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Performance Assessment of Mathematics and Statistics Students of a Tertiary Institution in Ghana

Mohammed Frempong and Michael Asare-Bediako
Department of Mathematics and Statistics, Takoradi Polytechnic, P. O. Box 256, Takoradi, Ghana

Abstract
The contribution of mathematics and its allied sciences is central to sustainable economic development of every nation. Students' performance in mathematics/statistics at tertiary level of education leaves much to be desired. This paper seeks to investigate academic performance of students of students of mathematics and statistics of a tertiary institution in Ghana. It examines students' performance in mathematics/statistics with respect to; gender, the period from 2000 to 2012, and the nature of relationship in terms of mathematics/statistics achievement between the various semesters of the study. The study made use of data on academic records of ten (10) cohorts of 617 Higher National Diploma, (HND) statistics students who were admitted to and graduated from the Mathematics and Statistics Department of the institution. The study revealed that, although males far outnumbered females, their performances are the same; students' performance differed among the various years of study. In general, students' performance increased across the study period. Further, students' performances in some of the semesters were found to be related to other semesters**.** It was recommended that; more females enroll into mathematics and mathematics related programmes to ensure a balanced representation of gender, students' CGPA be monitored persistently for appropriate advice, and the research work be replicated in other tertiary institutions to give a broader picture of students' achievement in mathematics/statistics
Keywords: Academic performance, Cumulative Grade Point Average, Mathematics/Statistics

1. Introduction

Development in the 21^{st} century which is based on the quality of human resource available is thought to be strongly related to education that is predominantly driven by technology. The role science and mathematics play in the development of technology cannot be gainsaid. In view of this, science, technology, mathematics, and its allied disciplines such as statistics, engineering, to mention a few, are given due attention more especially at the tertiary level. In tertiary institutions such as polytechnics and universities, students' academic performances are continuously assessed on semester basis and eventually their final cumulative grade point average, CGPA computed. These scores serve as indicators that classify students into various awards such as first class, second class upper, second class lower, third class, pass and fail. Class (award) obtained by a student is important. Generally, most organisations, and other tertiary institutions use these classes; to select and place students (applicants) from one stage to another on the academic ladder, as criteria for awarding qualification and promotion. Mathematics as academic discipline impacts all facets of human development at various stages. For instance, mathematics is employed as a tool in solving complex problems in fields of the social, natural, and applied sciences. The usefulness of mathematics/statistics is also seen in computer science. For instance computer scientists have developed mathematical software for teaching and learning mathematics in areas such as; developing visual/geometrical understanding, allowing students to concentrate on problem formulation and solution analysis, and other computations that have made life easy (Kumar and Kumaraesan, 2008**)**. Mathematics/ Statistics is imperative because apart from its strengthening of the human faculty, its study tends to promise many career avenues globally. To achieve meaningful progress in our communities, we must pay attention to mathematics in all the phases of our educational system; from basic education through senior high school to the tertiary education. This is because wealth creation of every nation depends on science and technology, of which mathematics is indispensable. In spite of the crucial role and the importance of mathematics/statistics in our contemporary society, students' achievement in mathematics has been a great concern to the general public more especially in respect of gender. For instance the 2014 West African Secondary School Certificate Examinations, WASSCE results show that out of 242162 candidates who sat for the May/June West African Senior School Certificate Examination (WASSCE), 78460 representing32.4 % obtained grades (A1-C6) that could qualify them admissions for tertiary schools, 77492 constituting 32.0% got weak passes of grades (D7-E8), while 86210 made up of more than one-third (35.6%) failed (ghananewsagency.org). Further, data obtained from Takoradi Polytechnic Admissions Office revealed that of the 3171 students admitted in 2013/2014 academic year, 1169(almost 37%) of the applicants failed to obtain minimum pass mark in; Mathematics, English Language and Integrated Science for the HND programme. Mathematics constitutes more than 70% of this number (1169). These affected students are therefore given conditional admission, made to undertake special access course before formally admitted into the HND programme. Further, 2015, 2016 congregation brochure of Takoradi Polytechnic revealed that lower numbers of females as compared to males, graduate in mathematics and mathematics related programmes. Also, it is discovered that women participation in mathematics, science and technology has decreased from 41% at the end of the 1990 to 38% in 2010 (Eurostat, 2010). It is on this note that this study seeks to statistically investigate thoroughly into the academic performance of mathematics/statistics students of the tertiary institution. In this respect, it aims at seeking answers to some pertinent issues such as; students' performance with respect to gender, it examines the general trend of students' performance in mathematics/statistics over the study period, and also the nature of relationship that exist between the semesters in terms of students' achievement in mathematics/statistics. This is achieved by putting the write-up into the following sections; Section 2 discusses the mathematical perspective of the main statistical techniques; paired sample t- test, analysis of variance, and correlation analysis used in analysing the data. Section 3 discusses the results of the analysis. Summary of the research, findings and the implications for practice are contained in the conclusion of section 4

