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Diagnosis and remediation of senior secondary students' misconceptions in quadratic equations using graphical method in Yenagoa Local Government Area, Bayelsa State

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Abstract
The study diagnosed and remediated senior secondary students' misconceptions in quadratic equations using graphical method in Yenagoa L.G.A., Bayelsa State. Quasi-experimental research design was used. The population of the study comprised 5840 senior secondary students in Yenagoa Local Government Area of Bayelsa state. 123 students {69 males and 54 females} were selected from four schools using purposive sampling technique. The research instrument was Performance Test on Quadratic Equations using Graphical Method (PTQEGM). The instrument was validated by three experts in Measurement and Evaluation as well as researchers' supervisors. The reliability of PTQEGM was determined by split-half method using Spearman-Brown Correlations with an index of 0.86. Frequency count, percentage, mean and standard deviation were used to answer the three research questions, while ANCOVA was used in testing the two hypotheses formulated for the study at 0.05 level of significance. The result revealed the areas (Inequalities, substitution, rules of signs, mensuration, coordinates of numbers, factorization, line of symmetry and gradient) of students' misconceptions when solving quadratic equations using graphical method. It also proffered ways to remediate (amend) misconceptions students have by using the key concepts of quadratic equations using graphical method with the lower-order concepts put into considerations. Based on the findings of the study, it was recommended that students and teachers should be familiar with the lower-order concepts of the key concepts of quadratic equations using graphical method for effective performance. Also, Mathematics teachers should diagnose their students' misconceptions and lay emphasis on those areas when teaching to minimize misconceptions which lead to errors.

Keywords: diagnosis, remediation, misconceptions, quadratic equations and graphical method

Introduction

Mathematics is a compulsory subject for every student at the primary and secondary level of education. The inclusion of Mathematics as a school subject is due to its usefulness in the society as observed by Ekwueme, 2013 that Mathematics has been a faithful companion due to its involvement in everyone's life as such Mathematics is a universal language shared by human beings irrespective of culture, religion or gender (Uka, Iji and Ekwueme, 2012) [25]. Mathematics has different areas of study such as number/numeration, algebraic process, statistics (data), geometry, and introducing calculus at the secondary school level. Algebra is Mathematics with letters and numbers. Usman and Musa (2015) [26] noted that these letters combined with figures bring much misunderstanding to students and most especially with a letter replacing a different letter at intervals or the values of letters being changed. Algebra has the following aspects: 1.) substitution (it is replacing the letters with numbers in an algebraic expression), 2.) Expansion (it is removal of brackets when simplifying an algebraic expressions), 3.) Factorization (it is introduction of brackets using its factors that lead to an algebraic expression) and 4.) It consists of equations, graphing a linear, simultaneous linear and quadratic equation. These aspects form topics in algebra.

This concept, Quadratic equation is an equation expressed as $ax^2+bx+c=0$, where x represents an unknown, and a, b, and c represent known numbers such that "a"$\neq$ 0. If 'a' is equal to zero, it is not quadratic, but in that case, the equation will be linear. The numbers a, b, and c are the coefficients of the equation and can be distinguished by calling them, respectively, the quadratic coefficient, the linear coefficient and the constant or free term. It can be solved using the factorization method, completing the square method and graphical method. Graphing is taking data and plotting (gives the exact position of a point on a coordinate grid) with the coordinates to form points on ordered axes (that is one variable as the x-axis and the y-axis as another variable) which are all done in a graph board. The graph board is a board where an ordered pair of a set of vertices jointly with a set of edges that joins these vertices is drawn. But, when there is no graph board for the teachers to use to aid the learning process, the teachers automatically make do with the conventional method. The conventional method of teaching referred to teacher-centred style whereby the method of learning and, the setting of the classroom/instructions are completely done by the teachers. The teachers transferred knowledge to students through memorization and recitation technique. This has been known to negatively affect the learning process and thereby leading to poor performances of students. This study is concerned with diagnosing students' misconceptions when solving quadratic equations by the graphic method and the possible ways to remediate the identified misconceptions using graph board to improve or correct the incorrect understanding of the concept.

Diagnosis is the state of knowing infection, uncertainty, otherwise difficulty with logical scrutiny of the past or background, assessment of the symptoms/signs, the evaluation of research or of the research results and research on the likely causes. It is the act of identifying problems by observing misconceptions.

