COMPARISON OF FOUR COVARIATE ADJUSTMENT METHODS IN ANALYSIS OF MATHEMATICS ACHIEVEMENT IN RANDOMISED CONTROLLED TRIALS AMONG SENIOR SECONDARY SCHOOL STUDENTS

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Abstract

The study investigated the Mathematics achievement of senior secondary school students in Mathematics in Saki using Project Based Learning Method (PBLM) in enhancing the Mathematics achievement in senior Mathematics among senior secondary school students in Saki. To ascertain the degree of treatment efficacy, a randomised sample of 45 senior secondary school students with 30 and 15 participants each from two different senior secondary schools in Saki West Local Government areas in Saki were selected for the purpose. The randomised control trial design was employed, and a randomized randomised sample that undertook training in PBLM and a control group were used. The instrument used for data collection is Mathematics achievement tests sampled from the National Examination Council (NECO) for 2017 & 2018 objective Mathematics papers. Since the instrument was standardised test prepared by Public Examination body there is no need for revalidation.

A pair of pre-test and post-test data was obtained from each participant who formed the basis of the findings using ANCOVA for data analyses. This study present the empirical application of four statistical methods (pre and post-treatment scores with analysis of covariance, post-test scores, difference in pre and post-treatment scores and percent difference in pre and post-treatment scores), using data from a randomised controlled trial of post-test among the senior secondary school students on Mathematics achievement using Project Based Learning Method (PBLM), with and without PBLM treatment, a Randomized Controlled Study trials. Analysis of covariance (ANCOVA) was used to determine the effectiveness of treatment, to adjust for baseline measures and to provide an unbiased estimate of the mean group difference of the post-treatment scores in Mathematics achievement among the participants used. Robustness tests were done by comparing ANCOVA with three comparative methods: the post-treatment scores, change in scores, and percentage change from baseline. All the four methods showed similar direction of effect; however, ANCOVA (93.503; 95% confidence interval [CI]: 89.332, 97.668; p = 0.019) and the post-treatment score (94.100; 95% CI: 89.733, 98.467; p = 0.001) method provided the highest precision of estimate compared with the change score (38.300; 95% CI: 34.215, 42.385; p = 0.001) and percent change (68.462; 95% CI: 60.358, 76.565; p = *0.001*). The empirical studies provide the best statistical estimation for analyzing the best statistical estimation for analyzing continuous outcomes requiring covariate adjustment. Our empirical findings support the use of

ANCOVA as an optimal method in both design and analysis of trials with a continuous primary outcome.

Keywords: Comparison, Covariate adjustment, Analysis, Mathematics Achievement, Randomized Controlled Trials

Introduction

Mathematics has been a complex subject for many students to effectively learn. Students' achievement in Mathematics is widely recognised as a national concern. For years educators have searched for ways to teach Mathematics to all students more effectively. All students must receive proper Mathematics education. Mathematics education enables learners to meet society demands for a capable and flexible work force (Niss, 1996). School officials try hard to improve the educational achievement of all its students so that all can try to reach the highest level of achievement. Although all education stakeholders together strive to change the education situation, there are still some problems in education and its improvements. Mathematics improvement is at the core of educational strategy in all over the world, but in Nigeria still teachers and learners face with Mathematics problem and there are still poor Mathematics achievements.

And since the hallmark of education is for learners to perform excellently well in theory and practical. The ability of the learners to be able to apply what he/she has learnt theoretical in to real life issues is what showcase a learner to have mastered what the learner has been learnt. Before this can be done, the learners have to be taught in such a way that he/she will be able to understand vividly and know the knitty-gritty of their chosen career or profession.

Therefore, this study employed project based learning (PBL) and Conventional method (CM) to impact the knowledge of Mathematics as mode of instruction among senior secondary school students. The motive of the researcher is that for learners to be able to practicalise what they have learnt theoretically the mode of instruction must be students centered. Many researchers have worked on the issue of Mathematics achievement and not much work has ever combined PBL and CMthe issue of Mathematics achievement and not much work has ever combined PBL and CM as mode of instruction to see the effect of it on mathematics achievement. Therefore, in this study the researcher has decided to combine both PBL and CM as mode of instructional techniques or strategy to enhance mathematics knowledge viz-a-viz mathematics achievement.

