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# Two-Factor Factorial Design Application in Analyzing Differential Performance Between Single-Sex Schools and Mixed Schools in Compulsory Subjects at KCSE:Case study in Homa Bay County, Kenya

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**ABSTRACT**
Despite the recent unabated proliferation of mixed schools, no effort has been directed towards finding out whether they are just as good as or even better than single - sex schools. This is in spite of the conventional wisdom which has in the past informed conversion of mixed schools into single - sex schools. (I am yet to come across a case in our country where two oppositely gendered single - sex schools have merged to form a mixed school). This state of affairs begs for attention and it is what motivated the researcher to carry out research in this area. The study applied two-factor factorial design in analyzing differential performance in compulsory subjects between mixed schools and single-sex schools. School type represented one factor while the other factor was represented by subjects. The objectives of the study were to determine whether there is significant effect due to; school type, subject and interaction between school type and subject. School type, subject and interaction between school type and subject were from the analysis of variance, found to have significant effects at $\alpha$ = 5%. The significant interaction effect made it necessary to carry out multiple comparisons. Scheff'e's method revealed statistically significant differences in mean performance in mathematics between single-sex schools and mixed schools. The mean performances in English and Kiswahili for single-sex schools were not, at 5% level of significance, different from those of mixed school using the same (Scheffes) method. The two- factor factorial design model $y_{ijk}=\mu+\alpha_i+\beta_j+(\alpha\beta)_{ij}+\varepsilon_{ijk}$ was found to be ideal in describing the observed data concerning the performance in compulsory subjects in KCSE.
**Keywords:** ANOVA, Two-Factorial Design

## 1. Background Information

### 1.1 Introduction

Secondary schools in Kenya can broadly be classified as boy's schools, girl's schools or mixed schools. Most of prominent secondary schools including all national schools are single-sex. Mixed schools are not as prominent and most are either Day schools or partly day and partly boarding schools. Existence of disparities in performance between these types of schools cannot be denied. To appreciate this fact, one needs only to examine the KCSE results for a given year. Scrutiny reveal that the list of the top 100 schools is dominated by National schools all of which are single-sex schools while the rest of the positions are taken by county schools and only a meager number of mixed schools occasionally find their way into that list of top 100 schools. It is this state of affairs which prompted the researcher to carry out a study in this area to determine whether the disparities in the performance are statistically significant. The researcher confined his study work in Homa Bay County. In this county, there are two National Schools, a handful number of county schools, with the rest being district schools. The greatest proportion of schools consists of mixed secondary schools.

### 1.2 Regression Analysis

Regression analysis models have been used in many areas like in science, business and engineering. Regression makes us understand the relationship between dependent variable $N_p$ and independent variable x. The random quantity $N_p$ is a function of one or more independent variables $x_1,x_2,\ldots,x_4$. Models have several functions in explaining phenomena, making predictions, decisions and communicating knowledge like done by Lepore[6]. Studies involving multivariate approaches to meta-analysis are more difficult to apply and justify[5]. This paper model will be concerned with analysis of entry behavior which will enable educators focus on better grades in their KCSE which will form a background that influences the learners academic performance in college [17]. When students view themselves as being incapable in a subject, they develop a negative attitude towards the subject and will most likely not do well. Their previous performance can play a role in shaping their study habits even at entry level to the end of the final examination [10]. Learners performance basically depends on attitude which they develop as they begin in form one which can be passed onto them by teachers, parents and peers8. Attitudes, beliefs, feelings, thoughts and emotions can be modified by new ex-periences13. Teachers do not use student centered approaches but lack of experiments and practical modeling activities and lack of professional exposure articulates issues relating to teaching in secondary schools [12]. Poor performance in Kenya is due to poor teaching methods and acute shortage of textbooks which are used as many as six students would share one textbook in some schools making it impossible for them to complete their homework [7]. Poor performance is due to the difficult language used in Mathematics classroom [14].

### 1.3 Purpose and Objective of the Study

The Purpose of this study was to analyze differential performance in compulsory subjects between Mixed Secondary Schools, Boys Schools and Girls Schools in Homa Bay County guided by the following specific objectives.

(i) To determine significant difference in performance by candidates from different schools.
(ii) To determine any significant difference in performance between subjects.
(iii) To determine the interaction effect between school type and subject performance.
(iv) To fit a model for performance in compulsory subjects
(v) To carry out multiple comparisons

### 1.4 Basic Concepts and Notation

In this study, terms have special meanings as used in a restricted sense. Below are some of these terms and the sense in which they are to be understood.