2. Materials and Methods

Data on a population of ten (10) cohorts of 617 Higher National Diploma, (HND) statistics students who were admitted to and graduated from the Mathematics and Statistics Department of the tertiary institution were obtained. This is made up of semester grade point averages, GPA scores as well as the cumulative grade point average, CGPA, of students. To ensure that student (respondent) privacy is secured, the data excluded names and registration numbers of the students. The results were grouped into semester 1, semester 2 …, and semester 6 to cover the three years for which the HND programme is run. The final cumulative grade point average scores, CGPA were also recorded. Also, based on names of the students, GPAs as well as CGPAs, the data were sorted into the gender dichotomy, that is grade for males was recorded separately from that of females. The class obtained by each student or recommended award was also recorded. By definition and convention as designed by The National Board for Professional and Technician Examination, NABPTEX, a student obtains first class when he scores CGPA from 4.00-5.00, earns second class upper division when he scores between 3.00-4.00, for a CGPA between 2.00-3.00 the student earns a second class lower award. Students obtaining CGPAs of 1.50-2.00 and less than1.50 earn the awards of pass and fail respectively. The data were analysed using the Statistical Product for the Service Solutions (SPSS) Version16.0. In establishing concrete statistical conclusions, paired sample t-test, one way analysis of variance, post-hoc analysis, and correlation analysis were employed to address the issue of gender difference in mathematics/statistics performance, students' performance in respect of the years, and the nature of relationship in terms of mathematics/ statistics achievement between the various semesters of study. The statistical methods are briefly reviewed below.

2.1 Paired Sample T- Test

This statistical technique is used to compare two population means in situations where; the two samples are correlated, different times ('before and after' experiment), there is a case-control study or matched pair samples. Suppose$x_1, x_2, ..., x_n$ and $y_1, y_2, \dots, y_n$ constitute observations on n individuals before and after study, then paired samples are (x_1, y_1), (x_2, y_2) , ..., (x_n, y_n). To compare the means of these data, the data are transformed to one- sample t-test, by constructing mean differences, between the observations $(y_1 - x_1)$, $(y_2 - x_2)$, ..., $(y_n - x_n)$ respectively. If $\bar{d}$, n , and $\boldsymbol{s^2}$ are the respective mean difference between the two samples, sample size, and sample variance, then the test statistic with $n-1$ degree of freedom is

$$t = \frac{\bar{d}}{\sqrt{\frac{s^2}{n}}} \text{ ……………………………………………………… (1)}$$

Equation (1) can further be re-written in terms of the difference, d and the sample, n as

$$t = \frac{\sum d}{\sqrt{\frac{n(\sum d^2)-(\sum d)^2}{n-1}}} \quad \text{(statisticssolution.com).}$$

The hypotheses in this case are H_o: $\mu_1 = \mu_2$ and H_1: $\mu_1 < \mu_2$ **.** The assumptions in these situations are; only the matched pairs can be used, data must be normally distributed, the variance of the two samples must be equal, and the cases must be independent of each other (statisticssolution.com)**.** Table of t values at certain level of significance, α and with corresponding $n-1$ degree of freedom is read. If the test statistic is greater than the table value, we reject H_0 and conclude that there exists significant difference between means of the two samples otherwise the sample means are the same.

