USE OF ANALYSIS OF VARIANCE IN ANALYZING THE PERFORMANCE IN MATHEMATICS: A case study of Rachuonyo District 2007 - 2011

by

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A project submitted in partial fulfillment

of the requirements for the degree of

Master of Science in Applied Statistics

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Abstract

In this study we set to determine whether there exists a difference in the performance in Mathematics occasioned by the category of the school (boarding or day secondary schools) and if such a difference occurs then to what extent is it influenced by the category of the school Ceteris Paribas. We intend to use Analysis of Variance (ANOVA) as a statistical tool to do this with our blocks being the 27 sampled schools blocked into two categories i.e. Day schools and Boarding schools, our treatments being the five years under study i.e. 2007 - 2011 and our parameter being the mean standard score (M.S.S.) in Mathematics. Two null hypotheses were posted and tested at 0.05 level of significance using the two-way analysis of variance for various means. A two-way ANOVA table for a randomized block design was used to study 135 scores drawn from 27 schools sampled out of the 120 schools in the study area. Collection of data was done using document analysis as a secondary source of data. The results of this study could be useful in advising the various stakeholders on the type of scho ols that are likely to produce the best results in order to make informed decisions on the cost factor versus the optimum score.

Chapter 1

Introduction

This project work has been organized as follows; Chapter 1 is an introductory chapter. Chapter 2 takes us to the literature review. In chapter 3 we look at the basic concepts involved in the study while chapter 4 focusses on the results obtained and the discussion from those results.

1.1 Background Information

Educational achievement has for a long time been a major factor of measurement of the level of success in the Kenyan society. Success or failure is measured by the academic prowess of an individual. In secondary school education one of the main benchmarks used to determine the level of competence is Mathematics. A lot of emphasis has always been placed on Mathematics as it also has a huge bearing on the career opportunities available to an individual after school. It is commonly noted that a student who is competent enough in Mathematics will generally do well in other subjects as well, particularly the science based subjects. Due to this Mathematics has been made a compulsory subject in the Kenyan secondary school curriculum.

Successful learning of Mathematics deviates from the rote memorization so commonly practiced by most learners in many of the subjects learnt in school. For a student to successfully study mathematics constant practice is not an option. The very common teaching tool of supervised practice in the form of " home work" was actually developed on this premise. As the name suggests this is work done outside the classroom environment in most cases in the evenings.

Since learners in boarding schools and those in day schools have considerably different learning environments in which to do this practice we want to examine how the differing learning environments impact on the learners' performance in mathematics at the end of the day. According to the needs survey conducted by Rachuonyo District SMASE Trainers and the

District Planning Committee in June 2010, statistics show that most students who operate as day scholars and especially in the rural areas where most of these day schools are situated are forced to undertake numerous chores back at home once they get back there in the evening. This is particularly worse with the girls who have their hands full already. In boarding schools students are normally left on their own in the evenings to conduct their personal studies. However it is at such times that negative peer influence takes its greatest toll on the otherwise good and serious students. Such students end up engaging in non-academic activities that hamper their academic achievement.

It is due to the above mentioned reasons that I take interest in this research to study the performance of Mathematics among secondary school students and particularly in relation to the variations that exist between day schools and boarding schools. We want to examine the discrepancies and give such discrepancies statistical interpretation.

The learning environment has got a lot to do with academic performance. A conducive environment is likely to produce better results. Whereas it is commonly agreed that in a boarding school the learners will have ample time to concentrate on their studies, the flipside to this argument is that in the same boarding schools learners develop a lot of negative behavior due to peer influence. This obviously impacts negatively on their academic performance and on their performance in Mathematics in particular.

1.2 Statement of the Problem

Due to the introduction of the Free Day Secondary Education programme to all students in public institutions in 2004 there has been an increased transition rate from primary to secondary school among the Kenyan youth. Due to this funding and the Constituency Development Fund so many low cost schools have been established across the country most of which are mixed and day as opposed to the traditional single sex and boarding secondary schools. We use Mathematics as a benchmark to try and analyze the performance of students in the national examinations in the two categories of schools primarily to ascertain whether the day schools are effective or not.

1.3 Objectives of the Study

The main objectives of this study are to

1. determine whether the category of school considerably affects the level of achievement in the teaching and learning of Mathematics,

2. use the randomized block design to analyze the performance in mathematics of learners in day schools and boarding schools.

1.4 Research Methodology

1.4.1 Sample

The sample used in this study has been collected from 27 schools in Rachuonyo District. These schools have been sampled randomly from the two categories we are studying i.e. day schools and boarding schools. The sample size was calculated as is explained later in Chapter 5.