(i) Compulsory subjects: English, Kiswahili and Mathematics taken in secondary schools
(ii) Boys school: A secondary schools whose student population consists of boys only.
(iii) Girls School- A secondary schools whose student population consists of girls only.
(iv) Single-sex (Single gender) school: boys school or girls school.
(v) Mixed school: school whose student population consists of both boys and girls.
(vi) Co-educational institution: mixed school or mixed-gender school as defined in (v) above.
(vii) School type: boy's school or girl's school or a mixed school.
(viii) Subject and compulsory will be used interchangeable.
(ix) KCSE;Kenya Certificate of Secondary Education

## 2. Literature Review

Various studies have been carried out exploring the relative merits of single gender and mixed gender or co-educational schooling. Some have yielded results which favour single gender schooling while others favor mixed gender schooling. For some, single-sex education favored girls with no clear advantages or with outright disadvantages to boys while in some others the results were the exact opposite of this situation. Yet for some studies single-sex schooling was found to be inferior to co-education in terms of academic success and molding of student's behavior. Wong [15] examined gender and school type effects on achievement on 45000 Hong Kong students. In Hong Kong, ten percent of public schools are single sex and thus do not simply cater to elite or religiously affiliated families. These schools do however practice streaming based on gender. In high school, girls are streamed into the stereotypically female areas of arts and social science whereas boys are generally streamed into the male areas of mathematics and science. Young and Frazer [16] used secondary data analysis to examine whether there were differences in the science achievement of grade [9] students attending independent, catholic and government, single-sex and co-educational schools in Australia. They found no significant differences in boys or girls overall science achievement in government, catholic and independent co-educational schools, although there were some significant sex differences among individual test questions with girls scoring higher on some items and boys higher on others. Baker in 1995 [1] investigated the relationship between grade 12 mathematics achievement and the proportion of single-sex schools in four countries using data from the International Educational Assessments (IEA) second international study(SIMS) hypothesizing that achievement differences will be largest in countries where the proportion of single-sex schooling is small using achievement data from two countries: Belgium and New Zealand, which had relatively high percentages of single-sex schools, 68 and 43 respectively and two countries which had relatively low availability of single-sex schools. Thailand with 19 percent and Japan with 14 percent. Baker[1] noted that the higher achievement of girls educated in single-sex schools in Thailand may be due to the fact that in Thailand most single-sex schools are in Bangkok and tend to be elite schools for girls, whereas co-educational schools are seen to offer more opportunities for boys. This, they argued, may explain findings of higher achievement differences for girls but not for boys. Lepore and warren in 1997 [6] Conducted a comparative study of single-sex and co-educational catholic schooling to determine whether or not there were academic and psycho-social differences between students educated in the different environments and whether any differences favored one gender over the other. Using data from National Educational longitudinal Study Nels (1998), Lepore and Warren[6] found no significant differences in achievements once social Economic status and prior achievement were controlled. Nor did they find any significant differences in Psycho-social test scores. Marsh and Rowe in 1996 [8] undertook a re-analysis of studies by Rowe (1995) and Rowe, Nix and Tepper (1986) that compared single-sex and co-educational mathematics classes within a co-educational school. This reanalysis provided no support for the claim that single-sex classes promoted higher achievement for either girls or boys. The achievements of boys attending single-sex classes were significantly greater than those by boys attending mixed classes. Robinson and Smithers in 1999 [10] used standardized government test scores to assess any quantifiable differences in school type effects. The authors found that overall single-sex schools produce students with higher average scores than co-educational schools. However, after schools were matched for Social Economic status, selectivity and academic tradition, there were no significant differences. Manger and Gjested in 1997 [7] took a slightly different approach to evaluating variables which may influence students performance in mathematics. The authors explored the possibility of existence of a relationship between the ratio of boys to girls and achievements in third grade mathematics classes. Forty nine third grade classes were randomly chosen in the Nowegian City of Bergen, which included a total of 440 girls and 484 boys. Smith [11] conducted a 10 year study of two single sex schools (one female, one male) in Australia, switched to co-educational. Smith was interested in examining possible effects on students self concept and academic achievement due to the change in school type. In terms of academic performance, particular attention was given to the subject areas of English and mathematics. Measures of academic achievement were collected using the results of externally moderated achievement tests at the end of all students grade 10 year, from 1982 to 1986.Smith found no effect on academic achievement on grade 10 test scores in English and mathematics, however, he did note that public examination scores tended to decline in grade12 at the former all girls school. Gillibrand[3] studied 58 girls in a study at a co-educational comprehensive school in England which sought to address the 7.1 gender ratio in physics at the school. 47 of the girls chose to enroll in the girls' only physics class created in the school with the hope that the number of 14 year old girls who wanted to study physics for general certificate of secondary education (G.C.S.E) would increase along with their confidence and achievement levels.