2.2 *Analysis of Variance*

This is a statistical technique that allows researchers to compare two or more populations of quantitative data. The ANOVA allows statisticians to determine whether differences exist among population means (Keller and Warrack, 2000). In ANOVA, one of the key elements worthy of consideration is the total sum of squares. This is based on the idea that the yield x_{ij} can be partitioned as follows:

$x_{ij} = \mu + (\mu_j - \mu) + (x_{ij} - \mu_j)$, where μ is the overall mean; $(\mu_j - \mu)$ is the effect due to treatment j and $x_{ij} - \mu_j$ is the random error within the treatment groups (Gordor and Howard, 2000). Replacing the parameters μ and μ_j by their estimates, it can be shown after some algebraic manipulation that

$$\sum_{i=1}^{nj}\sum_{j=1}^{k}\left(X_{ij} - \bar{X}_{00}\right)^2 = \sum_{j=1}^{k} n_j\left(X_{0j} - \bar{X}_{00}\right)^2 + \sum_{i=1}^{nj}\sum_{j=1}^{k}\left(X_{ij} - \bar{X}_{0j}\right)^2 \ldots\ldots\ldots\ldots (1)$$

Where

$\bar{X}_{00} = \frac{\sum_{i=1}^{nj}\sum_{j=1}^{k} X_{ij}}{n}$, is the grand sample mean; $\bar{X}_{0j}$ is the mean of the j^{th}

treatment and n is the total observation in the design. In equation (1), the term $\sum_{i=1}^{nj}\sum_{j=1}^{k}\left(X_{ij} - \bar{X}_{00}\right)^2$ is called total sum of squares(SS_T), $\sum_{j=1}^{k} n_j\left(X_{0j} - \bar{X}_{00}\right)^2$ is called the treatment sum of squares(SS_{Tr}), $\sum_{i=1}^{nj}\sum_{j=1}^{k}\left(X_{ij} - \bar{X}_{0j}\right)^2$ is called the error sum of squares(SS_E). Equation (1) can be written as $SS_T = SS_{Tr} + SS_E$. In one way ANOVA, the following formulated hypotheses are tested. H_o: $\mu_1 = \mu_2 = \cdots = \mu_k$ (treatment means are equal) and H_1: $\mu_i \neq \mu_j$ for some $i$and j

The test statistic, $F = \frac{SS_{Tr}/_{(k-1)}}{SS_E/_{(n-k)}}$, follows an F distribution with $k-1$ and $n-k$ degrees of freedom. If the F value calculated is larger than the table value at certain degree of freedom, then the null hypothesis H_O of equal means is rejected (Gordor and Howard, 2000).

Using equation (1) we can rewrite the following computing formulae

$$SS_T = \sum_{i=1}^{nj}\sum_{j=1}^{k} X_{ij}^{\ 2} - \frac{T_{\circ\circ}}{n}$$

$$SS_{Tr} = \sum_{j=1}^{k} \frac{T_{\circ j}^{\ 2}}{n_j} - \frac{T_{\circ\circ}^{\ 2}}{n},$$

and $SS_E = SS_T - SS_{Tr}$. The above considerations are valid when it is assumed that; the cases are independent, variances among the cohorts are equal, and the samples are coming from populations that are normally distributed.

2.3 Correlation Analysis

Correlation analysis is the process of measuring the strength of the relationship between two variables using appropriate statistical techniques (Gordor and Howard, 2000). If two random variables X and Y are related, then the measure of the strength of relationship is called the correlation coefficient. Suppose (x_1, y_1), $(x_2, y_2)\ldots$ (x_n, y_n) constitute n pairs of measurements on the two random variables X and Y, then the linear correlation coefficient, denoted by r is more conveniently calculated by

$$r = \frac{n\sum_{i=1}^{n} x_i y_i - \sum_{i=1}^{n} x_i \sum_{i=1}^{n} y_i}{\sqrt{\left(n\sum_{i=1}^{n} x_i^2 - \left(\sum_{i=1}^{n} x_i\right)^2\right)\left(n\sum_{i=1}^{n} y_i^2 - \left(\sum_{i=1}^{n} y_i\right)^2\right)}}$$ (Gordor and Howard, 2000).

Graphically, the sample correlation matrix which is made up of all possible correlation coefficients, r is

given by $R = \begin{pmatrix} 1 & r_{12} & r_{13} & \cdots & r_{1p} \\ r_{21} & 1 & r_{23} & \cdots & r_{2p} \\ r_{31} & r_{32} & 1 & \cdots & r_{3p} \\ \vdots & \vdots & \vdots & \ddots & \vdots \\ r_{p1} & r_{p2} & r_{p3} & \ldots & 1 \end{pmatrix}$

The array R consists of $p\ rows$ and $p\ columns$. The elements along the diagonal are one (1) each because they represent correlation between a variable and itself. The diagonal line serves a mirror line where elements above the upper diagonal are the same as elements below lower diagonal. Hence one half of the elements of the matrix can be used for interpretation without loss of information.

