Effects of Five Principles of Mathematics Teaching on Students Performance in Trigonometry

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Abstract

Junior Secondary School (JSS) students were observed to find word problems on trigonometric ratios unattractive and also, avoid solving problems related to it. There was the conjecture that the problem is related to teachers' lack of use of appropriate teaching strategy and instructional materials. The study engaged JSS2 in a quasi-experiment in which the topic was taught outside the classroom using inclinators to determine the height of the school flagpole in Uyo, Nigeria. The population and sample size of the study were 11,658 and 120 respectively. Four research questions and hypotheses guided the study. Data was gathered using a 10 item researcher made performance test with r= .79. Analysis was done with ANCOVA. Results showed that students who were taught the topic using inclinators in 'out-of-classroom' exercises determined accurately the height of the school's flagpole without having to climb up with a tape-measure in hand. Recommendations include, the call for teachers to sometimes engage mathematics students in out-of-classroom exercises and use appropriate instructional tools to facilitate students learning.

Key Words: *Principles, Teaching, Inclinators, Flagpole, Trigonometry.*

Introduction/Background

Stakeholders in Mathematics Education such as parents, teachers, mathematicians, scientists and society at large are worried; about why students' achievement in mathematics learning has not improved significantly at the secondary school level. It also does not seem that the phobia students had for mathematics is abating. The attendant consequences of these on students are poor achievement and negative attitude towards the subject. There are several dimensions to students' problems in mathematics learning. Among them are curriculum issues, students' learning problems, school problems and societal problems (Ale in Awodeyi, 2000).

However, researchers are not relenting on finding new ways the teacher can help to improve mathematics teaching in schools. Among these, are the calls for teachers to employ the use of Games, Activities, and Strategies including 'Method Combination Therapy' (Ibe, 2005; Awodeyi, 2017; Awodeyi & Udo, 2017). A method combination approach had been found in use in mathematics classrooms where four basic principles of deeply effective mathematics teaching were applied. The four principles were: Principle 1- Let it makes sense; Principle 2- Remember the goals; Principle 3- Know your tools; and Principle 4: Living and loving Mathematics (Homeschoolmath, n. d.).

The present study would discuss these four principles with a view to extend the scope. First, 'Let it make sense' simply implies that teachers should teach for understanding of the mathematical concepts and procedures. Concepts and procedures go together. A lack of this understanding by the teacher makes learning uninteresting, and the attendant students'

problems could be: forgetfulness of the knowledge acquired, poor performance in examinations and poor application of knowledge to problem solving when the need arises.

Second, 'remember the goals' of teaching mathematics. The Benin Conference of 1977 stated seven general objectives (ultimate goals) of mathematics teaching in Secondary Schools in Nigeria. These are to:

'**1.** Generate interest in mathematics and to provide a solid foundation for everyday living;

 2. Develop computational skills;

 3. Foster the desire and ability to be accurate to a degree relevant to the problem at hand;

 4. Develop precise, logical and abstract thinking;

 5. Develop ability to recognize problems and to solve them with related mathematical knowledge;

 6. Provide necessary mathematical background for further education;

 7. Stimulate and encourage creativity.'

(Benin Conference, 1977: 4)

These goals are broad. They are different from the usual behavioral objectives which teachers' state for a lesson. However, the aggregate of all behavioral objectives for lessons, for all years of school make the ultimate goals. It is necessary that mathematics teachers keep in mind the ultimate goals while focusing on the specific objectives during lessons. Unfortunately the situation we often had is that some teachers hardly bother about the ultimate goals let alone use them as guide. The attendant effect of this is students' poor application of knowledge to problem solving whenever the need arises.

Third, 'know your tools'. Tools are the instructional materials for teaching mathematics. The tools are many and the teacher must choose correctly. Committed teachers are expected to keep together a collection of the tools and go about with it to work. Among mathematics tools are: Curriculum guide, Class textbooks, interactive Mathematics games, Mathematics software; manipulative such as 3-D plastic forms, and Inclinator- an upgraded students' protractor with features that could determine the angle of elevation of a high-rise (NMCA,2010).

