social isolation, and personality traits, employing Mahalanobis Distance (MD) as a statistical tool. The research findings suggest that there are no significant differences observed between male and female students majoring in arts and sciences in terms of their dynamic personalities.

In the BTR area of Assam, India, Ahmed et al. (2022a) utilized Mahalanobis Distance (MD) to examine students' academic performance in Mathematics and other subjects at the tenth-grade level. Their analysis revealed insignificant variations in the dynamic characteristics of five dependent variables across different groupings of independent variables. Similarly, in a study by Ahmed et al. (2022b), MD was employed to explore the dynamic nature of academic achievement across five distinct disciplines among two student groups at the twelfth-grade level in the BTR area. The study considered five different categories of students, and MD was used to assess the differences in the dynamic nature of student achievement between the two groups across the five disciplines. The findings indicate that there is not much disparity in the dynamic character of academic success between the two groups.

In their study, Sen et al. (2023a) utilized Mahalanobis Distance (MD) to compare various leadership theories, including mentoring leadership, visionary leadership, dominating leadership, and democratic leadership. The analysis revealed that the dynamic nature of dichotomous categories remained unchanged even after consolidating the five dependent variables into a single category. Similarly, in a study by Sen et al. (2023b), MD was employed to conduct comparative research on postgraduate students' self-efficacy, depression, anxiety, and stress. The study considered five dependent variables and three unique dichotomous groupings of students. The findings indicated that there were no significant differences in the dynamic behavior of the five dependent variables across different sets of independent variables.

In a study by Adhikari (2023), titled “Application of Mahalanobis distance in Education and Educational Psychology: A Mini Review,” the immense potential of Mahalanobis distance analysis in educational psychology is explored. Adhikari et al. (2023a) delved into Mahalanobis Distance, Cluster Analysis, and Correlational study in education, aiming to provide a comprehensive overview of their application. The study discusses how cluster analysis, correlation coefficients, and Mahalanobis distance can be used to detect causation and analyze various data patterns. Adhikari et al. (2023b) emphasize that multi-dimensional analysis enables researchers to gain multiple perspectives on data, facilitating the identification of patterns or anomalies.

Additionally, Mohanta et al. (2023a) designed a study to examine employees' perceptions of autonomy, manager trust, teamwork, incentives and recognition, fairness, and organizational support using Mahalanobis Distance (MD). Their findings revealed consistent dynamical properties of the six dependent variables across different combinations of independent factors. In another study by Mohanta et al. (2023b), MD was employed to compare various aspects of institutional commitment among secondary school teachers in West Bengal. The study found no discernible difference in the dynamical nature of dichotomous classifications when four dependent variables were classified as a branch.

In a study by Sutradhar et al. (2023), Mahalanobis Distance (MD) is employed to assess differences in self-efficacy, depression, anxiety, and stress levels between two groups of university students. The study involves three distinct dichotomous categories

of students. MD is utilized to compare the dynamic diversity of five variables—general self-efficacy, specific self-efficacy, depression, anxiety, and stress—across these three unique dichotomous categories of students. The findings reveal that the dynamic behaviour of the five dependent variables remains relatively consistent across different sets of dichotomous independent factors, such as male-female, rural-urban, and arts-science students.

The present study aimed to compare the academic performance of 10th-grade students in four subjects—English, General Mathematics, General Science, and Social Science—before and during the COVID-19 pandemic by considering different dichotomous variables. The research was conducted on students from the Bodoland Territorial Region (BTR) in Assam, India.

Objectives

The following objectives have been outlined to accomplish the goals of our current study:

1. To assess the academic performance disparities among students who took the 10th-grade Board Examination before and during the COVID-19 epidemic, focusing on English, General Mathematics, General Science, and Social Science subjects.
2. To assess the academic performance disparities among tribal students who took the 10th-grade Board Examination before and during the COVID-19 epidemic, focusing on English, General Mathematics, General Science, and Social Science subjects.
3. To assess the academic performance disparities among non-tribal students who took the 10th-grade Board Examination before and during the COVID-19 epidemic, focusing on English, General Mathematics, General Science, and Social Science subjects.
4. To assess the academic performance of rural students who took the 10th-grade Board Examination before and during the COVID-19 epidemic, specifically in the subjects of English, General Mathematics, General Science, and Social Science.
5. To assess the academic performance of urban students who took the 10th-grade Board Examination before and during the COVID-19 epidemic, specifically in the subjects of English, General Mathematics, General Science, and Social Science.