From the literature cited above it can be contended that there is no clear verdict concerning which between mixed sex and single sex schools are best suited for students especially in terms of academic achievements. It is hoped that this proposed study will contribute in enriching the body of knowledge from studies already carried out in this area. It will also serve a pioneering role in the local context where literature in the said area is scantily available.

## 2. Model Building

Model building entails the development of prediction equations by statistical or mathematical methods from experimental data and the formula for effects model is given by

$$y_{ijk} = \mu + \alpha_i + ß_j + (\alpha ß)_{ij} + \varepsilon_{ijk} \tag{3.1}$$

where i = 1,2,…, a; j = 1, 2,….,b; k = 1, 2,…., n, where $\mu$ is the overall mean effect, $\alpha_i$ and $ß_j$ are the fixed treatment effects of factors A and B respectively and are defined as the deviations from the overall mean effect $\mu$ , hence $\alpha_i = 0$ and $ß_j = 0$. Also $(\alpha ß)_{ij}$ is the fixed interaction effect of factors A and B in the $(ij)^{th}$ cell and is defined in such a manner that $(\alpha ß)_{ij} = 0$;ijk in the measure of the deviations of the observed value $y_{ijk}$ in the $(ij)^{th}$ cell from $\mu_{ij}$:

### 3.1 Estimation of the Model parameters

The estimation of the parameters of the effects model above in equation 3.1 $y_{ijk} = \mu + \alpha_i + ßj + (\alpha ß)_{ij} + \varepsilon_{ijk}$ was done by using the least squares method .In summary, if there are a levels of factor A and b levels of factor B, then the model has (1 + a + b + ab) parameters to be estimated and there are (1 + a + b + ab) normal equations which are given by:

 

$$\mu: abn\mu + bn\boldsymbol{\alpha}_i + an\beta_j + n(\boldsymbol{\alpha}\beta)_{ij} = y \tag{3.2}$$

$$\boldsymbol{\alpha}_i : bn\mu + bn\boldsymbol{\alpha}_i + n\beta_j + n(\boldsymbol{\alpha}\beta)_{ij} = y_{i..} \tag{3.3}$$

where i = 1,2,… a

$$\beta_j : an\mu + n\boldsymbol{\alpha}_i + an\beta_j + n(\boldsymbol{\alpha}\beta)_{ij} = y_{.j.} \tag{3.4}$$

where i = 1,2,… a

$$(\boldsymbol{\alpha}\beta)_{ij} : n\mu + n\boldsymbol{\alpha}_i + n\beta_j + n(\boldsymbol{\alpha}\beta)_{ij} = y_{ij.} \tag{3.5}$$

where i = 1,2,… a and j = 1, 2,…, b
Applying the assumptions $\boldsymbol{\alpha}i = 0$; $\beta_j = 0$ and $(\boldsymbol{\alpha}\beta)_{ij} = 0$ gives us

$\mu = \bar{y}_{...}$; $\boldsymbol{\alpha}_i = \bar{y}_{i..} - \bar{y}_{...}$; $\beta = \bar{y}_{.j.} - \bar{y}_{...}$ and $(\boldsymbol{\alpha}\beta)_{ij} = \bar{y}_{ij.}\ \bar{y}_{i..}\bar{y}_{.j.} + \bar{y}_{...}$ substituting these values in the equations, we have $y_{ijk} = \mu + \boldsymbol{\alpha}_i + \beta_j + (\boldsymbol{\alpha}\beta)_{ij}$; gives $y_{ijk} = \bar{y}_{...} + (\bar{y}_{i..}\ \bar{y}_{...}) + (\bar{y}_{.j.}\ \bar{y}_{...}) + (\bar{y}_{ij.}\ \text{-}\bar{y}_{i..}\bar{y}_{.j.} + \bar{y}_{...}) = \bar{y}_{ij.}$ This means that, the $K^{th}$ observation in the $(ij)^{th}$ cell is estimated by the average of the n observations (replicates) in that cell.

### 3.2 The Two-Factor Factorial Design

The two factors of a two-factor factorial design are taken to be school type and subject, with school type being the row factor(A) and subject being the column factor(B). There will be three levels of factor A (a=3,i=1,2,3) namely Boys(1),Girls(2) and mixed schools(3) which will for the sake of convenience be represented by the numbers 1,2 and 3 respectively. Similarly there will be three levels of factor B (b=3, j=1, 2, 3) namely English (1), Kiswahili (2) and Mathematics (3) which will be represented by the numbers 1, 2 and 3 respectively. The points scored by a candidate as sampled from a list of candidates from a given school who had taken a particular subject.

