Higher Secondary Students' Performance in Math, English, and Other Science Subjects in Pre-COVID 19 and During COVID 19 Pandemic: A Comparative Study Using Mahalanobis Distance

Eusob Ali Ahmed
Department of Mathematics, Sapatgram College, Sapatgram, Assam, India

Mohammad Rezaul Karim[*]
Department of English Language and Literature, College of Science and Humanities, Prince Sattam Bin Abdulaziz University, Al Kharj, Saudi Arabia

Munmun Banerjee
Department of Education, Sapatgram College, Assam, India

Subir Sen
Department of Education, Sidho-Kanho-Birsha University, Purulia, W. B., India

Sameena Banu
Department of English Language and Literature, College of Science and Humanities, Prince Sattam bin Abdulaziz University, Al Kharj, Saudi Arabia

Wahaj Unnisa Warda
Department of English Language and Literature, College of Science and Humanities, Prince Sattam bin Abdulaziz University, Al Kharj, Saudi Arabia

Abstract—**The current study compared the achievements of higher secondary level students before and during the COVID 19 pandemic in five subjects-English, Biology, Physics, Chemistry, and Mathematics. This study was conducted on higher secondary level students from Bodoland Territorial Region (BTR), Assam, India. Dichotomous variables like rural and urban, tribal and non-tribal are considered for sample collection. A stratified random sampling technique is used for data collection. When five subjects are considered as a unit, the Mahalanobis Distance (MD) is used to measure the difference in dynamical character of achievements. There is a significant difference in the achievement of students between pre-COVID 19 and during COVID 19 pandemic.**

Index Terms—**Mahalanobis Distance, higher secondary level students, English, Biology, Physics, Chemistry, Mathematics, BTR, Assam, COVID-19 Pandemic**

I. INTRODUCTION

The Mahalanobis Distance (MD) has been used to distinguish features in a variety of fields. Image management, neuro-computing, clustering, categorization, precision medicine, and other fields are examples of fields where MD is used. When it comes to hypothesis testing, goodness of fit experiments, classification techniques, grouping testing, outlier spotting, and density calculating techniques, statistical distances are crucial. We can calculate how close two statistical objects are to one another using distance measurements (or their similarities). The MD is one of several statistical distance measures that have the advantage of detecting outliers in two or more variables (Venturin, 2015). In MD, the distance between groups is estimated in terms of a single number. In 1936, Mahalanobis proposed this metric (Mahalanobis, 1936). It was critical in data processing and statistics involving multiple measurements. P.C. Mahalanobis developed the MD, which is a well-known and useful indicator of the "closeness" of an analysis involving two or more variables (Mahalanobis, 1927, 1936). It was a significant contribution, and numerous studies were conducted on it using this statistics (Rao, 1963, 1973; Rudra et al., 1996). Scholastic attainment in those subjects represents the level of achievement in Mathematics and English when combined with other disciplines at the higher

---

[*] Corresponding Author

secondary level. When comparing math and English achievement with other subjects among various groups of students, significant issues emerge. For instance, are the learners' intelligence levels similar? Is the difficulty level consistent across groups? Are students in different groups in the same socioeconomic situation? As a result, the MD is thought to be a more broadly applicable concept for contrasting the significant variation in dynamical character for many subjects between two groups of learners with different learning preferences.

II. LITERATURE REVIEW

The MD is a clustering algorithm that can be found in a variety of situations. Occasionally, all of the clusters have the same covariance. This is a very restrictive assumption, and it may be more meaningful if each cluster is defined not only by its centroid, but also by its covariance matrix (Lapidot, 2018). Several researchers such as Rafati and Akbarpour (2018); Haldar et al. (2016); Mingliang et al. (2018); Xiang and Zhang (2008); Zeng et al. (2020), Law et al. (2016), Hirano et al. (2004), Zhao and Zhao (2015), Benaichouche et al. (2013), de la Hermosa Gonz ález (2018), Martino et al. (2019), Maesschalck et al. (2000), used MD to solve clustering problems. MD is also used to solve categorization problems by researchers like Hamill et al. (2016); Kojima et al. (2016); Kamoi and Kobayashi (2020); Chen et al. (2021); Zhang and Pan (2011). Image management is another area where MD is used by Pinho and Tavares (2009), Pinho et al. (2005), Kapoor et al. (2010), Sheikh et al. (2019), Liang et al. (2018).

Ahmed et al. (2020, 2021) used MD to address the disparity in educational mathematical achievement. Sen and Pal (2020) investigated the unit test and annual examination performance of students in the seventh and eighth grades in three different types of schools. They used MD in three different fields—mathematics, physical science, and life science and found a significant difference in achievement between formative and summative assessments in most of the cases. Mahato and Sen (2021) looked into the use of MD in educational psychology. MD is used to compare the two dependent variables for two groups of higher secondary students. The progressive characteristics of the three dependent variables do not differ significantly across independent variable combinations. Garain et al. (2021) conducted a study utilizing Mahalanobis Distance, a tool for comparing different psychological traits among postgraduate students. This research takes into account Internet dependence, social isolation, and five different personality traits. Several groups have been formed for this research, including male and female groups from the arts and sciences. In order to measure the two dichotomous independent variables of sex (male and female) and stream (arts and science), seven dependent variables—Internet Dependency, Social Isolation, Extraversion, Agreeableness, Conscientiousness, Neuroticism, and Openness—are taken as a branch. It is possible to declare that there are no observable differences to wrap up the topic. Ahmed et al. (2022a) used MD to compare tenth-grade students' academic achievement in subjects such as Mathematics and English, as well as other disciplines, in the BTR region of Assam, India. The dynamical nature of five dependent variables differed insignificantly across independent variable groupings. Ahmed et al. (2022b) used MD to examine the dynamical nature of academic attainment in five different disciplines, including Mathematics, English, Biology, Physics, and Chemistry, between two student groups of higher secondary level in the BTR regions of the Indian state of Assam. Students of tribal and non-tribal origins, boys and girls, urban and rural, urban boys and rural boys, and urban girls and rural girls are among the five types of groupings considered. In five fields, the MD is used to calculate the difference in the dynamic nature of student achievement between two sections. The dynamical character does not differ significantly in terms of achievement.