Hypotheses

The following hypotheses are considered to inform the requisite decisions aligned with the aforementioned objectives:

H₀₁: When considering a group of subjects, namely English, General Mathematics, General Science, and Social Science collectively, there is no statistically significant difference in student achievement between groups of pupils before and during the COVID-19 pandemic.

H₀₂: When considering a group of subjects, namely English, General Mathematics, General Science, and Social Science collectively, there is no statistically significant difference in student achievement between groups of tribal pupils before and during the COVID-19 pandemic.

H₀₃: When considering a group of subjects, namely English, General Mathematics, General Science, and Social Science collectively, there is no statistically significant difference in student achievement between groups of non-tribal pupils before and during the COVID-19 pandemic.

H₀₄: When considering a group of subjects, namely English, General Mathematics, General Science, and Social Science collectively, there is no statistically significant difference in student achievement between groups of rural pupils before and during the COVID-19 pandemic.

H₀₅: When considering a group of subjects, namely English, General Mathematics, General Science, and Social Science collectively, there is no statistically significant difference in student achievement between groups of urban pupils before and during the COVID-19 pandemic.

Methodology

• Population

The entire population consists of students who took the 10th-grade State Board Examinations conducted by the Board of Secondary Education Assam (SEBA) in the subjects of English, General Mathematics, General Science, and Social Science within the BTR region of Assam.

• Sample and Sampling

The following sampling procedures were employed:

- i. The results of 2008 students who took the 10th-grade Board Examinations in 2019 (before the COVID-19 pandemic) were randomly collected using the stratified random sampling technique.
- ii. The results of 2000 students who took the 10th-grade Board Examinations in 2021 (during the COVID-19 pandemic) were randomly collected using the stratified random sampling technique.

Table 1: Sample frame of the population.

Grade	Tenth Grade	N=2008	%
	Tribal Students	1004	50

Pre-COVID-19	Non-tribal Students	1004	50
	Rural Students	1004	50
	Urban Students	1004	50
During COVID-19	Tenth Grade	N=2000	%
	Tribal Students	1048	52.4
	Non-tribal Students	952	47.6
	Rural Students	747	37.35
	Urban Students	1253	62.65

Data Arrangement

Initially, achievement scores in General Mathematics, English, General Science, and Social Science before the COVID-19 pandemic are collected. Subsequently, achievement scores during the COVID-19 pandemic are also gathered. Additionally, both datasets are segmented into various strata, including rural, urban, tribal, and non-tribal. Finally, achievement scores are organized by stratum for both pre- and post-COVID-19 pandemic periods in General Mathematics, English, General Science, and Social Science.

Statistics

For the data organized into separate strata for both pre-COVID-19 pandemic and during the pandemic periods, mean, standard deviation, and variance-covariance matrices are computed.

The following equation is employed to calculate the Mahalanobis Distance (MD):

$$MD = [(M_1 - M_2)^T S^{-1} (M_1 - M_2)]^{1/2} \dots\dots\dots(1)$$

Where M_1 and M_2 represent the mean achievement of the respective groups, and S denotes the pooled Variance-Covariance matrix of different subjects for various strata (rural, urban, tribal, and non-tribal).

The pooled covariance matrix is calculated as follows:

$$S = [n_1 S_1 + n_2 S_2] / N \dots\dots\dots(2)$$

Where S_1 and S_2 represent the Variance-Covariance matrices, n_1 and n_2 denote the sample sizes for the pre-COVID-19 pandemic and during COVID-19 pandemic periods, respectively, and $N = n_1 + n_2$.

Results and Discussions

Initially, we include all students from both the pre-COVID-19 and COVID-19 pandemic periods. Subsequently, we compare the academic achievements between students from the pre-COVID-19 and COVID-19 pandemic periods, as outlined below:

Table 2: Descriptive statistics on group of subjects for pre COVID-19

Descriptive Statistics (PreCOVID-19)			
Total Pre-COVID	N	Mean	Std. Deviation
Mathematics	2008	47.09	17.541
General Science	2008	47.31	14.418
Social Studies	2008	53.12	14.574
English	2008	47.48	16.054

Table 3: Descriptive statistics on group of subjects for during COVID-19

Descriptive Statistics (During COVID-19)			
Total during COVID	N	Mean	Std. Deviation
Mathematics	2000	58.07	15.46
General Science	2000	58.43	13.835
Social Studies	2000	61.92	13.859
English	2000	61.34	15.162

Figure 1: Graph showing the descriptive statistics on group of subjects for pre COVID-19