3. Results and Discussion

Figure 1 is the visual display of the data distribution in a form of box and whisker plot. On this graph, five summary statistics of minimum value, lower quartile, median, upper quartile and maximum value are displayed. The year batches (2000-2003), (2001-2004)…, (2009-2012) are represented by Year A, Year B …, and Year J respectively. Using Figure 1, we observe that data distribution of years A and B are almost the same. They show the same minimum, lower quartile, median (3.00) and upper quartile, with difference in maximum values. The same distribution is observed in year H. Furthermore, we can see that maximum and minimum values of years I and J are the same but different quartiles. The same distribution is observed in year H.

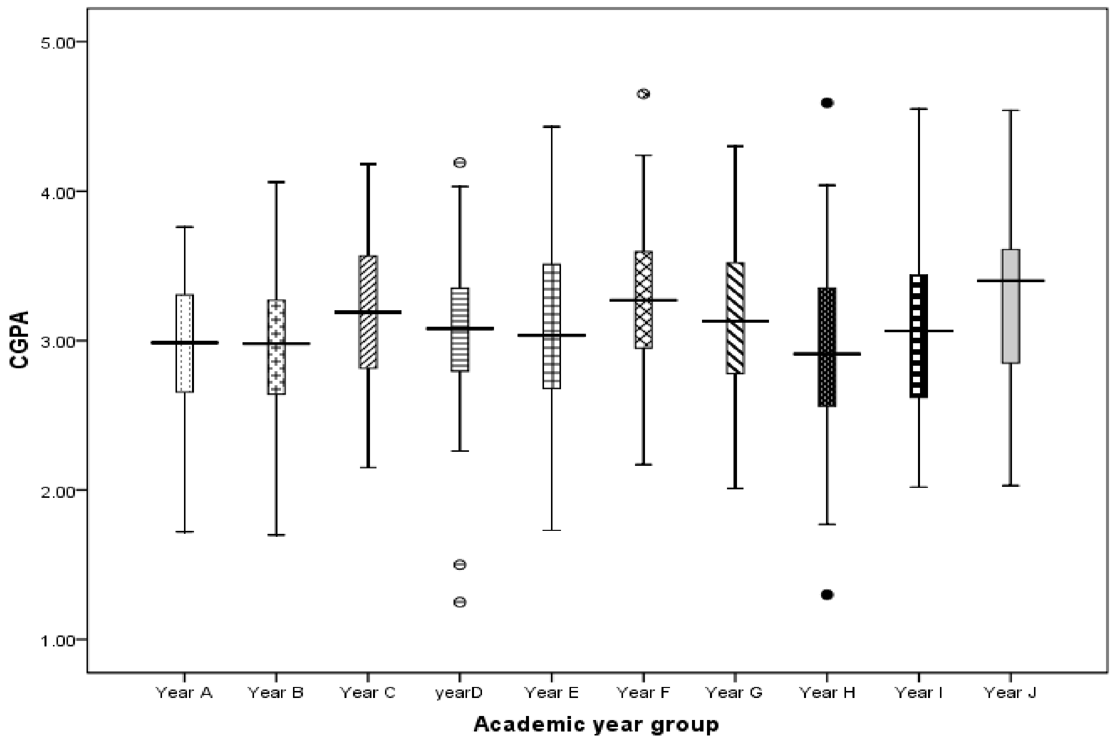

Figure 1: Box plot of students' general performance over the years

Also in the output of Figure 1 are unusual small and large values. These observations are considered as out liars. They represent two students who failed throughout the study period and three students who performed extremely well in the 1st class category. Also in Figure 1, we can see that apart from years A, B and H, the median value of the remaining years are slightly above 3.00. This indicates that at least 50% of the students who graduated between (2000 and 2012) obtained at least 2nd class upper division. In addition, no student obtained 1st class in A (2000-2003 cohort). In general, students' performance ranged between1.6 and 4.5. It can also be observed that, students of year E and I obtained an upper quartile of 3.50. This indicates that 75% of the students, in these years obtained CGPA of 3.50 or below, or 25% of the students scored CGPAs above 3.50. Students' performance increased across the year group. In addressing one of the objectives of the study, the following research question was explored.