Collection of data was done using document analysis as a secondary source of data. The mean standard score in mathematics was used as the parameter of investigation and was considered for a period of five years in the 27 schools sampled. A two way ANOVA table for a randomized block design was used to study 138 scores drawn from 27 schools sampled out of the 120 schools in the study area.

1.4.2 Sample Size Calculation

1. **Sample size based on confidence intervals.** In calculating the sample size, we were interested in calculating the population size to be used. Thus, we determined the confidence intervals, so that all the values of the sample lie within that interval.

2. **Sample size calculation based on the size effect.** An alternative approach of calculating the sample size is size of effect. Effect size is known as the difference between the sample statistics divided by the standard error. More efficiently it is as follows: Once an effect size has been estimated, the following table can be used to estimate a sample: α $(\widehat{I}\pm)$ = .05 α $(\widehat{I}\pm)$ = .01 Effect Size (ES) Effect Size (ES) Sample size Small (.2) Moderate (.5) Small (.2) Moderate(.5) 20 0.10 0.34 0.03 0.14 40 0.14 0.60 0.05 0.35 60 0.19 0.78 0.07 0.55 80 0.24 0.88 0.09 0.71 100 0.29 0.94 0.12 0.82 150 0.41 0.99 0.20 0.96 200 0.52 1.00 0.28 0.99. As mentioned above, the alpha is equal to the acceptable probability of the type I error and beta is the acceptable probability of type two errors and 1-β equal to the power. As the power will increase with different levels of alpha, sample size will also increase. Statistics Solutions can assist with determining the sample size / power analysis for your research

study.

3. The formula for calculating sample sizes involves several variables. Sample sizes are vital for conducting research. If your sample size is too small, you may not have a wide enough range of participants to see results, or your results may be dismissed as the result of chance. If your sample size is too large, the cost of your research will make it necessary for you to obtain more funding.

4. Determine the confidence interval of your study. The confidence interval is the number of percentage points above or below the proportion that you find in your study that the true proportion should be within. For example, if your confidence interval is 3.5 % and your study reveals a proportion of 57 % , the true proportion is likely between 53.5 % and 60.5 %.

5. Determine the confidence level of your study. The confidence level is how certain you need to be that the true proportion lies within your confidence interval. For example, if you use a confidence level of 95 %, you can predict with 95 % certainty that the true proportion lies within your confidence interval.

6. Convert your confidence level to a Z-score by using a Z-score table.

For example, a 98.5 % confidence level results in a 2.43 Z-score.

7. Predict the proportion of the study. For example, if you expect 53 % of respondents to respond affirmatively, 0.53 would be your proportion.

8. Compute the needed sample size by plugging your values into the following formula, where Z is the Z-score, P is the proportion and I is the confidence interval. Sample size needed is $n = \frac{Z^2 \times P(1-P)}{I^2}$ ....(i) For example, if your Z-score is 2.43, proportion is 0.53 and interval is 3.5 percent, you would need a sample size of 1,201 subjects.

NB:

- P = Proportion is the percentage of respondents that you expect to respond affirmatively e.g. if you expect 53 % to respond affirmatively, 0.53 would be your proportion.
- There are many advantages to using a sample of the population when conducting research.
- If you want your study to be meaningful, you must make sure your sample size is large enough.

We calculate the sample size under the following conditions: 5% level of significance and Proportion at 10%.

A 95% confidence level results in a 1.96 Z-score. Substituting these values into (i) gives

$$n = \frac{1.96^2 \times 0.1(0.9)}{0.05^2}$$

$$= 138.3$$

$$\approx 138.$$

We need a sample size of 138 scores which will be drawn from 27 schools.

The choice of our sample was informed by the following factors:

- Geographical diversity of the district.
- Gender disparities among the learners.
- Academic ability of the learners (high and low achievers sampled proportionately).
- Proportion taken into account in deciding how many boarding schools and how many day schools to be sampled.

From our sample size calculation we need a total of 138 scores for this analysis. A score here means the mean score in Mathematics for a particular school in a given year. Since the period under study has been given as 2007 - 2011 i.e. 5 years we need 27 schools to obtain our sample. In view of the above the following schools were selected for the study:

Public boys boarding schools	6
Public girls boarding schools	5
Public mixed day schools	16
Total	27

Table 1.1: Schools selected for the study

Public boys' boarding schools were Agoro - Sare, Wangapala, Ringa, Oriwo, Gendia and Ober.

Public girls' boarding schools were Dudi, Nyabola, Bishop Linus Okok, Nyangajo and Mawego.