Sen et al. (2023a) used MD to compare several leadership theories, including mentoring leadership, visionary leadership, dominant leadership, and democratic leadership in their study entitled "Comparison among different leadership styles of head of the institution of West Bengal by Mahalanobis distance". The findings showed that even after the five dependent variables were combined into one branch, the dichotomous categories' dynamic nature remained unchanged. The study "Comparison among self-efficacy, Depression, Anxiety, and Stress of Postgraduate Students by Mahalanobis Distance" was undertaken by Sen et al. (2023b). For this study, three distinct dichotomous groupings of students are taken into account. Five dependent variables—general self-efficacy, specific self-efficacy, depression, anxiety, and stress—are compared using Mahalanobis Distance to see how dynamically they differ. It is discovered that the dynamical nature of five dependent variables for various sets of independent variables is not significantly different. Adhikari (2023) examined the Mahalanobis distant research in education and its tremendous potential in educational psychology. In the context of educational psychology, MD was utilized to draw inferences based on a combination of factors, including anxiety, self-efficacy, personality, social isolation, internet dependence, and academic stress.

Through the use of MD, Mohanta et al. (2023a) conducted a study on "Comparison among different dimensions of organizational climate of secondary school teachers of West Bengal." This study examined how employees perceived autonomy, manager trust, teamwork, incentives and recognition, fairness, and organizational support. The outcomes showed that the dynamical characteristics of the six dependent variables are the same for various combinations of independent factors. In another study, Mohanta et al. (2023b) used Mahalanobis Distance to compare the various aspects of institutional commitment, including affective commitment, professional commitment, commitment to the learner, and academic commitment. The findings revealed that when four dependent variables were classified as a branch, there was no appreciable difference in the dynamical nature of the dichotomous classifications. Mahalanobis Distance, cluster analysis, and correlational research in education were examined by Adhikari et al. (2023a). This study

set out to give a comprehensive overview of the uses of cluster analysis, correlation coefficients, and Mahalanobis distance. Numerous analyses and interpretations are considered, starting with the assumption that causality can be determined using all three statistics. According to Adhikari et al. (2023b), those who employ multi-dimensional analysis have access to a variety of viewpoints on the data. They are capable of detecting trends or anomalies in the data. Sutradhar et al. (2023) used MD to compare the variations in self-efficacy, depression, anxiety, and stress levels between two groups of university students. Three distinct dichotomous categories of pupils are considered for this study. To determine how dynamically different five variables viz. general self-efficacy, specific self-efficacy, depression, anxiety, and stress are compared for three distinct dichotomous categories of pupils, MD is used. It is found that there are no discernible differences in the dynamical behavior of five dependent variables for different sets of dichotomous independent variables viz. male-female, rural-urban and arts-science students.

The current research compared the performance of higher secondary level students in five subjects in pre-COVID 19 and during COVID 19 pandemic viz. English, Biology, Physics, Chemistry, and Mathematics. This research was carried out on pupils from the BTR in Assam, India.

III. RESEARCH OBJECTIVES

Following objectives are considered for the present study:
1. To compare academic achievement in English, Mathematics, Physics, Chemistry and Biology between the students who appeared higher secondary final examination in pre-COVID 19 and during COVID 19 pandemic.
2. To compare academic achievement in English, Mathematics, Physics, Chemistry and Biology between the rural students who appeared higher secondary final examination in pre-COVID 19 and during COVID 19 pandemic.
3. To compare academic achievement in English, Mathematics, Physics, Chemistry and Biology between the urban students who appeared higher secondary final examination in pre-COVID 19 and during COVID 19 pandemic.
4. To compare academic achievement in English, Mathematics, Physics, Chemistry and Biology between the tribal students who appeared higher secondary final examination in pre-COVID 19 and during COVID 19 pandemic.
5. To compare academic achievement in English, Mathematics, Physics, Chemistry and Biology between the non-tribal students who appeared higher secondary final examination in pre-COVID 19 and during COVID 19 pandemic.

IV. HYPOTHESES

To draw necessary decision based on the objectives stated above, following hypotheses are considered.

H_{01}: There is no statistically significant difference in achievement between the students in pre-COVID 19 and during COVID 19 pandemic when bunch of subjects (English, Mathematics, Physics, Chemistry and Biology) are considered as a unit.

H_{02}: There is no statistically significant difference in achievement between the rural students in pre-COVID 19 and during COVID 19 pandemic when bunch of subjects (English, Mathematics, Physics, Chemistry and Biology) are considered as a unit.

H_{03}: There is no statistically significant difference in achievement between the urban students in pre-COVID 19 and during COVID 19 pandemic when bunch of subjects (English, Mathematics, Physics, Chemistry and Biology) are considered as a unit.

H_{04}: There is no statistically significant difference in achievement between the tribal students in pre-COVID 19 and during COVID 19 pandemic when bunch of subjects (English, Mathematics, Physics, Chemistry and Biology) are considered as a unit.

H_{05}: There is no statistically significant difference in achievement between the non-tribal students in pre-COVID 19 and during COVID 19 pandemic when bunch of subjects (English, Mathematics, Physics, Chemistry and Biology) are considered as a unit.