Four, 'Living and loving mathematics'. Mathematics should be taught in schools by relating the topics to the day to day activities of man. The subject has wide application in the home and in the environment of the learner. It is not always confined to the classroom. However, the present study would consider one additional principle which is the principle of 'learner centered activities'. In the combination therapy of methods, all principles complement one another. These five principles form the theoretical framework for the present sturdy. Learner centered activities can remove phobia for mathematics and motivate students.

The fifth principle is arising from psychology of learning where the law of exercise was established for motivating (Thorndike, 2010) students in school curriculum topics and securing their interest, especially in topics perceived difficult to learn. In trigonometric ratios where Junior Secondary School students had been found to have learning difficulties, for example, a right angle triangle (Figure 1) may be given to students to find the sine, cosine or tangent of the acute angles, or to find an unknown side, given certain parameters.
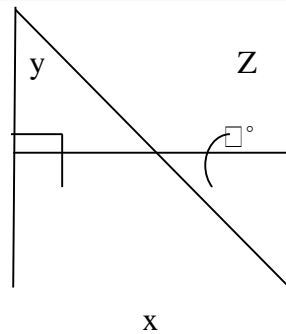
Fig.1: A right angle triangle   x

     In Fig. 1, Tan $\square°$ = y/x or y = x tan $\square°$; Sin $\square°$ = y/z or y = z sin $\square°$; Cos $\square°$ = x/z or x = z Cos $\square°$. In particular, y = x tan $\square°$ is the required formula for computation of the value of y.

Related to this problem are experiences from the school of 'Gestalt psychology' and 'activity based learning'. The determination of height of flagpole by students without having to climb up with tape-measure in hand is similar to Wolfgang Kholer's experiment of learning by insight, where monkeys were able to attach sticks together, using trial and error activities to reach far up bananas (Kholer, 1925; Gestalt Psychology, n. d.). Students also, develop insight into problem solving using available materials in their neighborhood.

     Professional teachers facilitate students to participate rigorously and to effectively determine height of the school's flagpole. This is a task that could be perplexing, especially when the students are not expected to climb with a tape-measure or ruler in hand. The required activities include using tools like the inclinator to determine the angle of elevation from the observer's eye to the top of the flagpole at various horizontal distances from the flagpole. Learning should be based on doing some hand-on experiments and activities (UNICEF, n. d.). Other students'-centered activities and required skills in topics like trigonometric ratios include: observations, recording, applying formula and computing.

Teaching Trigonometric Ratios Using Inclinators is Activity Oriented

     Word problem on trigonometric ratios is a topic students typically find unattractive because they were often restricted to the classroom during the learning process. The present researcher has also observed that pre-service teachers and in-service teachers alike, avoid word problem in trigonometry or geometry for Junior Secondary students. The topic however, should be interesting and exciting to students if teachers engage them in appropriate activities during lessons that go beyond the four corners of the classroom.

Activities could be structured as indicated in Figure 1, with a Table for recording observations.
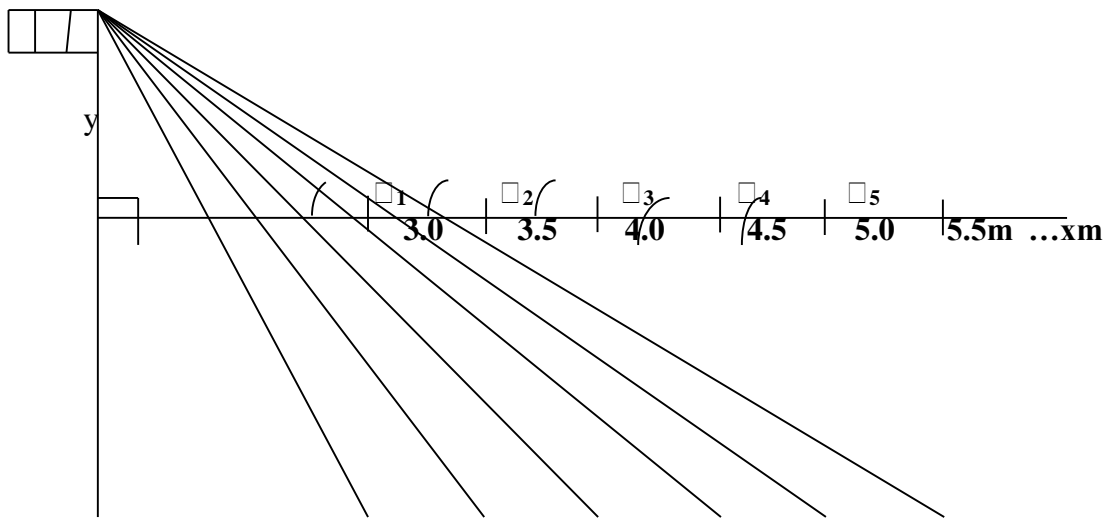