Public mixed day schools were Atemo, Mititi, Apondo, Got Rateng, Opanga, Owiro, Ogilo, Wire, Saye, Atela, Kandiege, Kowuor, Omboga, Akwakra, Kobala and Kajieyi.

1.5 Significance of the Study

A study on how effective the mixed day schools are in imparting the necessary skills and knowledge as stipulated in the secondary school curriculum was our major reason for conducting this research. This will inform our decision as to whether we can encourage the establishment of more of such schools or not.

1.6 Assumptions made in the study

1. All the day schools used in the study are endowed with equal resources and all boarding schools used in the study are also uniformly endowed.

2. The entry behavior of all the learners in the schools considered is similar and therefore the only thing to investigate is the learning environment.

3. All the students whose performance has been studied and used for analysis here were placed in the schools of their choice after KCPE and that this choice was a random process done at primary level. It is assumed that each KCPE candidate made his/her choice inde-

pendently and randomly.

4. Since we are using the mean standard scores in Mathematics in the various schools for our study, it is assumed that there are no individual differences in the schools sampled and therefore all the learners contribute equally towards the mean.

Chapter 2

Literature Review

Adetunde (see [2]) of the department of Mathematics, University of Mines and Technology, Tarkwa, Ghana and Asare of the department of applied Mathematics, University for development studies, Navrongo, Ghana in their work " Comparative performance of day and boarding students in secondary school certificate mathematics examinations" considered two districts of Ghana ie. Kasena-Nankana and Asuogyaman. They however concentrated on four schools, two that offered Mathematics as an elective subject and two that offered it as a non-elective subject while considering day scholars and boarders at the same time. Their findings revealed no significant difference in the performance of students from the two categories of schools.

Akpan (see [3]) University of Calabar, Nigeria in his project titled: " A comparative study of performance of science and art students in Mathematics in private and public secondary schools in Calabar- Cross River State - Nigeria" examines the differences that exist in the performance of students in Mathematics at secondary school majorly due to their inclination towards science or art subjects.

Alan Vanneman et al (see [4]) of U.S.A in their statistical analysis report of July 2009 talk about how black and white students in public secondary schools perform in Mathematics on the National Assessment of Educational Progress.

Dr. Antony Ezeife of the Faculty of Education, University of Windsor (see [7]) looks at curriculum development in mathematics education. In his thesis " Implications of the full day kindergarten on curriculum change", he examines the impact of the boarding school system on students' performance in mathematics and sciences among Nigerian senior secondary school students.

Lewis Brew (see [11]) of the department of Mathematics, University of

Mines and Technology, Tarkwa, Ghana examines " Mathematical activities and classroom based factors that support senior high school students' mathematical performance". In his work he examines the differences that are occasioned by the learning environment in highly endowed secondary schools versus lowly endowed ones.

M.F. Salman et al (see [12]) in their journal of Modern Mathematics and Statistics have examined the effect of two psychological techniques in improving academic performance of secondary school students in Mathematics. In their work they examined the enrollment and achievement of students in senior school certificate examinations between 2004 - 2006 and how this could be improved from a psychological perspective.

Philas Olatunde Yara and Kennedy Omondi Otieno (see [15]) in their research looked at " Teaching/Learning resources and academic performance in mathematics in secondary schools in Bondo district of Kenya". Some of their recommendations include in-servicing of trained teachers, motivation of learners, review of the curriculum, recruiting more competent teachers, improved government support to education, good teaching methods, improved student-book ratio and better remuneration for teachers.

Tella Adedeji (see [19]) in his publication Ife Psychologia published on March 1, 2011 looks at an assessment of Mathematics self - efficacy of secondary school students in Osun state, Nigeria. In his work he uses the Product Moment Correlation and Analysis of Variance (ANOVA) statistical tools to determine how the students' performance in Mathematics is determined by their capability to set high aspirations for themselves.

The National Assessment of Educational Progress chartered by the National Science Board of the U.S.A. studied and gave a report on the following areas:

i) Trends in Mathematics and Science performance from the early 1970s to the late 1990s.

ii) Performance trends for males and females in Mathematics.

iii) Performance trends for racial/ethnic subgroups.

iv) Mathematics achievement in high poverty schools.

v) Subgroup differences in Mathematics and Science literacy.

From the fore going work that has already been done we hope to bring in a vital component that will ascertain whether or not belonging to a boarding /day school has an effect on the academic achievement in mathematics at secondary school level.