### 3.3 Model Adequacy Checking

The primary diagnostic tool in model adequacy checking is the residual analysis which is mostly done by graphical analysis in different forms and simply called residual plots. Residual is defined as essentially an error in the fit of a model. The residual plots are; (i) The normal probability plot of the model (ii) Residual plot in time sequence used to check independence assumption on the error and (iii) Plot of the residuals versus fitted values ($y_{ijk}$), used to check consistency of variance. Montgomery [9] determined that, if the model is adequate, the residuals should be structure-less, that is, they should contain no obvious patterns. However, a very common defect that often shows up on the normal probability plots is one residual being much larger than the others, and this can seriously distort the analysis of variance. This residual is called an outlier. Mostly, the cause of the outlier is such human error as calculation error, data coding error, or copying error. However, a suspected outlier could be checked by examining the standardized residuals value ($d_{ijk}$) given by,

$$dijk = \frac{eijk}{\sqrt{MSE}} \tag{3.6}$$

A residual value ($d_{ijk}$) bigger than 3 in absolute value is a potential outlier which can cause a serous distortion to the conclusions drawn from the ANOVA.

## 4. Discussion of Results and Analysis

### 4.1 Two factorial design layout

The data were collected and displayed in two-factor factorial design layout as follows.

| Factor A | | Factor B | | | |
|---|---|---|---|---|---|
| | | | | | |
| School type | English | Kiswahili | Mathematics | $^{y}$i.. | $\bar{y}$i.. |
| | j=1 | j=2 | j=3 | Total s | Means |
| Boys school | 8,10,9,9,10 | 10,7,11,10,7 | 11,12,6,11,12 | | |
| i=1 | 5,8,9,9,9 | 8,9,12,10,11 | 6,10,12,10,8 | | |
| | 11,10,10,7,10 | 10,9,11,11,12 | 8,5,10,6,11 | | |
| | 9,10,10,9,8 | 7,9,12,10,10 | 12,6,7,11,1 | | |
| | 10,12,9,8,9 | 11,12,10,9,11 | 9,6,11,8,11 | | |
| | $y_{11:}$ = 228 | $y_{12:}$ = 249 | $y_{13:}$ = 227 | 704 | |
| | $y_{11:}$=9.12 | $y_{12:}$=9.96 | $y_{13:}$ = 9:08 | | 9.39 |
| Girls school | 9,8,6,8,6 | 7,6,8,6,9 | 8,4,7,1,3 | | |
| i=2 | 8,9,8,9,8 | 8,10,12,7,7 | 2,9,6,3,4 | | |
| | 10, 9,8,7,7 | 7, 5,9,8,10 | 4,2,8,7,4 | | |
| | 10,7, 8,5,10 | 10,8,12,10,7 | 6,7 ,4 ,5,9 | | |
| | 7, 8,8 ,9,8 | 9, 5 , 8 ,8,11 | 2,7, 3, 8,5 | | |
| | y11: = 200 | $y_{12:}$ = 207 | $y_{13:}$ = 128 | 535 | |
| | $y_{11:}$=8 | $y_{12:}$=8.28 | $y_{13:}$ = 5:12 | | 7.13 |
| Mixed school | 8,8,8 ,8, 10 | 10,10,7,10,11 | 7,4,6,3,4 | | |
| i=3 | 9,9,9, 8 ,8 | 10, 9,9,7,8 | 9,7,2,8,4 | | |
| | 10, 7,6,7,10 | 9,10,10, 9, 9 | 4,6 ,9,5,9 | | |
| | 8,9,9,10,8 | 9,6,10,10,8 | 5, 8,6,1,5 | | |
| | 9,11,9,8,7 | 5,9, 9,10,10 | 6,7,3, 8,7 | | |
| | $y_{11:}$ = 213 | $y_{12:}$ = 224 | $y_{13:}$ = 143 | 580 | |
| | $y_{11:}$=8.54 | $y_{12:}$=8.96 | $y_{13:}$ = 5:72 | | 7.73 |
| Total($y_{:j:}$) | 641 | 680 | 498 | 1819 | |
| Means($\bar{y}$... | 8.55 | 9.07 | 6.64 | | 8.08 |

Table 1: KCSE (2011) Performance (in points) data

In order to realize the analysis of variance table for the two factor factorial design, it is necessary to compute the various sums of squares. The table below shows the results of the working as follows.

| **Source of variation** | **Sum of squares** | **Df** | **MS** | **Calculated F** |
|---|---|---|---|---|
| Treatment | 524.036 | 8 | 65.505 | 20.286 |
| School type(factor A) | 204.276 | 2 | 102.138 | 31.636 |
| School type (factor B) | 244.862 | 2 | 122.431 | 37.922 |
| school type subject interaction (AB) | 74.898 | 4 | 18.725 | 5.800 |
| ERROR | 697.360 | 216 | 3.229 | |
| **Total** | **1221.396** | **224** | | |