Figure 1.

Required students activities
Table of observations

s/n	xcm	$\square°$
1	3.0	
2	3.5	
3	4.0	
4	4.5	
5	5.0	
	$\bar{x}$	

1. Vary the distance x meters between the observer and the flagpole, severally
2. Use clinometers to determine the corresponding angle of elevation $\square_1 \ldots \square_5$
3. Apply trigonometric ratios to compute height $y_{1\ldots}y_5$ that corresponds to $\square_1 \ldots \square_5$
4. Compute the average value $\bar{y}$ of $y_{1\ldots}y_5$ (this height is the section of flagpole above observer's eye level)
5. Determine the real height $\bar{y} + e$ of the pole, where 'e' is the vertical height from the observer's eye to the ground.

An Outdoor Experiment to Determine Height of School's Flagpole Using the Inclinator
Statement of Problem

Students at the junior secondary school level have problems solving word problems on trigonometric ratios and also avoid questions that are related to it. The situation may be traced to their teachers' inability to use appropriate teaching strategy that involves a combination of learning principles, use of inadequate instructional materials, and over reliance on indoor teaching as against outdoors when occasion demands. Students' performance is consequently hindered especially when they need to apply knowledge acquired in their environment.

The Purpose of the Study

The general purpose of the study is to apply the five fundamental principles of mathematics teaching, to the concept and procedure of trigonometric ratios for Junior

Secondary Two (JS2) students using inclinator as instructional tool. Specifically, the study is intended to task students in activities geared towards the determination of:

1. The height of the flagpole which hoists the national flag (or similar heights) in the school compound without having to climb up, with tape-measure or meter rule in hand.
2. The effects of application of the inclinator on students' determination of height of the school's flagpole in their groups of ability levels and gender.

Research Questions

1. What is the height of the pole hoisting the National Flag (flagpole) in the school?
2. What is the difference between the mean scores of students when taught the concept, procedures and application of trigonometric ratios to determine height of school's flagpole, using inclinators and charts?
3. What is the difference between the mean scores of high and low ability mathematics students when taught to use the concept, procedures and application of trigonometric ratios to determine height of flagpole, using inclinators and charts?
4. What is the difference between the mean scores of male and female mathematics students when taught the concept, procedures and application of trigonometric ratios to determine height of flagpole, using inclinators and charts?

Research Hypotheses

1. There is no significant difference between the mean scores of groups of students who were taught to apply trigonometric ratios using inclinators and charts.
2. There is no significant difference between mean scores of students by their ability levels when taught to apply trigonometric ratios using inclinators and charts
3. There is no significant difference between mean scores of students by their gender when taught to apply trigonometric ratios using inclinators and charts.
4. There is no significant interaction effect of method and gender when students are taught to apply trigonometric ratios using inclinator and charts.

Research Method

The study was carried out in public secondary schools in Uyo metropolis of Akwa Ibom State, Nigeria. Four schools were randomly sampled from the existing 65 in the area. The subjects of the study were year two Junior Secondary School (JSS2) Students. The curriculum topic of interest is trigonometric ratio in JSS2 (FME, 2007). Students find this topic difficult when solving word problems. The population size of the study was 11,658, while the sample size was 120. The small size of the sample was not a cause for worry because the design of the study was quasi-experimental. The intact classes used in the four schools were randomly sampled out from the existing four streams of JSS2 in each school. Students from two of the schools (58 of them) were taught Trigonometric ratios in the experiment using inclinators while 62 others from the other schools were taught same topic using charts in a typical lecture method. Students who scored below 50% in promotion examination to JS2 were classified as low ability and those with 50% and above were classified as high ability.