James, Taiwo and Ahmed (2015) [16] opined that diagnosing is a process of identifying problems encountered by students in learning Mathematics. It involves recognizing students' unexpected challenges and, remedial measures are developed based on the acquired knowledge to conquer these challenges (misconceptions).

Misconception is saying a different thing from the actual meaning. Paul (2008) [21] stated that misconceptions are not the same as mistakes. Anyone can make mistakes in Mathematics. It can happen when the basic work is absolutely understood, but due to lack of care. Misconceptions are often intelligent generalizations from previous learning. Wrong answers due to misconceptions can be observed and likely repeat itself again. It leads to an incorrect understanding of Mathematics. It is also conscious and systematic errors. In addition, George and Charles-Ogan (2015) [9] are of the opinion that students' misconceptions in Mathematics give rise to errors. Error in Mathematics is a deviation from the accepted and recognized standard of solving problems in Mathematics. Also, George and Charles-Ogan (2015) [9] emphasized that students misconceptions and errors must not be overlooked, but should be remediated appropriately by classroom teachers because misconception accounts for poor performances of students in Mathematics. On that note, the following questions should be considered. Does equivalence show in the misconceptions of students with respect to gender? Does the gender of a student play a significant role in the misconceptions of a concept (like quadratic equations using the graphical method)? Again, do the students encounter misconceptions in the process of learning, given the setting of the school (public or private) and how it is run? These are issues that need to be looked into and possibly corrected to avoid misconceptions. Therefore, there is a need for remediation of students' misconception.

Remediation is the correct action taken to help a circumstance. It is the process of using remedial lessons for those not meeting up with respect to a concept. James and Folorunso (2012) [15] opined that remediation is intended to remove learners' errors, either separately or as a set. However, there are 4 key concepts when solving quadratic expressions using graphical method which are: table of values (substitution, rules of signs), choosing scales/graduating the axes, plotting of graphs/joining of points, and readings graphs/solving related problems using the graphs. When students do not fully comprehend the above concepts, it leads to misconceptions which resulted in poor performance.

Hence, the need for diagnosis and remediation of misconceptions of students in quadratic equations using the graphical method, and should be implemented for outstanding performance in Mathematics.

Statement of the Problem

The analysis was carried out which suggested that many senior secondary Mathematics students did not even acquire instrumental competency (that is, the body of knowledge) with respect to quadratic equations (Muhammad, 2017) [18]. Also, it has been observed from previous works done that most students have misconceptions when answering quadratic equations by factorization method, method of completing the square and most especially with the graphical method. Likewise, in our first-semester assessment, we were sent to carry out an error analysis using 2017 WAEC scripts (Port-Harcourt centre), the researcher observed that majority of the students could not attempt the quadratic equations using the graphical method, and even the students who did attempt the questions did not answer the questions correctly. Graphical representations are vital in comprehending intricate standard systems like quadratic equations and modeling. Students are not meeting up to expectations due to lack of understanding of concepts due to misconceptions which includes quadratic expressions using the graphical method. It is the preconceived ideas held by students which are wrong and likely the procedural steps of teaching them that resulted in the misunderstanding of concepts. Diagnosing these misconceptions and implementing them can increase the students' performances. Hence to overcome these misconceptions, the study deemed it necessary to diagnose and remediate students' misconceptions in quadratic equations by graphical method.

Aim and Objectives of the Study

The aim of the study was to diagnose and remediate students' misconceptions in quadratic equations using the graphical method in Yenagoa LGA, Bayelsa State. Specifically, the objectives of the study are to:

1. Diagnose the areas of students' misconceptions in solving quadratic equations using the graphical method.
2. Remediate students' misconceptions in solving quadratic equations by graphical method using its key concepts with graph board and conventional method on SS2 students' performances in public and private schools.
3. Ascertain the differential effects of the key concepts with the graph board on the performance of male and female SS2 students taught quadratic equations using the graphical method in public and private schools.

Research Questions

The following research questions were raised and answered in the study:

1. What are the areas of students' misconceptions in solving quadratic equations using the graphical method?
2. How effective is the remediation of quadratic equations by graphical method using its key concepts with graph board and conventional method on SS2 students' performances in public and private schools?
3. What differential effects do the key concepts with graph board on the performance of male and female SS2 students taught quadratic equations using the graphical method in public and private schools?