In line with the above submissions and vis-à-vis the importance of Mathematics which can be seen in hidden ways, and in everyday usage, all around us in computers, airplanes, body scanners, software, coding, and much more. Have you ever heard about the Golden Ratio? In Mathematics, two quantities are in the golden ratio if their ratio is the same as the ratio of their sum to the larger of the two quantities. Why does this matter? Well, once Mathematics discovered the Golden Ratio, we have used it to our advantage: architects use it to design buildings, scientists apply it to nature's recurring spiral arrangement, and even artists use the proportions in their artistic designs. A Mathematics student will learn all about this and much more if they choose to pursue this field of study.

Here are other reasons to study Mathematics. What calculations were used to build the Pyramids? How do suspension bridges not fail? How is landing on the moon possible? In all of these questions lies a solution based in the usage of Mathematics. Curious minds have been solving humanity's biggest conundrums for centuries by harnessing the power of Mathematics. Seemingly impossible feats are achieved, like landing on the moon, or building the tallest tower...without Mathematics, none of this would be possible. Mathematics is an essential tool that helps make the world go around. It's no wonder that Mathematics is a fascinating and useful degree program to pursue as a field of study.

Knowing what Mathematics is and its importance in everyday life, researchers now present what achievement is - many researchers gave their definitions and explanations of Academic achievement based on perception. Narad and Abdullah (2016) defined academic achievement as the knowledge attained and designated by marks, assigned by teacher. Wigfield (2002) in Onuekwe (2015) stated that academic achievement as knowledge attainment or degree of competence in school tasks usually measured by standardised tests and expressed in a grade or units based on students' performance. Thus, Academic achievement is the knowledge or skills developed by students in their school subjects over a certain period, usually calculated by test scores or marks assigned by the teacher. Martha (2009) opined academic achievement as scores obtained by a student in an assessment such as class exercise, class test, mid-term, mock examination, and end of term examination. The above authors' definitions show that academic achievement is a measurable and observable behaviour of students in their class assignments, class tests, mid-term tests, mock examination, and endof-term examination. Therefore, added

that students' scores in an examination, test and class works may determine their academic achievement (Odikpo and Ejide, 2021).

In order to enhance the Mathematics achievement of the learners, two instructional methods were used to determine the effectiveness of the treatments and to know the effect size, precision of the mean difference of the treatments, and magnitude of the treatment difference obtained. Therefore, the two treatments used are Project Based Learning (PBL) and the Conventional method (CM)

According to Sirega (2012), PBL is sometimes used interchangeably with "experiential learning" or "discovery learning," the characteristics of project-based learning are clear, constant, and share the spirit of John Dewey's instrumentalism. PBL focuses on a big and open-ended question, challenge, or problem for the student to research and respond to and/or solve. It brings what students should academically know, understand, and be able to do into the equation. PBL is inquiry-based, stimulates intrinsic curiosity, and generates questions as it helps students seek answers. It uses 21st-century skills such as critical thinking, communication, collaboration, and creativity. PBL builds student choice into the process. It provides opportunities for feedback and revision of the plan and the project, just like in real life (Greeno, 2006). PBL requires students to present their problems, research process, methods, and results, just as scientific research or real-world projects must stand before peer review and constructive criticism.

In almost all the experimental studies carried out by psychologists, counselling psychologists, experimental researchers and clinicians that used ANCOVA as data analysis, none care to establish the precision, magnitude and the power of the differences found in their ANCOVA results. Therefore, this study is carried out to determine the experimental results obtained in enhancing Mathematics achievement by the use of project-based learning method as treatment in the experimental group and conventional learning method in the control group to know whether the mean difference between the experimental and control groups in Mathematics achievement is due to some other factors apart from the treatment used in the study. In this study researcher establish the direction of the treatment difference, the magnitude of the treatment difference and precision of the treatment difference in order to be sure of the effectiveness of treatment used (Project Based Learning) method over conventional method and to enlighten

other researchers that there is need to carry out power, precision and confidence level of their findings to be doubly sure that their results/findings is accurate and not due to variation. Although seemingly straightforward, the statistical comparison of a continuous variable in a Randomized Control Trial that has both a pre- and post-treatment score presents an interesting challenge for researchers and statisticians alike. The statistical properties of baseline adjustment methods are complex and often poorly understood, confusing the choice of the most appropriate statistical strategy.