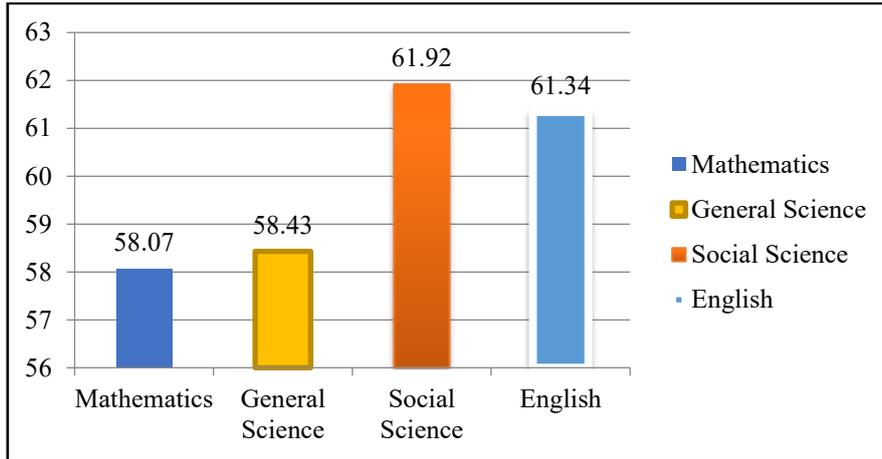
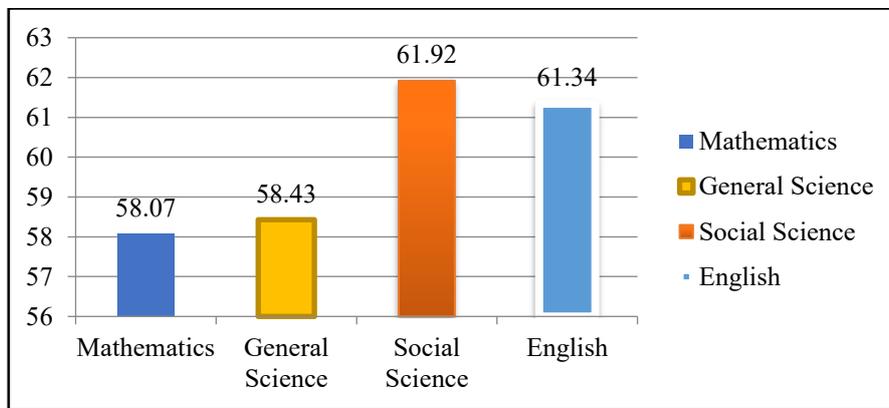


Figure 2: Graph showing the descriptive statistics on group of subjects for during COVID-19



The descriptive statistics for both the pre-COVID-19 pandemic and the COVID-19 pandemic are illustrated in Tables 2 and 3, respectively. Furthermore, Tables 4 and 5 represent the variance-covariance of student achievement in the tenth grade before and during the COVID-19 pandemic, respectively.

Table 4: Variance-covariance of group of subjects for pre COVID-19

Covariance	Mathematics	General Science	Social Science	English
Mathematics	307.695	192.994	166.167	192.087
General Science	192.994	207.870	152.849	159.546
Social science	166.167	152.849	212.401	159.008
English	192.087	159.546	159.008	257.719

Table 5: Variance-covariance of group of subjects for during COVID-19

Covariance	Mathematics	General Science	Social Science	English
Mathematics	239.003	187.417	177.187	190.824
General Science	187.417	191.394	165.808	173.568
Social science	177.187	165.808	192.062	167.025
English	190.824	173.568	167.025	229.872

The pooled variance-covariance matrix of tenth-grade students' achievements before and during the COVID-19 pandemic is estimated using Equation (2) with the aid of Tables 3 and 4. This matrix is presented below:

$$A = \begin{bmatrix} 273.4176 & 190.2111 & 171.666 & 191.4568 \\ 190.2111 & 199.6484 & 159.3156 & 166.543 \\ 171.666 & 159.3156 & 202.2518 & 163.0085 \\ 191.4568 & 166.543 & 163.0085 & 243.8233 \end{bmatrix} \dots\dots\dots(3)$$

The Mahalanobis Distance is computed using Equation (1) with reference to Tables 2 and 3, and the inverse of the matrix A indicated by (3) and its value is 0.9259.

The Mahalanobis Distance (MD) serves as a robust statistic for comparing two sets of variables using a single dimensionless value. With an MD score of 0.9259, it indicates that there is no significant difference in achievement between the periods before and during the COVID-19 epidemic. Consequently, our null hypothesis H_{01} is accepted. Hence, we can conclude that the academic performances of tenth-grade students, whether during the pre-COVID-19 or COVID-19 pandemic periods, exhibit similarity when considering disciplinary groups.