Chapter 3

Basic Concepts

3.1 Analysis of Variance

The problem here is to establish whether there exists any difference in the performance in Mathematics between students learning in day schools and those in boarding schools and if such a difference exists what is the source of error.

For the purposes of this research we allot five treatments in two blocks in our study of a *randomized block design.* In this design the experimental material is divided into groups or blocks with the aim of keeping experimental errors within blocks as small as possible, that is, blocks should be as homogenous as possible. The advantages of a randomized block design include the following:

1. Reduced mean square due to error is usually obtained than in completely randomized designs.
2. Any number of treatments and any number of replicates can be included.

Our interest in this design is to determine the contribution of treatments and blocks. We place five treatments in two blocks as follows:

β_1 : mean performance in Mathematics at KCSE in day schools,

β_2; mean performance in Mathematics at KCSE in boarding schools,

T_1 : 2007 mean score in Mathematics,

T_2 : 2008 mean score in Mathematics,

T_3 : 2009 mean score in Mathematics,

T_4 : 2010 mean score in Mathematics,

T_5 : 2011 mean score in Mathematics,

Our hypotheses will thus be as follows:

$$H_0 : \beta_1 = \beta_2$$

against

$$H_1 : \beta_1 \neq \beta_2$$

and

$$H_0 : \mu_1 = \mu_2 = \cdots = \mu_5$$

against

H_1 : treatment means are not the same for at least two treatments.

Our score will be given by

$$y_{ij} = \mu + t_i + b_j + \varepsilon_{ij} \quad i = 1, 2, \cdots, v \quad \text{while} \quad j = 1, 2, \cdots, b,$$

where y_{ij} is the score of the ith treatment in the jth block, μ is the grand mean of the scores, t_i is the effect of the ith treatment, b_j is the effect of the jth block, ε_{ij} is the error term, which is assumed to be normal with mean 0 and variance σ^2.

From this model we obtain the following ANOVA table:

A statistical hypothesis is an assertion or conjecture about the distribution of one or more random variables. If the statistical hypothesis com-

Source of variation	Sum of squares	df	Mean sum of squares	Fisher ratio
Due to treatments	$S_1 = \sum\sum(y_{i.} - y_{..})^2$	$v-1$	$\frac{S_1}{v-1}$	$\frac{\frac{S_1}{v-1}}{\frac{S_3}{(v-1)(b-1)}}$
Due to blocks	$S_2 = \sum\sum(y_{.j} - y_{..})^2$	$b-1$	$\frac{S_2}{b-1}$	$\frac{\frac{S_2}{b-1}}{\frac{S_3}{(v-1)(b-1)}}$
Error	$S_3 = S_4 - S_2 - S_1$	$(v-1)(b-1)$	$\frac{S_3}{(v-1)(b-1)}$	
Total	$S_4 = \sum\sum(y_{ij} - y_{..})^2$	$vb-1$		

pletely specifies the distribution it is called simple, otherwise it is called composite.

For the purposes of this research the hypothesis will be stated as follows:

H_0 : The performance of students in mathematics at secondary school level in Rachuonyo district does not depend on whether they are boarders or day scholars.

against

H_1 : The performance of students in mathematics at secondary school level in Rachuonyo district depends largely on whether they are boarders or day scholars.

We intend to test this hypothesis using the Analysis of Variance technique.

3.2 Types and Sizes of Errors

Rejecting H_0 when it is true is called a type I error while accepting H_0 when it is false is called a type II error. The size of type I error is the probability that type I error is made that is;

$$\text{Size of type } I \text{ error} = \alpha = Pr(\text{Reject} H_0 | H_0 \text{is true}).$$

and

$$\text{Size of type } II \text{ error} = \beta = Pr(\text{Accept} H_0 | H_0 \text{is false}).$$

Chapter 4

Results and Discussion

The following tables show the results of the schools under study for the period 2007 - 2011.

In this case $\overline{y}_{..}$ is the grand mean and it is used to estimate μ. Hence

$$\overline{y}_{..} = \sum_{i=1}^{v}\sum_{j=1}^{b} y_{ij}/vb$$

$$= 4.09479$$

Sum of squares due to blocks has an estimate b_j and is given by

$$\sum_{i=1}^{v}\sum_{j=1}^{b}(y_{ij} - \overline{y}_{.j})^2$$

SCHOOL	2007	2008	2009	2010	2011	Mean
Agoro Sare	7.359	6.085	5.044	5.292	8.461	6.4481
Wangapala	4.64	4.65	3.935	4.734	5.393	4.6704
Ringa	4.323	4.377	3.492	3.734	5.572	4.29942
Oriwo	5.844	8.602	6.282	7.187	8.138	7.2107
Gendia	5.568	4.477	5.985	6.136	7.242	5.88152
Ober	3.92	3.881	3.087	3.322	6.67	4.17592
Dudi	3.2	4.5	4.28	3.656	4.646	4.05646
Mawego	2.181	2.172	2.781	3.325	3.73	2.83788
Nyabola	1.4	2.44	1.78	2.6	2.6	2.164
Bishop Linus Okok	3.22	1.855	1.922	2.2	2.607	2.3608
Nyangajo	1.452	1.766	1.898	2.633	2.714	2.09266
AVERAGE	3.919	4.073	3.68	4.074	5.252	4.1998