Table 2: ANOVA Table of performance in compulsory subjects

In carrying out statistical tests of hypotheses, a 5% ($\alpha$= 0:05) level of significance was used throughout in this study. To test the hypothesis of no interaction between school type and subject, the computed F-ratio,$F_{AB}$ = 5.800 from the ANOVA *table 2* above was compared with the table F $_{:(a\ 1)(b\ 1);ab(n\ 1)}$ = $F_{0.05;4;216}$ = 2:3719 from the table for F- distribution. Note that it was assumed that $F_{0.05;4;216}$ = $F_{0.05;4;1}$ = 2:3719 since extrapolation would give a value for $F_{0.05;4;216}$ smaller than $F_{0:05;4;1}$ which is not reasonable. Since $F_{AB}$ = 5:800 > $F_{0.05;4;216}$ = 2.3719, the null hypothesis of no interaction between school type and subject is rejected. It is therefore concluded that there is statistical evidence that there is interaction between school type (A) and subject (B). This gives the general

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indication that performance is dependent on both school type and subject.

The analysis was continued by testing the null hypothesis of no difference among treatment combinations. From the table for F distribution, $F_{;(ab\ 1);ab(n\ 1)} = F_{0.05;8;216} = 1.9384$. Since the calculated F for treatment combination means difference ($F_{Tr}$) from the ANOVA *table 2* is equal to $20.286 > F_{0.05;8;216} = 1.9384$ the treatment combination variance is significant. Hence the null hypothesis of no difference among treatment means is rejected. Note that it was assumed that $F_{0.05;8;216} = F_{0.05;8;1} = 1.9384$ since extrapolation of $F_{0.05;8;120}$ would give a value smaller than $F_{0.05;8;1}$ which is not reasonable.

To test the two null hypotheses that effects due to the two main factors A and B are equal to zero, the calculated F ratio, $F_A = 31.636$ and $F_B = 37.922$ were compared with the respective table values $F_{;(a\ 1);ab(n\ 1)} = F_{0.05;2;216} = 2.9957$ and $F_{;(b\ 1);ab(n\ 1)} = F_{0.05;2;216} = 2.9957$

Since $F_4 = 31.636 > F_{0.05:2;216} = 2.9957$ and $F_B = 37.922 > F_{0.05;2;216} = 2.9957$ both null hypotheses were rejected and it was concluded that the effects due to the two main factors namely; school type( factor A) and subject( factor B) are significant.

## 4.2 Multiple Comparisons for Performance in Compulsory Subjects

### 4.2.1 Scheffes method

Three contrasts of interest one for each level of j(subjects) were identified. They were derived from the desire to compare the average performance of single sex schools with that of mixed school for each subject. The hypothesis tested is.

$H_{0i} = 1/2\mu_1 - ½\mu_{2i} = \mu_{3i}$ $\overset{+}{\underline{1}}$

$H_{1j} : {}_{1/2}\mu_{1j} + {}_{1/2}\mu_{2j} \neq \mu_{3j}$

(j = 1, 2,3) This can be expressed in terms of a contrast as

$H_{oj} : \Gamma_j = 0$; $H_{1j} : \Gamma_j \neq 0$

Where

$$\sum_{i=1}^{a} c_i\mu_{ij} = \frac{1}{2}\mu_{1j} + \frac{1}{2}\mu_{2j} - \mu_{3j}$$

Note that the contrast coefficients $c_i$ sum to zero i.e i

$$\sum_{i=1}^{3} c_i = \frac{1}{2} + \frac{1}{2} - 1 = 0$$

Satisfying the fundamental requirement for Γj to be a contrast.

The corresponding contrast in the treatment average $\bar{y}_{ij.}$ is $c_{i=1}\sum_{i=1}^{3} c_i\,\bar{y}_{ij.} = \frac{1}{2}\bar{y}_{1j.} + \bar{y}_{2j.} - \bar{y}_{3j.}$ and the standard error of this contrast is $S_{cj} = \sqrt{MSE\sum_{i=1}^{a}\frac{c_{ij}^2}{n_i}}$. The critical value against

Which Cj should be compared is.$S_{\alpha,J} = SC_j\sqrt{(\alpha-1),(F_{(\alpha,\alpha-1),(N-a)}}$ if $|C_j| > S_{\alpha,j}$ the hypothesis that the contrast Γj equals zero is rejected. The three identified contrasts $\Gamma_1$, $\Gamma_2$ and $\Gamma_3$ corresponding to the subjects levels; English (j = 1), Kiswahili (j = 2) and Mathematics (j = 3) respectively were:

$\Gamma_1 = \frac{1}{2}\mu_{11} + \frac{1}{2}\mu_{21} - \mu_{31}$

$\Gamma_2 = \frac{1}{2}\mu_{12} + \frac{1}{2}\mu_{22} - \mu_{32}$ and

 

$$\Gamma_3 = \frac{1}{2}\mu_{13} + \frac{1}{2}\mu_{23} - \mu_{33}$$

The numerical values of these contrasts are $C_1 = \frac{1}{2}\bar{y}_{11.} + \frac{1}{2}\bar{y}_{21.} - \bar{y}_{31.} = \frac{1}{2} * 9.12 + \frac{1}{2} * 8 - 8.52 = 0.04$

$$C_1 = \frac{1}{2} * 9.96 + \frac{1}{2} * 8.288.96 = 0.04$$

$$C_1 = \frac{1}{2} * 9.08 + \frac{1}{2} * 5.125.72 = 1.38$$

$$SC_1 = SC_2 = SC_3 = \sqrt{MSE \sum_{i=1}^{a} \frac{c_{ij}^2}{n_i}}$$

$$= \sqrt{3.229 \left(\frac{0.25+0.25+1}{25}\right)} = 0.4402 \quad ; s_{\alpha j} = s_{0.05,1} = s_{0.05,2} = s_{0.05,3}$$

$$= SC_j\sqrt{(\alpha-1),(F_{(\alpha,\alpha-1),(N-a)}} = 0.4402 = \sqrt{2 * F_{0.05,2,212}} = 0.4402 * 2.9957 = 1.0775$$

Because C1 = 0:04 < S0:05, 1 = 1:0775, it was concluded that the mean performance of single-sex schools in English is not significantly different from that of mixed schools. Similarly, since $C_2$ = 0:16 < $S_{0:05,\ 2}$ = 1:0775; it was concluded that the average performance of single sex schools in Kiswahili is not significantly different from that of mixed schools. Since $C_3$ = 1:38 > $S_{0:05,3}$ = 1:0775 it was concluded $\Gamma_3 = \frac{1}{2}\mu_{13} + \frac{1}{2}\mu_{23} - \mu_{33}$ does not equal zero; that is, it was concluded that mean performance of single sex schools in Mathematics is significantly different from the performance of mixed schools.

### 4.2.2 Tukeys Method

Tukeys method was used to carry out pairwise comparisons between the means of factor A (school type). Since interaction was significant, this was done when factor B (subject) was fixed at its respective levels, j = 1 (English) j = 2 (Kiswahili) and j = 3 (Mathematics). The test statistic ($T_{\alpha}$) for the turkeys test is given by $T_{\alpha} = q_{\alpha(\alpha,f)}\sqrt{\frac{MSE}{n}}$

$=T_{0.05} = q_{0.05(3,216)}\sqrt{\frac{3.229}{25}} = 3.365 * 0.3594 = 1.209381$ Note that it is assumed that $q_{0.05(3;216)} = q_{0.05(3;1)}$, since extrapolation would give a value for $q_{0:05(3;216)} < q_{0:05(3;1)}$, which is unreasonable. When factor B (subject) is fixed at j = 1(English), the means for Boys schools (i = 1), Girls schools (i = 2) and mixed schools were: $y_{11.}$ = 9:12, $y_{21.}$ = 8:00 and $y_{31.}$ = 8:52 respectively. When factor

B (subjects) is fixed at j=2(Kiswahili),the mean performance for Boys schools (i = 1), Girls schools (i = 2) and mixed schools (i = 3) were $y_{12.}$ = 9:96; $y_{22.}$ = 8:28 and $y_{23.}$ = 8:96 respectively. And when factor B was fixed at j = 3(Mathematics) the mean performance for boys schools (i = 1), girls schools (i = 2) and mixed schools (i = 3) were $y_{13.}$ = 9:08; $y_{23.}$ = 5:12 and $y_{33.}$ = 5:72 respectively. Any pair of mean performances that differ in absolute value by more than $T_{0:05}$ = 1:209381 would imply that the corresponding pair of population means are significantly different. For factor B fixed at j = 1(English), the absolute differences in mean performance were as follows:

$|\bar{y}_{11.} - \bar{y}_{21.} = |9.12 - 8.00|| = 1.12$
$|\bar{y}_{11.} - \bar{y}_{31.} = |9.12 - 8.52|| = 0.6$ and
$|\bar{y}_{11.} - \bar{y}_{31.} = |8.00 - 8.52|| = 0.52$

For factor B fixed at j = 2 (Kiswahili), the absolute differences in mean performances were as follows:

$|\bar{y}_{12.} - \bar{y}_{22.} = |9.96 - 8.28|| = 1.68$
$|\bar{y}_{12.} - \bar{y}_{32.} = |9.96 - 8.96|| = 1.00$ and
$|\bar{y}_{22.} - \bar{y}_{32.} = |8.28 - 8.96|| = 0.68$

 

And finally when factor B was fixed at j = 3 (mathematics), the absolute differences in mean performances were as follows: $|\bar{y}_{13.} - \bar{y}_{23.} = |9.08 - 5.12|| = 3.96 *$
$|\bar{y}_{13.} - \bar{y}_{33.} = |9.08 - 5.72|| = 3.36 *$ and $|\bar{y}_{23.} - \bar{y}_{33.} = |5.12 - 5.72|| = 0.60$

The starred values indicate pairs of means that were significantly different. These were

(1) The mean performance in Kiswahili between Boys and Girls schools,
(2) The mean performance in Mathematics between Boys and Girls Schools and
(3) The mean performance in Mathematics between Boys Schools and Mixed Schools. There was no evidence the rest of the pair of mean performances are statistically different

### 4.3 Parameters Estimation for the Model of Performance in Compulsory Subjects

Given the fixed effects model for the performance in compulsory subjects in KCSE as $y_{ijk} = \mu + \boldsymbol{\alpha}_i + ßj + (\boldsymbol{\alpha}ß)_{ij} + \varepsilon_{ijk}$ the parameters ;$\boldsymbol{\alpha}_i$; $ß_j$ and $(\boldsymbol{\alpha}ß)_{ij}$ are respectively estimated as $\mu = \bar{y}$ = 8:08. That is, the overall population mean is estimated by the grand mean performance. $\boldsymbol{\alpha}_i = y_{i..}\, y = y_{i..}$=8.08. That is, the row level effects are estimated by the corresponding row level mean minus the grand mean performance and the $ß_j = \bar{Y}_{.j.}\ \bar{y} = \bar{y}_{.j.}$ =8:08. That is, column level effects re-estimated by the corresponding column level mean minus the grand the grand mean performance $(\alpha\beta)_{ij} = \bar{y}_{ij.}\bar{y} - (\bar{y}_{...}\bar{y})(\bar{y}_{.j.}\bar{y})$ That is, the (ij)th interaction effect is estimated by the corresponding (ij)th call mean minus the grand mean performance, the corresponding row level effect and the corresponding column level effect. This simplifies as follows:$(\alpha\beta)_{ij} = \bar{y}_{ij.} - \bar{y}_{i..} - \bar{y}_{.j.} + \bar{y}) = \bar{y}_{ij.} - \bar{y}_{i..} - \bar{y}_{.j.} + 8.08$ ;$e_{ijk} = y_{ijk} - \bar{y}_{ij.}$

That is, the error due to unexplained source in the recording of an observation in the data for the performance in compulsory subjects in KCSE is the value of the observation minus the corresponding cell mean performance

| | | Subjects | | |
|---|---|---|---|---|
| | | | | |
| **School type** | **English** | **Kiswahili** | **Maths** | **Mean** |
| | | | | |
| **Boys school** | $y_{11.}$ = 9:12 | $y_{12.}$ = 9:96 | $y_{13.}$= 9:08 | $y_{1..}$ = 9:39 |
| | $(\boldsymbol{\alpha}ß)_{11}$ = 0:74 | $(\boldsymbol{\alpha}ß)_{12}$ = 0:42 | $(\boldsymbol{\alpha}ß)_{13}$ = 1:13 | $\boldsymbol{\alpha}_1$ = 1:31 |
| **Girls school** | $y_{21.}$ = 8:00 | $y_{22.}$ = 8:28 | $y_{23.}$ = 5:12 | $y_{2..}$ = 7:13 |
| | $(\boldsymbol{\alpha}ß)_{21}$ = 0:40 | $(\boldsymbol{\alpha}ß)_{22}$ = 0:16 | $(\boldsymbol{\alpha}ß)_{23}$ = 1:57 | $\boldsymbol{\alpha}_2$ = 0:95 |
| **Mixed school** | $y_{31.}$ = 8:52 | $y_{32.}$ = 8:96 | $y_{33.}$ = 5:72 | $y_{3..}$ = 7:73 |
| | $(\boldsymbol{\alpha}ß)_{31}$ = 0:32 | $(\boldsymbol{\alpha}ß)_{32}$ = 0:24 | $(\boldsymbol{\alpha}ß)_{33}$ = 0:57 | $\boldsymbol{\alpha}_3$ = 0:35 |
| **Mean** | $y_{.1.}$ = 8:55 | $y_{.2.}$ = 9:07 | $y_{.3.}$ = 6:64 | $y_{...}$ = 8:08 |
| | $ß_1$ = 0:47 | $ß_2$ = 0:99 | $ß_3$ = 1:44 | |