Purpose of the Study

In this study, four methods of baseline adjustment were used to demonstrate empirically whether the ANCOVA is statistically efficient compared with statistical analysis by post-treatment score, change score, or percent change score. To compare methods, previously reported outcome data (Mathematics achievement) was analysed using ANCOVA and the other three methods outlined above. The robustness of the latter three methods was evaluated by qualitatively comparing the direction, magnitude of effect and the estimate's precision with the ease of interpretation of the results.

Hypotheses

The following null hypotheses were tested at $\alpha = 0.05$ level of significance.

1. There is no significant main effect of treatment on Mathematics achievement of students exposed to treatments and control group among senior secondary school students.
2. There is no significant difference in the magnitude of the treatment difference.
3. There is no significant difference in the direction of the treatment difference.
4. There is no significant difference in the precision of the treatment difference.

Methodology

Design

The randomised control trial design with (pre-test, post-test and control group experimental design) was used for this study. There was only one treatment group Project Based Learning Method (PBLM) and control group. The effect of such on dependent variable (Mathematics Achievement) was also determined.

Population

The population for this study consisted of Senior Secondary School Two Students (SSS II) in Saki, Oyo State, Nigeria. The students were selected from public Senior Secondary Schools. Two Schools were selected in Saki Township: Baptist High School and Community High school. These two schools have SSII students' population of 137 and 115 respectively; totaling 252 in their SSS II class.

Sample and Sampling Technique

Simple random sampling technique was used to select the participants from the selected schools from each chosen school. Participants from each school were selected based on cumulative academic performance records on class Mathematics. These constituted the first stage of the screening process adopted to determine the students in Mathematics achievement. Those students who had poor cumulative academic performance records in the previous school terms in Mathematics were assumed to be affected by the conventional method of teaching them mathematics and these set of students were selected for further screening as a confirmatory test, they were further subjected to Mathematics achievement test prepared by NECO 2017 for entrance examination into Senior Secondary school. Using this technique, the first 30 and 15 students with the worst scores in each of the two schools were finally selected. The total sample size consisted of 45 students for the study.

Instrumentations

This study utilised two instruments for data collection. **Section A:** Demographic information of the students such as gender and age are required. The researcher developed this section:

1. Mathematics Achievement Test (MAT-BECE Prepared by NECO, 2017 and 2018) for screening the participants and measuring the dependent variable

   Mathematics Achievement Test (MAT) was constructed by National Examination Council (NECO) and it is made up of 60 items covering the Junior Mathematics curriculum. The items have 4 options response format of A, B, C & D out of which only one option is the correct answer. The administration of the test lasts for 90minutes. MAT is a standardised test since it was developed by NECO a public examination body, it is believed that the psychometric properties of it had been established. The Basic Certificate Examination paper for 2017 was used for screening exercise while that for 2018 was used for real study.

Procedure for Data Collection

Project Based Learning Treatment Package: The following are the stages in administering project based learning:

Session One: Learners create time to solve real world

Session Two: Challenging

Session Three: Personally engaging problem

Session Four: Students seek in-depth understanding of a question

Session Five: They research and develop explanation and solution

Session Six: Finally students present their product to an audience which can be mixture of teachers, peer and real-world.

Control Group - The following are the procedure Adopted for Control group:

Session One: Administration of pre-test instrument

Session Two: Given placebo.

Session Three: Given placebo.

Session Four: Administration of the post-test instrument at the 8th week.

Copies of MAT were administered to the participants in their various groups before they were exposed to treatment and after the treatment the copies of MAT questionnaire was also administered for the post-test score. The data collection spread over eight weeks during which 75 score. The data was scored, coded, and analysed using SPSS version 19.

Data Analysis

Analysis of Covariance (ANCOVA), Descriptive statistics of Mean & Standard deviation and Confidence Interval were the primary statistical tools employed in this study. ANCOVA was used to remove initial differences between the participants in the experimental and control groups. Scheffee Post-hoc analysis was also used in this study to determine the directions of differences and significance that were identified.

Results and Discussion of Findings

Hypothesis One: There is no significant main effect of treatment on Mathematics achievement of students exposed to treatments and control group among senior secondary school students.