Table 4.1: Mean standard score in Mathematics for boarding schools in Rachuonyo district from 2007 - 2011.

for single scores or

$$\sum_{i=1}^{v}\sum_{j=1}^{b}(y_{.j}-\overline{y}_{..})^2$$

for replicates. Hence

$$\sum_{i=1}^{v}\sum_{j=1}^{b}(y_{.j}-\overline{y}_{..})^2$$

$$= (3.9897 - 4.09479)^2 + (4.1998 - 4.09479)^2$$

$$= 0.0110439 + 0.0110271$$

SCHOOL	2007	2008	2009	2010	2011	Mean
Atemo	3	4.35	3.66	3.52	4.524	3.81072
Mititi	3.65	3.146	3.519	4.037	3.554	3.58126
Got Rateng	5.851	6.115	5.03	5.811	7.255	6.01226
Ogilo	4.156	3.79	3.03	4.03	4.345	3.87012
Wire	5.125	4.73	2.864	3.489	4.939	4.22936
Saye	3.209	3	3	3.189	3.53	3.18566
Kandicgc	2.823	3.955	3.815	3.587	4.125	3.66096
Kowuor	3.222	4.444	3.586	3.476	3.739	3.6934
Omboga	4.38	6.214	3.172	4.319	5	4.61714
Akwakra	2.3	3.048	2.652	2.875	2.586	2.69216
Kobala	4.3	4.975	4.154	4.786	4.456	4.5342
AVERAGE	3.82	4.342	3.516	3.951	4.32	3.9897

Tablc 4.2: Mathcmatics mcan standard scorc for Day Schools in Rachuonyo District.

$$= 0.022071$$

Sum of squares due to treatments has an estimate v_i and is given by

$$\sum_{i=1}^{v}\sum_{j=1}^{b}(y_{ij} - \overline{y}_{i.})^2$$

for single scores or

$$\sum_{i=1}^{v}\sum_{j=1}^{b}(y_{i.} - \overline{y}_{..})^2$$

for replicates. Hence

$$\sum_{i=1}^{v}\sum_{j=1}^{b}(y_{i.} - \overline{y}_{..})^2$$

$$= (3.8695-4.09479)^2+(4.2075-4.09479)^2+(3.598-4.09479)^2+(4.0125-4.09479)^2+(4.786-4$$

$$= 0.0507555 + 0.0127035 + 0.2468003 + 0.0067716441 + 0.4777712$$

$$= 0.7948021.$$

Total sum of squares has an estimate given by;

$$\sum_{i=1}^{v}\sum_{j=1}^{b}(y_{ij} - \overline{y}_{..})^2/vb = 2.2588$$

From these values our ANOVA table will be as follows:

Source of variation	Sum of squares	df	Mean sum of squares	Fisher ratio
Due to treatments	0.7948021	4	0.1987005	0.5512082
Due to blocks	0.022071	1	0.022071	0.0612264
Error	1.4419269	4	0.3604817	
Total	2.2588	9		

Table 4.3: Analysis of Variance table for results

Conclusions and Recommendations

The Fisher-ratio (F-ratio) table value at 5% level of significance with 1 and 4 degrees of freedom is 7.71. Since our study is basically concerned with the category of school (day or boarding) which we called our blocks, we contrast this with the F-ratio calculated to draw our conclusion.

The F-ratio calculated for blocks is 0.0612264 which is not significant at 5% level of significance with 1 and 4 degrees of freedom. We accept the null hypothesis H_0 and conclude that the performance of learners in Mathematics at secondary school level is not affected by the category of school they attend.

From the fore-going conclusion it is our recommendation to the Government of Kenya through the Ministry of Education to promote further the establishment of more community based day schools that are cheap to access in terms of cost while at the same time offering quality education just as the boarding schools. This will make education accessible to more youth of school-going age in line with the basic education act no. 14 of 2013 that demands affordable and compulsory basic education to all Kenyan children.

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