The instrument used for data collection was a researcher made Mathematics Performance Test on Trigonometric Ratios. It contains 10 open ended items for the subjects to complete. Its reliability coefficient was .79, obtained on test-retest basis. The duration of the study was one week. Five lessons of 40 minutes each were sufficient. The study engaged students' outdoors using inclinators to determine height of the school flagpole while their counterparts in the control groups were engaged indoors. The outdoor practical exercise was achieved in 80 minutes (a double lesson of 40 minutes each). The researcher's laboratory

Technologist demonstrated the use of the inclinator for both groups of students. Each student in the experimental group practiced with inclinator outdoors, but those in the control group worked with charts indoors following the initial outdoor demonstration. The schools used for the experiment were at some distance from one another, but were equivalent in all respects such as: identical average age, same mathematics curriculum for the schools, same textbook as prescribed by the Ministry of Education and, all the teachers had first degree qualifications. All students were given pretest before treatment and posttest after. Analysis of Covariance was employed for data analysis and the pretest scores were used as covariates with posttest scores.

Results
Table 1: Description of variables in the study by size

		Value Label	N
METHOD GROUPS	1	EXPERIMENTAL	58
	2	CONTROL	62
ABILITY LEVEL OF STUDENTS	1	HIGH ABILITY LEVEL	68
	2	LOW ABILITY LEVEL	52
SEX OF STUDENTS	1	MALE	46
	2	FEMALE	74

Table 1 contains the sizes of the various groups in the study. In the method groups are 58 students in the experiment and 62 in the control. Students in the high and low ability levels are 68 and 52 respectively. Male and female students are 46 and 74 respectively.

Research Question One:
Table 2: A record of all measurements relevant to the determination of height of flagpole

Groups	Average Height	Eye-level from the ground	Actual Height of Flagpole	Obtained height of Pole	Observed Error
Technologist	1.61m	1.50m	6.00m	6.08m	0.08m
Experimental	1.42m	1.33m	6.00m	6.05m	0.05m
Control	1.41m	1.32m	6.00m	4.68m	1.32m

Table 2, contains recorded observations in the experiment. The height of the Technologist, who carried out initial demonstration for students using the inclinator, is 1.61m. His eye-level from the horizontal ground is 1.50m, and he obtained the height of the school flagpole to be 6.08m. The actual height of the flagpole was 6.00m. The experimental group obtained 6.05m (average answer), introducing an error of 0.05m over actual height. The control group on the other hand obtained 4.68m (average), and committed an error of 1.32m.

Research Question Two:
Table 3: Description of Posttest Scores with Pretest scores as Covariate for Experimental and Control Groups

Method Groups	Mean	Std. Error	Difference
Experimental	6.177[a]	.080	1.959
Control	4.218[a]	.077	

[a]Covariate appearing in the model are evaluated at: Pretest mean sores=1.12
On Table 3, the mean scores of students in the experimental and control groups are 6.177 and 4.218 respectively. The difference between the two means is 1.959.

Research Question Three:
Table 4: Description of Posttest Scores with Pretest Scores as Covariate for Two Ability Level Groups

Ability level of students	Mean	Std. Error	Difference
High Ability	5.768	.080	1.141
Low Ability	4.627	.092	

[a]Covariate appearing in the model are evaluated at: Pretest mean sores=1.12
On Table 4, the mean scores of students in the high and low ability level groups are 5.768 and 4.627 respectively. The standard error of scores in the high and low ability groups are also, .080 and .092 respectively. The difference between the group means is 1.141.

Research Question Four:
Table 5: Description of Posttest Scores with Pretest as Covariate for Males and Females

Gender Group	Mean	Std. Deviation	Difference
Male	5.278[a]	0.086	0.160
Female	5.118[a]	0.069	

[a]Covariate appearing in the model are evaluated at: Pretest mean sores=1.12
The mean scores of male and female students in the groups are 5.278 (with .086 standard error) and 5.118 (with .069 standard error) respectively. The difference between the group means is 0.160.