Are academic achievements of males and females the same in Mathematics and Statistics Department of the tertiary institution from 2000 to 2012?

Figure 2 shows comparison of students' performance over the study period with respect to gender. We can deduce from Figure 2 that, apart from the mean CGPAs for the year groups (2002-2005), and (2009-2012) which appear to be close to each other for males and females, students' performance in the remaining years differ. It is also seen from the figure that minimum and maximum CGPA of females is 2.84 and 3.34 which occurred in (2000-2003) and (2001-2004) year batches respectively. The corresponding least and greatest CGPA of males is 2.89 and 3.32 which also occurred in (2001-2004) and (2005-2008) year batches respectively. Considering the above discussion, it becomes necessary to conduct paired sample t-test described in section 2 to address the above research question using the following hypotheses.

H_0: There is no significant difference between performance of male and female students.

H_1: There is significant difference between performance of male and female students.

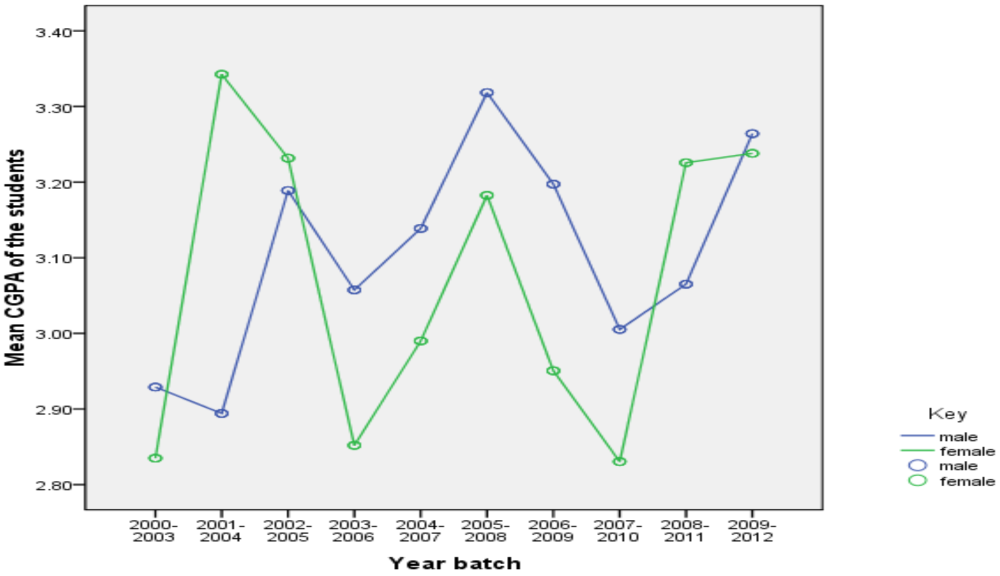

Figure 2: Distribution of students' mean CGPA by gender

To justify the use of paired sample t-test, Kolmogorov-Smirnov test for the ten cohorts was performed to determine whether the distribution of the difference between the mean CGPA of males and females follows the normal distribution. The p $-$value of the test is $0.821 > p(0.05)$. This shows that test is insignificant. Which further indicates that the data are normally distributed hence paired sample t-test is appropriate. The results of the paired sample t-test at 95% confidence interval with $t(9) = -0.556$, Sig (2-tailed) $= 0.592$ which is greater than $p(0.05)$. This t-test is further supported by Wilcoxon Signed Ranks test with Sig (2-tailed) $= 0.359 >$ than $p(0.05)$. This means that the t-test is statistically insignificant and therefore we must fail to reject the null hypothesis,H_0, and conclude that the performances of male and female's students in mathematics/statistics at the tertiary institution are the same. It should be noted that throughout the study period, out of the total 617 students, the ratio of males to females is $510:107$ respectively, which is almost$5:1$. This implies that throughout the study period, the number of males who enrolled was five times the number of females. Also, in using one way analysis of variance (ANOVA) *to address the issue of students' performance among the ten cohorts (2000 to 2012),* the normality about the data was examined first. The results of normal Q-Q plots for each cohort displayed points threading a reasonably straight line moving from bottom left to top right. This means that one way ANOVA was appropriate**.** The ANOVA test leads to the following hypotheses. H_0: There is no significant difference between students' performance among the year batches. H_1: At least there is significant difference between students' performance in some of the year batches