V. METHODOLOGY

Method
Descriptive survey method was used in this investigation.
Population
All the students who appeared in class XII state board examinations, which was conducted by Assam Higher Secondary Education Council (AHSEC) having subjects English, Mathematics, Physics, Chemistry and Biology of BTR of Assam considered as the population.
Sample and Sampling
For this study, samples are collected as follows:
1. Results of 2250 students who appeared in higher secondary examination 2019 and 2020 (pre-COVID 19 Pandemic) are collected randomly by stratified random sampling technique.
2. Results of 1873 students who appeared in higher secondary examination 2021 (during COVID 19 Pandemic) are also collected randomly by stratified random sampling technique.
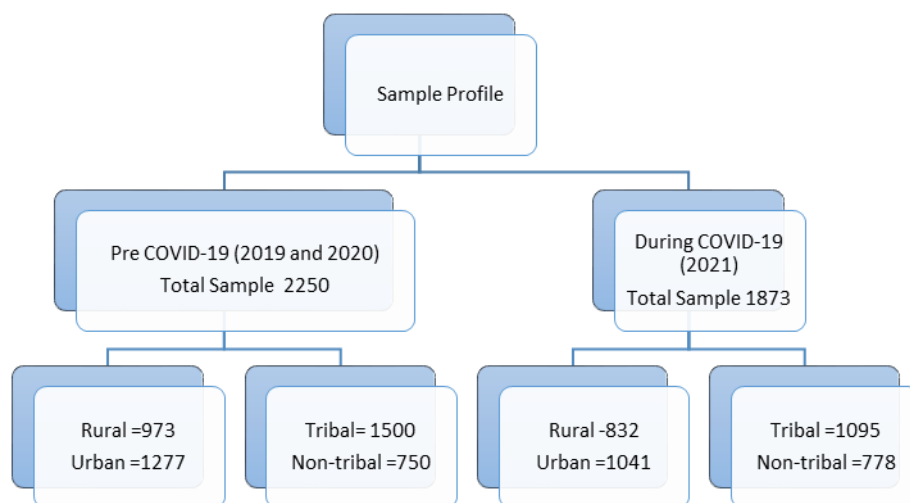
Figure 1. Sample Profile for the Study

Data Arrangement

Firstly, pre-COVID 19 pandemic achievement scores in English, Mathematics, Physics, Chemistry and Biology are collected and classified into different strata i.e. rural, urban, tribal and non-tribal. Secondly, during COVID 19 pandemic achievement scores in English, Mathematics, Physics, Chemistry and Biology are collected and classified into different strata i.e. rural, urban, tribal and non-tribal. Finally, strata-wise achievement scores in English, Mathematics, Physics, Chemistry and Biology are arranged for pre-COVID 19 and during COVID 19 pandemic.

Statistics

Mean, Standard Deviation, Variance-covariance are calculated for finding MD of different strata for pre-COVID 19 and during COVID 19 pandemic.

MD is calculated by applying the following equation:

$$\text{MD} = \left[(X - Y)^T \Sigma^{-1} (X - Y) \right]^{\frac{1}{2}} \quad \text{.........(1)}$$

Where X *and* Y are the mean of the achievement represented by the first and second groups of data respectively and Σ is a pooled Variance-covariance matrix of both groups viz. rural and urban, tribal and non-tribal etc.

VI. RESULTS AND DISCUSSIONS

Case I: Comparison of achievement between pre-COVID 19 and during COVID 19 pandemic of total students.

TABLE 1
DESCRIPTIVE STATISTICS OF DIFFERENT SUBJECTS FOR PRE-COVID 19

Descriptive Statistics (Pre-COVID 19)			
Total Pre-COVID	N	Mean	Std. Deviation
English	2250	55.63	15.393
Biology	2250	62.74	12.894
Physics	2250	50.72	12.812
Chemistry	2250	55.76	10.399
Mathematics	2250	35.31	12.777

TABLE 2
DESCRIPTIVE STATISTICS OF DIFFERENT SUBJECTS FOR DURING COVID 19

Descriptive Statistics (During COVID 19)			
Total during COVID	N	Mean	Std. Deviation
English	1873	67.34	12.930
Biology	1873	76.60	11.776
Physics	1873	75.87	11.737
Chemistry	1873	76.51	11.502
Mathematics	1873	68.14	12.781

The descriptive statistics for the pre-COVID 19 pandemic and the COVID 19 pandemic are shown in Tables 1 and 2, respectively. The mean scores for each subject have shown notable fluctuations. During the COVID 19 epidemic, means increased; the largest increase was observed in Mathematics.

Again, Tables 3 and 4 as given below represent the variance-covariance of achievements for pre-COVID 19 and during COVID-19 pandemic respectively for the students of higher secondary level.

TABLE 3
VARIANCE-COVARIANCE OF DIFFERENT SUBJECTS FOR PRE-COVID 19

Covariance	English	Biology	Physics	Chemistry	Mathematics
English	236.937	88.010	76.388	83.771	60.194
Biology	88.010	166.258	61.626	71.978	62.942
Physics	76.388	61.626	164.147	74.357	70.779
Chemistry	83.771	71.978	74.357	108.139	76.873
Mathematics	60.194	62.942	70.779	76.873	163.240

TABLE 4
VARIANCE-COVARIANCE OF DIFFERENT SUBJECTS FOR DURING COVID 19

Covariance	English	Biology	Physics	Chemistry	Mathematics
English	167.179	130.845	131.072	125.852	158.984
Biology	130.845	138.680	128.605	126.802	117.573
Physics	131.072	128.605	137.765	130.070	124.299
Chemistry	125.852	126.802	130.070	132.286	119.113
Mathematics	158.984	117.573	124.299	119.113	163.364

Also the pooled variance-covariance matrix of achievements of pre-COVID 19 and during COVID 19 is computed by using equation (2) with the help of tables 3 and 4 and is given by

$$A = \begin{bmatrix} 205.2473 & 107.4691 & 101.2299 & 102.8876 & 105.0724 \\ 107.4691 & 153.7298 & 92.05328 & 96.88349 & 87.75982 \\ 101.2299 & 92.05328 & 152.1622 & 99.66635 & 95.09211 \\ 102.8876 & 96.88349 & 99.66635 & 119.1085 & 96.06182 \\ 105.0724 & 87.75982 & 95.09211 & 96.06182 & 163.2963 \end{bmatrix} \ldots\ldots\ldots\ldots(3)$$

Mahalanobis Distance is calculated by using equation (1) with the help of Tables 1 and 2, and the inverse of the matrix A and its value is given by-

Mahalanobis Distance (MD) = 2.8896

This is a powerful statistic having the ability to compare two branches of variables together by one single dimensionless number. Since the value of the MD is 2.8896, it represents highly significant difference in achievement between pre-COVID 19 and during COVID 19 pandemic. According to the result, our null hypothesis H_{01} is rejected. Alternatively, we can conclude that the performance of achievement of students who are appeared during COVID 19 pandemic is better than the performance of achievement of students who are appeared pre COVID 19 when the group of subjects are taken as a branch.