Research Hypotheses:
Data on Table 6 is used to answer research hypotheses 1 to 4.

Table 6: ANCOVA Table of Significance of Difference between Mean Performance Scores of Students by Method, Ability and Gender.

Source	Type III Sum of Square	df	Mean Square	F	Sig.	Partial Eta Squared (η^2)
corrected Model	367.938[a]	8	45.992	136.035	.000	.907
intercept	217.185	1	217.185	642.384	.000	.853
PRETEST	70.612	1	70.612	208.855	.000	.653
METHOD	106.220	1	106.220	314.174	.000	.739
ABILITY	25.246	1	25.246	74.671	.000	.402
GENDER	.705	1	.705	2.085	.152	.018
METHOD * ABILITY	1.047	1	1.047	3.098	.081	.027
METHOD * GENDER	.391	1	.391	1.157	.284	.010
ABILITY * GENDER	.435	1	.435	1.288	.259	.011
METHOD * ABILITY * GENDER	.018	1	.018	.054	.817	.000
Error	37.528	111	.338			
Total	3692.000	120				
Corrected Total	405.467	119				

a. R Squared = .907 (Adjusted R Squared = .901)

H_{01}: There is no significant difference between the mean scores of groups of students who were taught trigonometric ratios using 'inclinators' and charts.

The methods of teaching adopted in the study are activities involving the use of inclinators and lecture method involving the use of charts. On Table 6, method (row 4, col 1) indicated an F-value of 314.174 (row 4, col 5) with a corresponding P-value of .000 (row 4, col 6). Method is therefore significant ($p \le .05$). In other words, the difference between the mean performance scores of those taught using inclinators and charts is not by chance. Furthermore, the obtained Eta squared (row 4, col 7) is .739, which is a high index of relationship between performance and method.

H_{02}: There is no significant difference between the mean scores of high and low ability level students when taught trigonometric ratios using inclinator and charts.

On Table 6, Students ability level (row 5, col 1) indicated an F-value of 74.671 (row 5, col 5) with a corresponding p-value .000 and eta squared .402 (F = 74.671; p =.000; η^2 = .402). Ability of students is significant ($p \le .05$). The index of relationship eta squared (η^2) is average.

H_{03}: There is no significant difference between the mean test scores of students by gender when taught the concept and procedures of trigonometric ratios using inclinators and charts.

The F-value obtained for gender on Table 6, is 2.085, with a corresponding p-value .152 and eta squared (η^2) = .018. Gender is therefore not significant. The index of relationship between performance and gender is negligible (η^2 = .018).

H_{04}: There is no significant interaction effect of method and gender when students were taught the concept and procedures of trigonometric ratios using inclinators and charts.

On Table 6, the interaction effect of gender and method is not significant at p≤.05 (F =1.157, p =.284, η^2 = .010).

Summary of Findings

1. The outdoor strategy involving five principles of mathematics teaching in which students manipulated clinometers to observe, record readings and hence determine height of the schools' flagpole enhanced accuracy of results, while those who worked indoors with charts were not that accurate.
2. Ability of students was found to be significant. This was not anticipated. The teaching strategy adopted was expected to bridge the gap between low and high ability students. This is probably due to the short duration of the experiment. However, the index of relationship between performance and method (i.e. η^2 = .402) suggests that a continuous application of the five principles of mathematics teaching to the rest topics in the mathematics curriculum will most likely bridge the existing gap with time.
3. The five principles of mathematics teaching as combined enhanced performance of both males and females adequately.
4. Interaction effect between gender and method was not significant in the study, suggesting that the five principles of mathematics teaching affect both males and females positively and in the same direction.

Discussion

Activity based method with appropriate instructional material:

The activity based method in which student's used 'inclinator' to learn trigonometric ratios led to significant increased performance in their ability to solve related problems in their environment. This agreed with the Gestalt school of psychology that learning takes place by insight. In the present case, students thought of how to obtain the height of the flagpole without tape-measure in hand and the inclinator was handy. It also agrees with the 'law of exercise' (of Behaviorism) that in learning the more frequently a stimulus and response are associated with each other (practice and exercise) the more likely the particular response will follow the stimulus. The experimental group had opportunity to practice with the inclinator (Thorndike, 2010; Gestalt psychology, n. d.; UNICEF, n. d.).