When comparing the achievement of tribal, non-tribal, rural, and urban students before and during the COVID-19 epidemic using the same process outlined previously, we obtain the Mahalanobis Distance values as depicted in Table 6 below:

Table 6: Mahalanobis Distance for different pair of variables

Variables	Mahalanobis Distance
Pre-COVID-19 vs COVID-19 of Tribal Students	1.2607
Pre-COVID-19 vs COVID-19 of Non-tribal Students	0.6779
Pre-COVID-19 vs COVID-19 of Rural Students	1.2572
Pre-COVID-19 vs COVID-19 of Urban Students	0.7087

Table 6 illustrates the Mahalanobis Distance for different pairs of variables when considering all four subjects for computing the distance. The Mahalanobis Distance exceeds 1 in only two cases, specifically for tribal and rural students. Consequently, there exists a statistically significant difference in student achievement for the set of subjects considered as a whole between the pre-COVID-19 and COVID-19 pandemics for tribal and rural students, leading to the rejection of null hypotheses H_{02} and H_{04} . Notably, students from tribal and rural areas demonstrate improved achievement during the COVID-19 pandemic. Conversely, in the remaining two instances involving non-tribal and urban students, the Mahalanobis Distance is less than one, indicating no significant differences between pre-COVID-19 and COVID-19 pandemics among non-tribal and urban tenth-grade students. Therefore, null hypotheses H_{03} and H_{05} are accepted, suggesting that non-tribal and urban students performed similarly before and during the COVID-19 pandemic.

Limitations and Future Research

While this study provides valuable insights, it has several limitations. The primary focus was on understanding achievement in a set of subjects—Mathematics, General Science, Social Science, and English—before and after quarantine, without considering other variables that could impact student performance. Consequently, questions regarding potential cheating by students during remote learning assessments or possible score inflation by teachers remains unanswered. Additionally, factors such as student motivation, satisfaction with new teaching methods, and effort during the COVID-19 pandemic could warrant further exploration. Further research is necessary to gain a comprehensive understanding of the phenomenon under investigation.

Nevertheless, this paper offers preliminary insights into the distribution of subject groups before and after the pandemic in the Bodoland Territorial Region (BTR) of Assam, India. The observation that tribal and rural students exhibit higher achievement during the pandemic than before suggests potential evidence of achievement inflation, where students may receive incomplete or inaccurate feedback about their actual knowledge and competencies. This underscores the importance for policymakers and educators to interpret student achievements with added caution.

Furthermore, our findings reveal no statistically significant differences in achievement among total, non-tribal, or urban students before and after the pandemic. However, additional research is needed to fully comprehend whether distance learning could help narrow such achievement gaps.

In summary, while this research provides preliminary insights into the distribution of student achievement before and during the epidemic in the BTR of Assam, India, further investigation is required to address the identified limitations and provide a more comprehensive understanding of the phenomenon.

Conclusion

Given the limited number of research studies utilizing Mahalanobis Distance (MD) in achievement analysis, our findings align with Sen and Pal (2020) and Ahmed et al. (2024), indicating a statistically significant difference between two branches of subjects. However, our results contrast with those of Ahmed et al. (2022a, 2022b) and Mahato and Sen (2021), as we found no statistically significant difference between two branches in their studies.

The Mahalanobis Distance exceeds 1 for two pairs of observations: tribal and rural students who took the board examination before and during the COVID-19 pandemic. Consequently, tribal and rural students performed worse before the COVID-19 outbreak and nationwide lockdown compared to during the pandemic. This outcome may not align with public expectations of improved performance during the pandemic.

Our study underscores the urgent need for educational institutions to enhance their e-learning facilities in response to the impact of the COVID-19 lockdown on online academic activities. Prompt action is imperative, given the perceived convenience and time-saving benefits of online learning (Mahdy, 2020). Moreover, we advocate for similar studies to be conducted in other departments and faculties to broaden the scope of research in this area.

It is evident that during a pandemic, administering achievement tests effectively within the online education system poses challenges. Despite concerns about the adequacy of real classroom teaching and learning during the pandemic, our results

indicate a significant increase in achievement. Therefore, there is a pressing need for an accredited mechanism to ascertain the true nature of this substantial improvement in achievement.

When considering all students, including urban and non-tribal, the Mahalanobis Distance is less than 1, indicating similar performance before and during the COVID-19 pandemic. These findings are noteworthy, as they demonstrate that student performance during the pandemic surpassed pre-pandemic levels, contrary to public expectations. However, it is crucial to acknowledge the limitations of this study.

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