Case II: Comparison of achievement between rural students who appeared pre-COVID 19 and during COVID 19 pandemic.

The performance of students living in rural areas was examined by the researchers through a comparison of their academic results of pre-COVID 19 and during COVID 19 pandemic. Tables 5 and 6 (shown below) represent the descriptive statistics for rural students who completed the higher secondary examination before the COVID 19 pandemic and during the pandemic, respectively. During the COVID 19 epidemic, mean scores increased dramatically, particularly in Mathematics.

TABLE 5
DESCRIPTIVE STATISTICS OF DIFFERENT SUBJECTS FOR RURAL STUDENTS (PRE-COVID 19)

Descriptive Statistics			
Rural	Mean	Std. Deviation	N
English	51.76	14.181	973
Biology	62.06	11.387	973
Physics	50.28	14.374	973
Chemistry	55.84	10.429	973
Mathematics	36.92	12.135	973

TABLE 6
DESCRIPTIVE STATISTICS OF DIFFERENT SUBJECTS FOR RURAL STUDENTS (DURING COVID 19)

Descriptive Statistics			
	Mean	Std. Deviation	N
English	69.62	10.767	832
Biology	77.80	9.137	832
Physics	76.70	9.171	832
Chemistry	77.28	9.186	832
Mathematics	70.10	10.588	832

Regarding rural higher secondary students, Tables 7 and 8 (as shown below) show the variance-covariance of the students' achievements for the pre-COVID 19 and COVID 19 period, respectively.

TABLE 7
VARIANCE-COVARIANCE OF DIFFERENT SUBJECTS FOR RURAL STUDENTS OF PRE-COVID 19

Covariance	English	Biology	Physics	Chemistry	Mathematics
English	201.098	75.038	63.940	77.331	68.442
Biology	75.038	129.653	52.010	74.371	58.643
Physics	63.940	52.010	206.624	64.708	55.801
Chemistry	77.331	74.371	64.708	108.770	69.530
Mathematics	68.442	58.643	55.801	69.530	147.248

TABLE 8
VARIANCE-COVARIANCE FOR DIFFERENT SUBJECTS FOR RURAL STUDENTS DURING COVID-19

Covariance	English	Biology	Physics	Chemistry	Mathematics
English	115.926	85.173	86.220	85.578	110.144
Biology	85.173	83.480	78.483	79.294	79.132
Physics	86.220	78.483	84.103	81.572	83.398
Chemistry	85.578	79.294	81.572	84.389	83.203
Mathematics	110.144	79.132	83.398	83.203	112.105

Once more, using equation (2) and Tables 7 and 8 as indicated above, the pooled variance-covariance matrix of the rural students' achievements for the pre-COVID 19 and COVID 19 period is provided by:

$$B = \begin{bmatrix} 161.8387 & 79.70965 & 74.20978 & 81.13239 & 87.6642 \\ 79.70965 & 108.3699 & 64.21251 & 76.64022 & 68.08724 \\ 74.20978 & 64.21251 & 150.1489 & 72.48132 & 68.52161 \\ 81.13239 & 76.64022 & 72.48132 & 97.53178 & 75.83246 \\ 87.6642 & 68.08724 & 68.52161 & 75.83246 & 131.0491 \end{bmatrix} \quad \dots\dots\dots\dots\dots\dots(4)$$

In this case, the values of Mahalanobis Distance is given by-

Mahalanobis Distance (MD) = 301234

A highly significant difference is found and hence our null hypothesis H_{02} is rejected. Alternatively, it is possible to draw the conclusion that there is a very statistically significant difference in students' achievement for the branch of subjects taken together as a unit between pre-COVID 19 and COVID 19 pandemic students. In actuality, COVID 19 examinees do better in terms of accomplishment.

Case III: Comparison of achievement between urban students who appeared pre-COVID 19 and during COVID 19 pandemic.

The descriptive statistics for the pre-COVID 19 and COVID 19 pandemic periods of urban students are displayed in Tables 9 and 10, respectively. There have been significant changes to the average scores for all subjects. During the COVID 19 pandemic, means increase, with mathematics seeing the most increase.

TABLE 9
DESCRIPTIVE STATISTICS OF DIFFERENT SUBJECTS FOR URBAN STUDENTS (PRE-COVID 19)

Descriptive Statistics			
	Mean	Std. Deviation	N
English	58.57	15.633	1277
Biology	63.26	13.916	1277
Physics	51.05	11.473	1277
Chemistry	55.70	10.380	1277
Mathematics	34.06	13.149	1277

TABLE 10
DESCRIPTIVE STATISTICS OF DIFFERENT SUBJECTS FOR URBAN STUDENTS (DURING COVID 19)

Descriptive Statistics			
	Mean	Std. Deviation	N
English	65.52	14.183	1041
Biology	75.63	13.448	1041
Physics	75.19	13.409	1041
Chemistry	75.86	13.029	1041
Mathematics	66.56	14.112	1041

Tables 11 and 12 (shown below), correspondingly, display the achievement variance-covariance for the pre-COVID 19 and COVID 19 periods.