Hypotheses

Two null hypotheses were formulated to guide the study at 0.05 level of significance:

1. There is no significant difference on the effectiveness of the remediation of quadratic equations by a graphical method using its key concepts with graph board and conventional method on SS2 students' performances in public and private schools.
2. There is no significant difference effects' using its key concepts with graph board on the performance of male and female SS2 students taught quadratic equations using the graphical method in public and private schools.

Methodology

The study adopted a quasi-experimental design of non-randomized control group, pretest-posttest design. The

population of the study comprised of all the SS2 students in Yenagoa Local Government Area of Bayelsa state. The sample for this study consists of one hundred and twenty-three (69 males and 54 females) students which were drawn from four (4) schools using Purposive sampling technique. The researcher developed one instrument for the study known as the "Performance Test on Quadratic Equations Using Graphical Method (PTQEGM)".The PTQEGM consists of ten (10) objective questions with 4 options A-D and two (2) theory questions which were constructed from past WAEC questions. Each objective question is 5marks with a total of 50 marks and each theory question is 25marks with a total of 50marks. The total marks of 100% for the PTQEGM. The validation of the instrument PTQEGM was done by the researcher's supervisors, as well as an expert in Measurement and Evaluation. The split-half reliability test using Spearman-Brown Correlation was used to compute the reliability coefficient index of Performance Test on Quadratic Equations using Graphical Method (PTQEGM). The reliability coefficient index of PTQEGM was 0.86. Frequency count, percentage, mean, standard deviation and ANCOVA were the statistical tools used for analyzing the data.

Result

The results of the data analyzed were presented according to the serial order of stated research questions and hypotheses. The data is presented in a tabular form and responses of the students were analyzed.

Research Question 1: What are the areas of students' misconceptions in solving quadratic equations using graphical method?

Table 1: Analysis of Areas of Students' Misconceptions in Solving Quadratic Equations Using Graphical Method

S/N	Key Concepts	No. of SS2 Students			Mean ($\bar{X}$)	Sd	Decision
		With Misconceptions	Without Misconceptions	Total			
A.	**Table of Values**						
1.	Inequalities	104(84.6%)	19(15.4%)	123	1.15	0.36	Misconception
2.	Substitution	102(82.9%)	21(17.1%)	123	1.17	0.38	Misconception
3.	Power of numbers	113(91.9%)	10(8.1%)	123	1.08	0.27	Misconception
4.	Removing brackets	104(84.6%)	19(15.4%)	123	1.15	0.36	Misconception
5	Rules of signs	120(97.6%)	3(2.4%)	123	1.02	0.15	Misconception
B.	**Choosing scale/graduating the axes**						
6.	Measuration	120(97.6%)	3(2.4%)	123	1.02	0.15	Misconception
7.	Graduate the axes	102(82.9%)	21(17.1%)	123	1.17	0.38	Misconception
C.	**Plotting of graph/joining points**						
8.	Co-ordinates of table of values	82(66.7%)	41(33.3%)	123	1.33	0.47	Misconception
9.	Plotting graph	106(86.2%)	17(13.8%)	123	1.14	0.35	Misconception
10.	Joining co-ordinates of points	95(77.2%)	28(22.8%)	123	1.23	0.42	Misconception
D.	**Reading Graphs/Solving related problems**						
11.	Roots/truth set/solution of quadratic equation	83(67.5%)	40(32.5%)	123	1.33	0.47	Misconception
12	Derive roots of equation by factorization	102(82.9%)	21(17.1%)	123	1.17	0.38	Misconception
13.	Deduction of x from a given quadratic equation	117(95.1%)	6(4.9%)	123	1.05	0.22	Misconception
14.	To find the values of x when y is given	106(86.2%)	17(13.8%)	123	1.14	0.35	Misconception
15.	To find the value of y when x is given	108(87.8%)	15(12.2%)	123	1.12	0.33	Misconception
16.	Range of values of x for which quadratic equation is positive, negative and less than zero	105(85.4%)	18(14.6%)	123	1.15	0.36	Misconception
17.	Estimate the co-ordinates of the minimum point of y	93(75.6%)	30(24.4%)	123	1.24	0.43	Misconception
18.	Find minimum and maximum values of y	78(63.4%)	45(36.6%)	123	1.37	0.48	Misconception
19.	Line of symmetry of the graph	88(71.5%)	35(28.5%)	123	1.28	0.45	Misconception
20.	Gradient of a curve	97(78.9%)	26(21.1%)	123	1.21	0.41	Misconception