Table 3: Summary of the cell means, level means and grand mean and Estimate of $\boldsymbol{\alpha}_i$; $ß_j$ and $\boldsymbol{\alpha}ß_{ij}$

From table 3 above $\hat{\mu} = \hat{y}$ = 8:08 if $\bar{y}_{i..} = \bar{y}_1$ = 9.39 then $\alpha_1 = \bar{y}_{1..} - \bar{y}$ = 9.39-9.08 = 1.31. That is, the effect of school type 1(i = 1) (boys schools) on the performance in compulsory subjects in K.C.S.E is 1.31. Also $\bar{y}_{.j.} = y_{.1.}$ = 8.55, implies $ß_1 = \bar{y}_{.1.} - \bar{y}_{...}$ = 8.55-8.08 = 0.47. That is, the effect of English (i = 1) on the performance in compulsory subjects in K.C.S.E is 0.47.This further implies that: $\boldsymbol{\alpha}ß_{ii} = \boldsymbol{\alpha}ß_{11} = \bar{y}_{11.} - \bar{y}_{1..} - \bar{y}_{.1.} + \bar{y}$ = 9.12-9.39-8.55+8.08= -0.74. That is, the effect due to interaction between school type1 (i = 1 implying boys schools) and subject 1(j = 1 implying English) on the performance in compulsory subjects in KCSE is - 0.74.if "$\varepsilon_{ijk}$ = "$\varepsilon_{111}$, then "$\varepsilon_{111} = y_{111} - \bar{y}_{11.}$ = 8.00-9.12 = -1.12. That is, the error due to unexplained source in the first value of the observed performance is -1.12.Now to adequately describe an observation like 8 (the first observation) in the data for the performance in compulsory subjects in K.C.S.E as displayed in table 4.1,then $y_{ijk} = y_{111} = \mu + \boldsymbol{\alpha}_1 + ß_1 + (\boldsymbol{\alpha}ß)_{11} + \varepsilon_{111}$ =
8.08 + 1.31 + 0.47 + (- 0.74) + (-1.12) = 8 since $y_{111}$ = 8 tallies with the first observation in the data shown in table 3, it implies that the fixed effects model adequately describes the first observation (8).

 

## 5 Conclusions and Recommendation

### 5.1 Conclusion

The analysis resulted in a number of findings consistent with the objectives of the study. Both school type and subject were found to have a significant effect at $\boldsymbol{\alpha}= 0.05$. However, presence of significant interactive effect between the two would not make it possible to render straight forward interpretation of the analysis. The Kiswahili subject was the best performed subjects followed by English and finally Mathematics according to the results. Multiple comparison tests were carried out to determine which mean performances were responsible for the presence of significant main factor-effects. The contention that single-sex schools performance is different from mixed schools performance was only supported in the case of Mathematics where Scheffes method showed the mean performance of Boys schools and Girls schools to be significantly different from the mean performance of mixed schools at 5% level of significance. The same method (Scheffes method) showed that the mean performance of boys schools and Girl schools were not statistically significant at $\boldsymbol{\alpha}= 0.05$ for both and Kiswahili. Thus, it can generally be concluded that there were no significant differences (at $\boldsymbol{\alpha}= 0.05$) in mean performances between single-sex school and mixed schools in a majority of the compulsory subject that is, English and Kiswahili. Pairwise comparisons using Tukeys method revealed statistically significant differences in mean performance between boys schools and girls schools in both Mathematics and Kiswahili and between boys schools and mixed schools in Mathematics. The two-factor factorial model was found to adequately and accurately describe the performance in K.C.S.E compulsory subjects. This is due to the perfect equality between the observed value of the performance and the corresponding value as determined from the model.

### 5.2 Recommendation

Subsequent studies can be conducted involving the other subjects taken at secondary level since the performance of a school is judged from the performance in the collectivity of subjects at the end of the four year cycle. The study could also involve a category of subjects such as languages, science subjects or humanities/arts. The studies could use data for performance in K.C.S.E over several years instead of just a year or two. Differential performance exists between categories of schools other than those based on gender can be considered. Thus some of the futures studies in this area can be dedicated to exploring differential performance between such categories of school as public schools and private schools, religiously affiliated schools and secular ones, boarding schools and day schools. It is recommended that future studies on differential performance focus attention on other institution such as colleges, technical institutes and vocational training institutes. Following the successful application of the two-factor factorial design in this study, it is recommended that other factorial designs such as three-factor factorial,$2^k$; $3^k$ etc. factorial designs be used in some of the subsequent studies on differential performance in examinations.

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