TABLE 11
VARIANCE-COVARIANCE FOR DIFFERENT SUBJECTS FOR URBAN STUDENTS (PRE-COVID 19)

Covariance	English	Biology	Physics	Chemistry	Mathematics
English	244.377	94.431	83.665	89.171	62.710
Biology	94.431	193.651	68.605	70.287	67.601
Physics	83.665	68.605	131.637	81.818	83.273
Chemistry	89.171	70.287	81.818	107.735	82.528
Mathematics	62.710	67.601	83.273	82.528	172.883

TABLE 12
VARIANCE-COVARIANCE FOR DIFFERENT SUBJECTS FOR URBAN STUDENTS (DURING COVID 19)

Covariance	English	Biology	Physics	Chemistry	Mathematics
English	201.169	163.784	164.589	155.838	192.060
Biology	163.784	180.856	167.365	163.537	145.371
Physics	164.589	167.365	179.791	167.988	155.099
Chemistry	155.838	163.537	167.988	169.758	146.018
Mathematics	192.060	145.371	155.099	146.018	199.139

The pooled variance-covariance matrix of achievement, which is obtained by using equation (2) with the help of Tables 11 and 12, is given by –

$$C = \begin{bmatrix} 224.9725 & 125.577 & 120.0075 & 119.1108 & 120.8003 \\ 125.577 & 187.9048 & 112.9575 & 112.165 & 102.527 \\ 120.0075 & 112.9575 & 153.2627 & 120.5164 & 115.5296 \\ 119.1108 & 112.165 & 120.5164 & 135.5892 & 111.041 \\ 120.8003 & 102.527 & 115.5296 & 111.041 & 184.6744 \end{bmatrix} \quad \text{………………..(5)}$$

In this case, the value of MD is given by-

Mahalanobis Distance (MD) = 2.8827.

The fact that the MD value is 2.8896 indicates that there is a sizable achievement difference between students enrolled prior to the COVID 19 outbreak and those enrolled during it. Our null hypothesis, **H03**, is thus refuted. Alternatively, the conclusion might be made that urban pupils who showed up during the COVID 19 pandemic performed better than students who showed up prior to the outbreak.

Case IV: Comparison of achievement between tribal students who appeared pre-COVID 19 and during COVID 19 pandemic.

The descriptive statistics for the pre-COVID 19 pandemic and during COVID 19 pandemic of tribal students are shown in Tables 13 and 14 respectively. The average test results have changed noticeably across all discipline.

TABLE 13
DESCRIPTIVE STATISTICS OF DIFFERENT SUBJECTS FOR TRIBAL STUDENTS (PRE-COVID 19)

Descriptive Statistics			
	Mean	Std. Deviation	N
English	54.74	14.744	1500
Biology	62.55	13.179	1500
Physics	49.42	13.181	1500
Chemistry	54.92	9.618	1500
Mathematics	34.83	12.319	1500

TABLE 14
DESCRIPTIVE STATISTICS OF DIFFERENT SUBJECTS FOR TRIBAL STUDENTS (DURING COVID 19)

Descriptive Statistics			
	Mean	Std. Deviation	N
English	66.47	12.416	1095
Biology	75.97	11.385	1095
Physics	75.06	11.329	1095
Chemistry	75.83	11.051	1095
Mathematics	67.08	12.456	1095

Again Tables 15 and 16 (shown below) display the accomplishment variance-covariance for pre-COVID 19 and during COVID 19.

TABLE 15
VARIANCE-COVARIANCE FOR DIFFERENT SUBJECTS FOR TRIBAL STUDENTS (PRE-COVID 19)

Covariance	English	Biology	Physics	Chemistry	Mathematics
English	217.387	75.083	63.968	72.386	59.058
Biology	75.083	173.685	52.466	61.385	64.408
Physics	63.968	52.466	173.747	59.136	64.052
Chemistry	72.386	61.385	59.136	92.499	67.774
Mathematics	59.058	64.408	64.052	67.774	151.755

TABLE 16
VARIANCE-COVARIANCE FOR DIFFERENT SUBJECTS FOR TRIBAL STUDENTS (DURING COVID 19)

Covariance	English	Biology	Physics	Chemistry	Mathematics
English	154.163	120.604	121.838	115.441	150.783
Biology	120.604	129.608	121.505	119.064	113.459
Physics	121.838	121.505	128.355	119.560	117.107
Chemistry	115.441	119.064	119.560	122.121	111.417
Mathematics	150.783	113.459	117.107	111.417	155.149

The polled covariance matrix for tribal students is given below, which was obtained by using equation (2) with the help of Table 15 and 16.

$$D = \begin{bmatrix} 190.7087 & 94.29128 & 88.38713 & 90.55372 & 97.76277 \\ 94.29128 & 155.086 & 81.59806 & 85.72354 & 85.10582 \\ 88.38713 & 81.59806 & 154.5932 & 84.63283 & 86.43937 \\ 90.55372 & 85.72354 & 84.63283 & 104.9985 & 86.18983 \\ 97.76277 & 85.10582 & 86.43937 & 86.18983 & 153.1872 \end{bmatrix} \ldots\ldots\ldots\ldots..(6)$$

In this case, the Mahalanobis Distance is given by-

Mahalanobis Distance (MD) = 2.9838.

The Mahalanobis Distance in this instance is 2.9838, indicating a fairly substantial academic performance differential between students enrolled prior to the COVID 19 epidemic and those enrolled during it in higher secondary level examinations. In light of the data, our null hypothesis, H_{04}, is rejected. Alternatively, it might be concluded that tribal students who appeared during the COVID 19 pandemic outperformed students who appeared prior to the pandemic when the group of subjects was analysed.

Case-V: Comparison of achievement between non-tribal students who appeared pre-COVID 19 and during COVID 19 pandemic.

The descriptive statistics for the pre-COVID 19 pandemic and the during COVID 19 pandemic are presented in Tables 17 and 18, respectively. There have been noticeable changes to the mean scores across all subjects. During the COVID 19 outbreak, means increase with Mathematics showing the largest expansion.