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Table 1: The results of the ANOVA test

Attributes	Sum of squares	Df	Mean Square	F	Sig
Between groups	8.447	9	0.939	3.006	0.002
Within groups	189.519	607	0.312		
Total	197.966	616			

Table 1 shows the results of the ANOVA test. These results indicate that there was significant difference $\{F(9{,}607) = 2.989, p = 0.002 < 0.05\}$ between performances over the years. Tukey's HSD post-hoc comparison test was conducted to examine the year batches that differ. In this test, the general performances over the various year cohorts are compared on the basis of their CGPA. The results of this test are shown in Table 2.

Table 2: Tukey's HSD comparison of general performance of students over the years according to their mean CGPA

Acad. Group	2000-2003	2001-2004	2002-2005	2003-2006	2004-2007	2005-2008	2006-2009	2007-2010	2008-2011	2009-2012
Mean CGPA	2.92^{a}	2.93^{a}	3.20^{ab}	3.04^{ab}	3.11^{ab}	3.28^{b}	3.15^{ab}	2.97^{ab}	3.09^{ab}	3.26^{ab}

It must be noted that mean CGPA columns with different superscripts are significantly different at 0.05 *significant level, but mean CGPA columns with same superscripts are not significantly different at* 0.05 *significant level.*

Using these results, we observe that the mean CGPA of (2000-2003) and (2001-2004) are statistically the same but different from other year batches. Also apart from the score of (2005-2008), scores of the remaining year batches show no statistical difference of the same kind. *To examine trend of students' performance over the study period*, the line graph of Figure 3 is displayed. Figure 3 shows distribution of mean CGPA by the year batches. Using Figure 3, we can see that students' mean CGPA increased steadily from 2.92 in (2000-2003) to 3.20 in (2002-2005). It slightly declined in the next two years batches, and reached a maximum CGPA of 3.28 in (2005-2008). Further, students' academic output declined slightly through CGPA of 3.15 in (2006-2009) to 2.97 in (2007-2010).

The last two year batches of the study period witnessed a growth from CGPA of 3.09