Table1: Analysis of Covariance (ANCOVA) of Pretets-Posttest Effects of Project Based Learning Method among Participants in Enhancing Mathematics Achievement

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	14016.067[a]	2	7008.034	41.705	.000	.665
Intercept	482.082	1	482.082	2.869	.098	.064
prescore	1008.023	1	1008.023	5.999	.019	.125
treatment	9359.821	1	9359.821	55.701	.000	.570
Error	7057.577	42	168.038			
Total	370258.000	45				
Corrected Total	21073.644	44				

a. R Squared = .665 (Adjusted R Squared = .649)

The table 1 show that there was significant main effect of treatment on students Mathematics achievement ($F_{(1, 42)} = 55.701$, $p < .05$, $\eta^2 = .570$). This implies that treatment in the group test mean scores significantly impacted students' Mathematics achievement. Therefore, the null hypothesis which stated that there is no significant main effect of treatment on students' Mathematics achievement was rejected; the Table 1 also shows the contributing effect size of 57%. Effect size is a statistical concept that measures the strength of the relationship between two variables on a numerical scale. For instance, the mean score difference between the experimental and control groups on average is 94.100. The mean score of experimental group is more than that of control group, the difference between the mean scores of the two groups is known as the effect size. The greater the effect size the greater the mean difference between the experimental and control group is. The effect size is 0.570, therefore, the difference is real it is not due to a change of factors. According to Cohen (1988 & 1992), the effect size is low if the value of effect size varies around 0.1, medium if it varies around 0.3 and large if it varies more than 0.5

Table 2: The Results of the Sensitivity Analyse between the Different Baseline Adjustment Methods

			95% Confidence Interval		
	Mean	Standard Deviation	Lower Bound	Upper Bound	P - value
Pretest &Posttest Data	93.503	2.064	89.337	97.668	0.019
Posttest Data Only	94.100	2.165	89.733	98.467	0.000
Pretest – Posttest Data	38.300	2.026	34.215	42.385	0.000
%(Pretest–Posttest)Data	68.462	4.018	60.358	76.565	0.000

Hypothesis Two: There is no significant difference in the direction of the treatment difference.

The group effect obtained using the post-treatment scores method without a baseline adjustment had the most similar results compared with ANCOVA. Along with having the same direction and almost identical magnitude of effect, the 95% CI was narrower and had a correspondingly smaller *P*-value. Overall, the results of the post-treatment scores remained robust, and the findings were consistent. The results obtained from the change score and percent change score methods had larger deviations compared with the primary analysis. Although they had the same effect direction, the effect magnitude was less, and a wider 95% CI was obtained (mean = 94.100, CI = 89.733 and 98.467, $p < 0.001$). Of the three comparator methods, post-treatment offered the most robust method of analysis compared with ANCOVA, and the change score and percent change score methods offered favorable method in terms of precision and magnitude of effect.

Hypothesis Three: There is no significant difference in the magnitude of the treatment difference.

The results from Table 2 showed that PBLM has a mean treatment group of 38.300. This indicated that the Mathematics achievement of the participants in the treatment group was 38.300 more, on average than that of participants in the control group. The lower and upper 95% CIs were 34.215 and 42.385, p - value was less than 0.001 and the difference between the two treatment arms was statistically significant..

Hypothesis Four: There is no significant difference in the precision of the treatment difference.

The results from Table 2 showed that the mean score, CI and p - value is (mean = 68.462, CI = 60.378 and 76.565 and $p < 0.001$) of percentage difference between the post-treatment treatment group and baseline. The level of confidence level indicates the probability with which the estimation of the location of a statistical parameter (mean) in a sample survey is also true for the population. A confidence interval is an indicator of the measurement's precision. It is also an indicator of how stable the estimate is, that is the measure of how close the measurement will be to the original estimate if the experiment is repeated. Therefore, $p < 0.001$ means the measurement precision is 99%.

Conclusion

In this study, the researcher compared the most commonly used methods for adjusting the baseline data of a continuous outcome in an RCT, using an existing empirically derived dataset. The study results suggest that ANCOVA is a statistically efficient method of data of this nature and that the use of change and percent change scores should be employed with caution since the statistical power of these methods is highly dependent on the correlation between the baseline and the outcome. The findings of this study can be generalised since there is correlation between the adjustment variables, it should be noted that the study contributed to the growing body of literature on this subject, where ANCOVA has been shown as the method with the most advantages.

Recommendations

Based on the findings of this study, the following recommendations were made that:

1) The future studies should be conducted to strengthen the interpretation of this study.
2) Future studies may look at logistic regression and how the method of covariate adjustment affects the results.
3) Future studies should try as much as possible to include ambulation in case there are omissions of data to educate other researchers further.

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