TABLE 17
DESCRIPTIVE STATISTICS OF DIFFERENT SUBJECTS FOR NON-TRIBAL STUDENTS (PRE-COVID 19)

Descriptive Statistics			
	Mean	Std. Deviation	N
English	57.39	16.483	750
Biology	63.12	12.305	750
Physics	53.31	11.621	750
Chemistry	57.44	11.634	750
Mathematics	36.28	13.603	750

TABLE 18
DESCRIPTIVE STATISTICS OF DIFFERENT SUBJECTS FOR NON-TRIBAL STUDENTS (DURING COVID 19)

Descriptive Statistics			
	Mean	Std. Deviation	N
English	68.56	13.551	778
Biology	77.47	12.263	778
Physics	76.98	12.210	778
Chemistry	77.44	12.050	778
Mathematics	69.61	13.103	778

Tables 19 and 20 (shown below) display the accomplishment variance-covariance for pre-COVID 19 and during COVID 19 pandemic.

TABLE 19
VARIANCE-COVARIANCE FOR DIFFERENT SUBJECTS FOR NON-TRIBAL STUDENTS (PRE-COVID 19)

Covariance	English	Biology	Physics	Chemistry	Mathematics
English	271.702	112.994	94.453	102.221	59.982
Biology	112.994	151.401	78.561	92.318	59.541
Physics	94.453	78.561	135.059	98.365	80.546
Chemistry	102.221	92.318	98.365	135.357	92.747
Mathematics	59.982	59.541	80.546	92.747	185.037

TABLE 20
VARIANCE-COVARIANCE FOR DIFFERENT SUBJECTS OF NON-TRIBAL STUDENTS (DURING COVID 19)

Covariance	English	Biology	Physics	Chemistry	Mathematics
English	183.634	143.987	142.307	139.073	168.105
Biology	143.987	150.378	137.152	136.486	121.825
Physics	142.307	137.152	149.074	143.222	132.245
Chemistry	139.073	136.486	143.222	145.214	128.163
Mathematics	168.105	121.825	132.245	128.163	171.692

The polled covariance matrix which is obtained by using Table 19 and Table 20 and equation (2) is given by-

$$E = \begin{bmatrix} 226.8611 & 128.7745 & 118.8185 & 120.9846 & 115.0342 \\ 128.7745 & 150.8801 & 108.3933 & 114.8067 & 91.25366 \\ 118.8185 & 108.3933 & 142.1949 & 121.2045 & 106.8692 \\ 120.9846 & 114.8067 & 121.2045 & 140.3758 & 110.7795 \\ 115.0342 & 91.25366 & 106.8692 & 110.7795 & 178.2422 \end{bmatrix} \quad \ldots\ldots\ldots\ldots\ldots\ldots(7)$$

In this case, the value of MD is given by-

Mahalanobis Distance = 2.8013.

The distance's value of 2.8013 shows that pupils enrolled before the COVID 19 outbreak and those enrolled during it had significantly different accomplishment levels. Thus, **H₀₅** our null hypothesis, is disproved. Alternatively, one could draw the conclusion that non-tribal pupils did better than those that showed before to the COVID 19 pandemic when they presented.

Though many researches were carried out using MD in achievement analysis, this study found that the results are in line with only Sen and Pal (2020) in relation that there are statistically significant differences between two branches of subjects. This study disagrees with the findings of Ahmed et al. (2022a), Ahmed et al. (2022b), and Mahato and Sen (2021) as in their studies there were no statistically significant difference between two branches.

VII. CONCLUSION

It is a fact that Mahalanobis Distance is greater than 2 for every pair of observations, i.e. between rural students appeared in pre-COVID 19 and during COVID 19 pandemic. This result is also same for urban students who appeared higher secondary examinations pre-COVID 19 and during COVID 19. When we consider tribal students it is also found the same result. And again, when non-tribal students are considered, we found the same result that the results of pre-COVID 19 pandemic is inferior then during COVID 19 pandemic. If we consider the total students as a whole the result shows the same scenario. It is obvious that during pandemic, the examinations of achievements are not properly administered during online education system. However, during pandemic the real classroom teaching learning was not performed properly but result shows that achievements increased remarkably during the pandemic. It is a serious concern that, this achievement scores will affect future life of the students regarding admission in any course or getting

a job in government sector. Therefore, there should be an authenticated method to evaluate this significant change in achievement actually reflects the real difference or not.

VIII. RECOMMENDATIONS FOR FUTURE STUDIES

Following recommendations may be considered for further studies.
- It is recommended that this research can be done in any state of India.
- It can be done in different district of BTR, Assam.
- It can be done by considering many more subjects with English, Biology Physics, Chemistry and Mathematics.
- It can be done by considering different levels also like secondary, graduation, post graduation.
- This can be done by considering different streams like general education, technical education, medical education and many more together to compare the distance.

ACKNOWLEDGEMENTS

REFERENCES

[1] Adhikari, A. (2023). Application of Mahalanobis distance in education and educational psychology: A Review. *Innovare Journal of Education*, *11*(4), 5-7. https://dx.doi.org/10.22159/ijoe.2023v11i4.47671.

[2] Adhikari, A., Gayen, P., Sutradhar, A., & Sen, S. (2023a). A measure for measure: statistics in education. *International Journal of Research Publication and Reviews*, *4*(5), 4239-4243.

[3] Adhikari, A., Gayen, P., Mahato, R.C., Pal, I., Sen, S. (2023b). Multi-Dimensional Data Analysis in Education: Accumulation and Comparison among Variables, *International Journal of Research Publication and Reviews*, *4*(5), 2243 – 2245.

[4] Ahmed, E. A., Banerjee, M., Sen, S., & Chatterjee, P. (2020). Application of Mahalanobis Δ^2 on Achievement Tests on Mathematics: A Study on Higher Secondary Level Students. *Indian Journal of Psychology and Education*, *10*(1), 36-40.

[5] Ahmed, E. A., Banerjee, M., Sen, S., & Chatterjee, P. (2021). Comparison of Achievement of Higher Secondary Subjects among Tribal and non-Tribal Students of Bodoland Territorial Region, Assam, India using Mahalanobis Distance. *Journal of the Calcutta Mathematical Society*, *17*(1), 61-66.