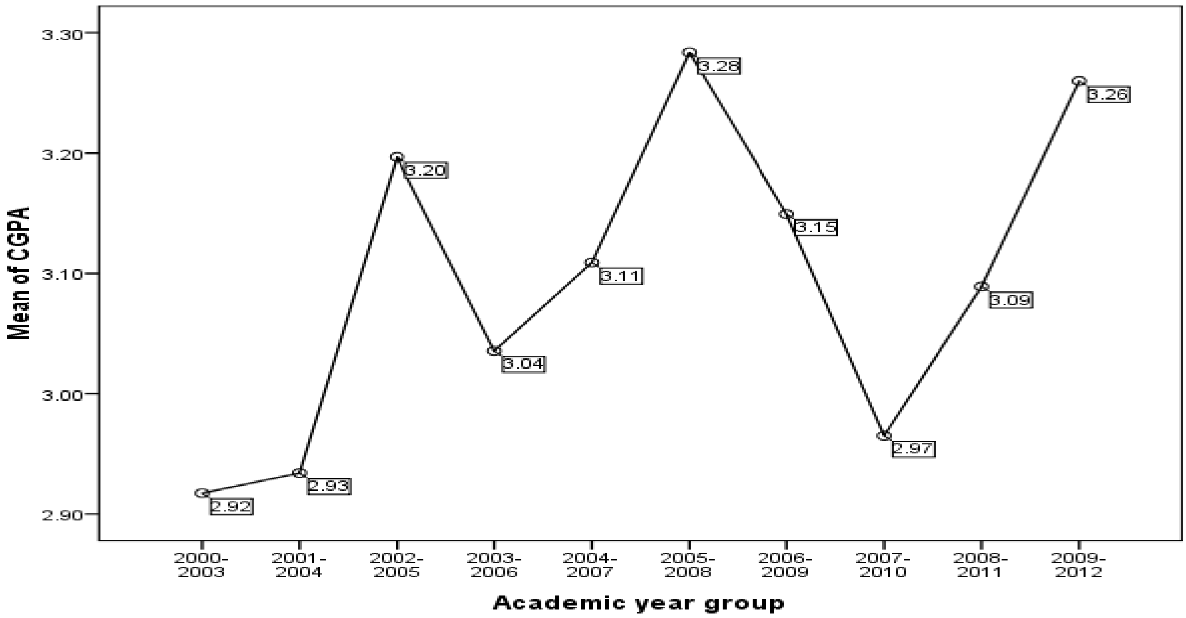

Figure 3: Distribution of mean CGPA by year batches

to 3.26. Using Figure 3, we could conclude that in general, students' performance increased across the study period. Last but not least, *to examine the nature of relationship between students' academic performance among the various semesters of study*, correlation analysis was used. This led to the generation of correlation matrix which aided us in the interpretation of the links (relationships) between the semesters. This matrix is shown in Table 2. In this table, correlations of all the various semesters of the study are displayed. Correlation is observed at a significant level of 0.01, that is α = 10%. Table 2 further shows the values of Pearson correlation coefficients.

Table 2: Correlation of students' performance between the various semesters

Attributes	Semester 1	Semester 2	Semester 3	Semester 4	Semester 5	Semester 6
Semester 1	1.000					
Semester 2	0.683	1.000				
Semester 3	0.622	0.739	1.000			
Semester 4	0.576	0.681	0.753	1.000		
Semester 5	0.523	0.573	0.645	0.617	1.000	
Semester 6	0.508	0.598	0.669	0.630	0.650	1.000

Correlation is significant at 0.01 levels (2-tailed); the p-value for all correlations is 0.000

The correlation between a variable (semester) and itself is 1.00. As stated at the bottom of the table, correlations between the semesters are all significant with p −values of 0.000. The highest correlation of 0.753 is observed between semesters 3 and 4. This implies that students' performance in semester 3 strongly relates to performance in semester 4. This further indicates that students' score in semester 3 can strongly predict his/her score in semester 4. Also, the second highest correlation of 0.739 is seen of semester 2 and semester 3.

Again, this is interpreted as students who performed well in semester 2 also performed well in semester 3. Similarly, we can see Pearson correlation coefficients occurring in descending order of magnitudes; 0.683, 0.681, 0.669, 0.650, 0.645, 0.630, 0.622 and 0.617. Finally, relatively lower correlations of 0.598, 0.576, 0.573, 0.523 and 0.508 are seen in Table 2. The lowest correlation of 0.508 occurs between semester1 and semester 6. This is explained as comparatively a moderate relation between students' performance in the first and last semesters. Generally, we can safely conclude from Table 2 that students' performances between the six semesters were moderately and positively related.

4. Conclusion

This study sought to statistically investigate thoroughly into academic performance of mathematics/statistics students in a tertiary institution in Ghana from the period 2000 to 2012. Paired sample t-test, one-way ANOVA, and correlation analysis are statistical tools used examine the data. The study revealed that although females' participation in mathematics and statistics related courses were far lower than males; male and female students' performances are the same. More men as opposed to women participation in mathematics and statistics is in conformation to research results of Mathematics Association of Ghana, MAG workshop (2000) at Sunyani. While the results of equal achievement of males and females in mathematics, agrees with results of researchers such as; Janet Hyde (et al, 2010), (Frost, Hyde, and Fennema, 1994, about test designed to reflect curricular tasks); it disagrees with findings of investigators such as (Fennema, 1974, Johnson, 1987; Martin & Hoover, 1987). The trend analysis also, established that students' performance increased over the study period. This outcome concurs with research discoveries of (Campbell, Hombo, and Mazzeo, 2000). In sum, students' performance throughout the study period was high.

Further, students' performance in semester 3 could strongly predict his/her achievement in semester 4. Generally; students' performances between the six semesters were found to be interrelated. Based on these findings; more females are encouraged to enroll into mathematics and mathematics related programmes to ensure fair representation of gender. Also, CGPA monitoring persistently will inform lecturers as to the state of students' performance and hence advise appropriately in decision pertaining to the; past, present, and future. Further, the research was conducted in one school. It is therefore suggested that the research work be replicated with data of similar structure in other tertiary institutions to enable us establish firm external validity about the study results**.** Also, the reason(s) for which number of males exceedingly dominated females in the study of mathematics/statistics is recommended for future research. Finally, it is suggested that a research be conducted to ascertain why students' performances in the first two semesters (1st year) were lower than other semesters (years).

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