Ability level of learners in activity based method involving use of inclinators

It was expected that the activity based method would close up the gap initially existing between the high and low ability level students in the study. The reason for the non-closure of the gap could not be immediately traced. This requires further investigation.

Gender issues in students' mathematics learning

Gender was brought into the study on the assumption that there is no significant difference between males and females in their performance in mathematics (Fennema and Carpenter, 1981; Awodeyi and Harbor-Peters, 2000). It was however necessary to bring gender in, so as to find out if there was interaction effect between method and gender. However, interaction effect was not significant in the study. The "inclinator' therefore influenced the performances of males and females in the same way and equally too.

Conclusion:

The use of inclinators to generate activities for students in their learning of trigonometric ratios enhanced their performance in problem solving. It is also rewarding in application of knowledge and experience towards finding the height of high-rises generally,

and height of the school's flagpole in particular. The five principles thus have significant effects on students learning and academic performance in schools.

Recommendations
The following recommendations are suggested:
1. Mathematics teachers should prepare adequately by selecting appropriate instructional strategies which may sometimes require students to be taken out of the classroom to the field or on field trip.
2. Teachers should be competent enough to select materials that are adequate for lessons and generate adequate learning activities in which observations could be accurately made, recorded and utilized for necessary computations by students.
3. The activities selected for students should be fair and favourable to both males and females and to different ability levels of learners in class.
4. The learning activities selected by the teacher should be such that could bridge the initial gap existing between performances of high and low ability level students.

References
Awodeyi, A. F. (2017). A Modified 'Method Combination Therapy' as Instructional Strategy for Teaching Secondary School Geometry and Effects on Students' Achievement and in Mathematics. *Journal of Education and Practice, 8*, (4), 129-137.

Awodeyi, A. F. and Harbor-Peters, V. F. A. (2000). "The Relationship between some Teachers' Classroom Variables and Secondary School Students Achievement in Mathematics. *International Journal of Education Development (IJED), 2,* (2), 65 – 72.

Awodeyi, A. F. and Udo, R. J. (2017). Method Combination Therapy as Instructional Strategy for Teaching Secondary School Geometry & Effects on Students' Achievement and Retention in Mathematics. *Mathematical Theory and Modeling, 7*, (2), 33-50.

Benin Conference, (1977). A Report on the Mathematics conference held at the University of Benin, Nigeria 6th and 7th January.

Fennema, E. H. and Carpenter, J. P. (1981). Sex-Related Differences in Mathematics: Results from National Assessment. *The Mathematics Teacher, 74*(3).

Federal Ministry of Education (FME), (2007). *Senior Secondary Education Curriculum: Maths for SS1-3.* Nigerian Education Research and Development Council (NERDC) press: Abuja.

Gestalt Psychology (n.d). Learning by Insight. Retrieved 13th June, 2007 at http://www.zeepedia.com/read.

Homesschoolmaths, (n.d). Four principjles of deeply effective math teaching. Retrieved on 10th May, 2018 at www.homeschoolmath.net

Ibe, G. C. (2005). Effects of Mathematics Games on Students' Achievement, Retention and Attitude in School Mathematics. *Unpublished M.Sc. (Ed) Thesis,* University of Uyo, Uyo.

Kholer, W. (1925). Principles of Insight Learning. Retrieved 9th July, 2017 at https://www.google.com

National Mathematical Centre, Abuja (NMCA), (2010). *Inclinator: A resource for Teaching Geometry and Trigonometry.* Nigeria: NMCA.

Thorndike, E. L. (2010). *Laws of Learning.* Retrieved 9th July, 2017 at http://dywaymade.blogsport.com

UNICEF (n.d). Activity Based Learning: A Radical Change in Primary Education. Retrieved 14th June, 2017 at https://en.m.wikipedia.org