[6] Ahmed, E. A., Karim, M.R., Banerjee, M., Sen, S., Chatterjee, P., & Mondal, G. (2022a). A Comparative Study on Academic Achievement of Mathematics and English with Other Subjects of Secondary Level in BTR of Assam, India, Using Mahalanobis Distance. *Education Research International*, *2022*, 1-10. https://doi.org/10.1155/2022/3669065

[7] Ahmed, E. A., Karim, M.R., Banerjee, M., & Sen, S. (2022b).Comparison of Scholastic Attainment in English and Math amongst Other Studies at the Higher Secondary Level: A Study using Mahalanobis Distance, *Educational Administration: Theory and Practice*, *28*(4), 1-13. https://doi.org/10.17762/kuey.v28i4.469

[8] Benaichouche, A. N., Oulhadj, H., & Siarry, P. (2013). Improved spatial fuzzy c-means clustering for image segmentation using PSO initialization, Mahalanobis distance and post-segmentation correction. *Digital Signal Processing*, *23*(5), 1390-1400.

[9] Chen, S. H., Kuo, Y., & Lin, J. K. (2021). Using Mahalanobis distance and decision tree to analyze abnormal patterns of behavior in a maintenance outsourcing process-a case study. *Journal of Quality in Maintenance Engineering*, *27*(2), 253-263.

[10] de la Hermosa González, R. R. (2018). Wind farm monitoring using Mahalanobis distance and fuzzy clustering. *Renewable energy*, *123*, 526-540.

[11] Gorain, S. C., Adhikari, A., Saha, B., & Sen, S. (2021).A Study on Internet Dependency, Social Isolation and Personality using Mahalanobis Distance. *EPRA International Journal of Research and Development (IJRD)*, *6*(9), 179-184. DOI: https://doi.org/10.36713/epra8471

[12] Haldar, N., et al. (2016). Arrhythmia classification using Mahalanobis distance based improved fuzzy C-Means clustering for mobile health monitoring systems, *Neurocomputing*, *220*, 221–235.

[13] Hamill, P., Giordano, M., Ward, C., Giles, D., & Holben, B. (2016). An AERONET-based aerosol classification using the Mahalanobis distance. *Atmospheric Environment*, *140*, 213-233.

[14] Hirano, S., Sun, X., & Tsumoto, S. (2004). Comparison of clustering methods for clinical databases. *Information Sciences*, *159*(3-4), 155-165.

[15] Kamoi, R., & Kobayashi, K. (2020). Why is the Mahalanobis distance effective for anomaly detection? *arXiv preprint arXiv:2003.00402*.

[16] Kapoor, S., Khanna, S., & Bhatia, R. (2010). Facial gesture recognition using correlation and Mahalanobis distance. *arXiv preprint arXiv:1003.1819*.

[17] Kojima, K., Taniue, H., & Kaneko, J. I. (2016, May). Mahalanobis distance-based road condition estimation method using network-connected manual wheelchair. In *2016 IEEE International Conference on Consumer Electronics-Taiwan (ICCE-TW)* (pp. 1-2). IEEE.

[18] Lapidot, I. (2018). Convergence problems of Mahalanobis distance-based k-means clustering, *IEEE International Conference on the Science of Electrical Engineering in Israel (ICSEE)*, Eilat, Israel, 1-5, doi: 10.1109/ICSEE.2018.8646138.

[19] Law, M. T., Yu, Y., Cord, M., & Xing, E. P. (2016). Closed-form training of Mahalanobis distance for supervised clustering. In *Proceedings of the IEEE Conference on Computer Vision and Pattern Recognition* (pp. 3909-3917).

[20] Liang, W. Z., Kirk, K. R., & Greene, J. K. (2018). Estimation of soybean leaf area, edge, and defoliation using color image analysis. *Computers and electronics in agriculture*, *150*, 41-51.

[21] Maesschalck, R. De., Jouan-R, D. & Massart, D. L. (2000). The Mahalanobis distance, *Chemometrics and Intelligent Laboratory Systems*, *50*, 1-18.

[22] Mahalanobis, P.C. (1927). Analysis of race mixture in Bengal. *Journal and Proceedings of the Asiatic Society of Bengal*, *23*, 301-333.

[23] Mahalanobis, P.C. (1936). On the Generalized Distance in Statistics. *Proceedings of the National Institute of Sciences of India*, *2*(1), 49-55.

[24] Mohanta, R., Gayen, P., Pal, I., Mahato, R. C., & Sen, S. (2023a). Comparison among different dimensions of organizational climate of secondary school teachers of West Bengal by Mahalanobis distance. *EPRA International Journal of Research and Development (IJRD)*, *8*(4), 129 – 133. DOI: https://doi.org/10.36713/epra2016

[25] Mohanta, R., Gayen, P., Pal, I., Sutradhar, A., & Sen, S. (2023b). Comparison among different dimensions of institutional commitment of secondary school teachers of West Bengal by Mahalanobis distance. *International Research Journal of Modernization in Engineering Technology and Science*, *5*(4), 4088 – 4093.

[26] Mahato, R. C., & Sen, S. (2021). Application of Mahalanobis Distance to Determine the Dynamical Nature of Academic Stress, Self-efficacy in Mathematics and Anxiety in Mathematics. *International Journal of Advances in Engineering and Management (IJAEM)*, *3*(5), 1398-1401.

[27] Martino, A., Ghiglietti, A. & Ieva, F. (2019).A k-means procedure based on a Mahalanobis type distance for clustering multivariate functional data. *Statistical Methods &Applications*, *28*, 301–322. https://doi.org/10.1007/s10260-018-00446-6

[28] Mingliang, S. et al (2018). Fuzzy Bayes risk based on Mahalanobis distance and Gaussian kernel for weight assignment in labeled multiple attribute decision making, *Knowledge-Based Systems*, *152*, 26-39.

[29] Pinho, R. R., & Tavares, J. M. R. (2009). Tracking features in image sequences with Kalman filtering, global optimization, Mahalanobis distance and a management model. *Computer Modeling in Engineering & Sciences*, *46*(1), 51-76.

[30] Pinho, R. R., Tavares, J. M. R., & Correia, M. V. (2005). A movement tracking management model with Kalman filtering, global optimization techniques and Mahalanobis distance. *Advances in Computational Methods in Sciences and Engineering, 4A & 4B*.

[31] Rafati, A. & Akbarpour, S. (2018). A New Credibilistic Clustering Method with Mahalanobis Distance, I.J. *Mathematical Sciences and Computing*, *4*, 1-18. doi: 10.5815/ijmsc.2018.04.01.

[32] Rao, C. R. (1963). *Essays on Econometrics and Planning* (Presented to Professor P. C. Mahalanobis on the occasion of his 70th Birthday). Calcutta, India: Pergamon Press.

[33] Rao, C. R. (1973). Prasantha Chandra Mahalanobis, 1893-1972. *Biographical Memoirs of Fellows of the Royal Society*, *19*, 454-492.

[34] Rudra, A., Rao, B.L.S.P., Ghosh, J.K. & Bhattacharya, N. (1996). *Prasanta Chandra Mahalanobis: A Biography*. Oxford, UK: Oxford University Press.

[35] Sen, S., Gayen, P., Pal, I., Sutradhar, A., Ansary, K., Mahato, R. C., & Adhikari, A. (2023a). Comparison among different leadership styles of head of the institution of West Bengal by Mahalanobis distance. *International Research Journal of Modernization in Engineering Technology and Science*, *5*(4), 5005 – 5010.

[36] Sen, S., Pal, I., & Adhikari, A. (2023b). Comparison among self-efficacy, Depression, Anxiety and stress of postgraduate students by Mahalanobis Distance. *International Journal of Advanced Education and Research*, *8*(1), 85 – 58.

[37] Sen, S. & Pal, I. (2020). Mahalanobis Distance: A Study on Achievement of Science and Mathematics. *International Journal of Creative Research Thoughts*, *8*(7), 2542-2547.

[38] Sheikh, V., Kornejady, A., & Ownegh, M. (2019). Application of the coupled TOPSIS–Mahalanobis distance for multi-hazard-based management of the target districts of the Golestan Province, Iran. *Natural Hazards*, *96*, 1335-1365.

[39] Sutradhar, A., Sen, S., Adhikari, A., & Mondal Sutradhar, S. (2023). Self-efficacy, depression, anxiety and stress of university students: a study by Mahalanobis distance. *Galore International Journal of Applied Sciences & Humanities*, *7*(3), 7-15. DOI: https://doi.org/10.52403/gijash.20230302

[40] Venturini, G. M. (2015). *Statistical Distances and Probability Metrics for Multivariate Data, Ensembles and Probability Distributions.* Retrieved on 25 August 2023 from https://core.ac.uk/download/pdf/30276753.pdf

[41] Xiang, S., Nie, F. & Zhang, C. (2008) Learning a Mahalanobis distance metric for data clustering and classification, *Pattern Recognition*, *41*(12), 3600-3612.

[42] Zhao, X., Li, Y., & Zhao, Q. (2015). Mahalanobis distance based on fuzzy clustering algorithm for image segmentation. *Digital Signal Processing*, *43*, 8-16.

[43] Zhang, S., & Pan, X. (2011, March). A novel text classification based on Mahalanobis distance. In *2011 3rd International Conference on Computer Research and Development* (Vol. 3, pp. 156-158). IEEE.

[44] Zeng, S., Wang, X., Duan, X., Zeng, S., Xiao, Z., & Feng, D. (2020). Kernelized Mahalanobis distance for fuzzy clustering. *IEEE Transactions on Fuzzy Systems*, *29*(10), 3103-3117.

Eusob Ali Ahmed is an Assistant Professor, Department of Mathematics, Sapatgram College, GU, Assam, India. He did his Ph.D. on educational data using Mahalanobis Distance from Visva-Bharati University, Kolkata. He has in his credits 13 research papers published in peer-reviewed international journals. He also authored two books. His main areas of interest are mathematics education and statistics. He is available at eusob1974@gmail.com

Mohammad Rezaul Karim is currently working as an Assistant Professor of English in the College of Science and Humanities, Prince Sattam bin Abdulaziz University, KSA. He holds a Ph.D. from Gauhati University, India. He has been teaching English language to the undergraduate students for the last 7 years. He has presented papers at both national and international conferences, published more than 25 research articles and papers in various Scopus and WOS indexed journals, and authored two books. His main area of interest is English language and comparative literature. He is available at karimrezaul318@gmail.com

Munmun Bannerjee is an Assistant Professor in Education, Sapatgram College, GU, Assam, India. She obtained JRF from NCERT, India during her doctoral research. Her research area includes evaluation system in elementary schools of North East India. At present, she is doing research on educational data using Mahalanobis Distance. She has published several research papers in these areas of interest.

Subir Sen is currently posted as an Associate Professor, Department of Education, Sidho-Kanho-Birsha University, Purulia, West Bengal, India. He is an alumnus of Visva-Bharati University, Kolkata. He has been associated with teaching for around 20 years. He has published many research articles in national and international peer-reviewed journals. He authored two books – *Pedagogy of Mathematics Teaching* and *Understanding the Self: An Introduction*. His research interest lies in mathematics education, educational research, curriculum studies, and educational psychology. He is available at subirsenmath@gmail.com

Sameena Banu is currently working as a lecturer in the College of Science and Humanities, Prince Sattam bin Abdulaziz University, KSA. She has been teaching English language to the undergraduate students for the last 10 years. She has published research articles and papers in Scopus and WOS indexed journals. Her main area of interest is English language and literature.

Wahaj Unnisa Warda, has been working in the Department of English Language and Literature, Prince Sattam Bin Abdulaziz University, Saudi Arabia for the past ten years. Prior to that she worked as a senior lecturer in India for thirteen years. She has presented and published papers at various International conferences and journals in London, India, Australia and Saudi Arabia. She is a member of various national and international organizations besides being a reviewer for international journals. Her areas of interest are psychoanalysis, Classical Mythology, and detective fiction of the 19th century.