Table 1 shows the analysis of areas of students' misconceptions in solving quadratic equations using graphical method. Students were graded 2 points as correct answer and 1point as an incorrect answer.

$$\text{Mean } (\bar{X}) = \frac{\Sigma fx}{\Sigma f} = \frac{2+1}{2} = \frac{3}{2} = 1.5$$

Note: The area with a mean ($\bar{X}$) < 1.5 reveal students' misconceptions and the area with mean ($\bar{X}$) ≥1.5 show students without misconceptions. The areas of students' misconceptions in solving quadratic equations using graphical method are all below the rating mean viz: table of values (inequalities, substitutions, power of numbers, removing brackets and rule of signs), choosing scales/graduating the axes (mensuration, graduate the axes - multiplication tables), plotting of graphs/joining points (coordinates of numbers, plotting graphs, joining co-ordinates of points), and reading graphs/solving related problem (root/truth set/solution of quadratic equation, derive roots of equation by factorization, deduction of x from a given quadratic equation, to find the values of x when y is given, to find the value of y when x is given, range of values of x for which quadratic equation is positive, negative and less than zero, estimate the co-ordinates of the minimum point of y, find minimum and maximum values of y, line of symmetry of the graph and gradient of curve).

Research Question 2: How effective is the remediation of quadratic equations by graphical method using its key concepts with graph board and conventional method on SS2 students' performances in public and private schools?

Table 2: Analysis of remediation using Graph board and Conventional method on SS2 students' mean performances and standard deviation in public and private schools

Schools	Groups	N	Pre-PTQEGM		Post-PTQEGM		Mean Gain
			Mean	SD	Mean	SD	
Public	Experimental	48	15.0	7.9	22.8	10.1	7.8
	Control	55	13.5	8.1	19.1	9.2	5.6
	Mean difference		1.5		3.7		
Private	Experimental	11	26.6	9.8	37.9	16.4	11.3
	Control	9	26.2	14.7	33.8	21.1	7.6
	Mean difference		0.4		4.1		

The experimental and control groups of private schools had a post – PTQEGM mean of 37.9 and 33.8 respectively which shows that the control group performed less than the experimental group. Likewise, the public schools revealed that the experimental group with post – PTQEGM mean of 22.8 performed better than the control group with post – PTQEGM mean of 19.1.

Research Question 3: What differential effects do the key concepts with the graph board on the performance of male and female SS2 students taught quadratic equations using the graphical method in public and private schools?

Table 3: Analysis of remediation using Graph board on male and female SS2 students' mean performances and standard deviation in public and private schools

Schools	Groups	Gender	N	Pre-PTQEGM		Post-PTQEGM		Mean Gain
				Mean	SD	Mean	SD	
Public	Experimental	Male	26	13.9	6.4	21.9	11.1	8.0
		Female	22	16.4	9.4	23.9	9.0	7.5
	Mean difference			-2.5		-2.0		
Private	Experimental	Male	4	29.0	14.0	38.0	18.5	9.0
		Female	7	25.3	7.5	37.9	16.6	12.6
	Mean difference			3.7		0.1		

The private school had a post-PTQEGM mean of 38.0 (male) and 37.9 (female) of the experimental group, while the public school had a post- PTQEGM mean of 21.9 (male) and 23.9 (female) of the experimental group. The mean difference from the private school of male and female students indicates a slight difference, while that of public school shows that female students have a better performance than the male students.

Hypothesis 1: There is no significant difference on the effectiveness of the remediation of quadratic equations by the graphical method using its key concepts with graph board and conventional method on SS2 students' performances in public and private schools.

Table 4: Summary of ANCOVA of SS2 students taught with the use of key concepts of quadratic equations using the graphical method with graph board and the conventional method.

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	4663.162[a]	2	2331.581	18.288	.000
Intercept	6218.289	1	6218.289	48.773	.000
PREPTQEGM	4057.894	1	4057.894	31.828	.000
GROUP	329.330	1	329.330	2.583	.111
Error	15299.330	120	127.494		
Total	86882.500	123			
Corrected Total	19962.492	122			

*Significant (P < 0.05) and *not significant (P > 0.05)

The table 4 reveals that F (1, 120) = 2.583 with p =0.111, P > 0.05. The hypothesis one is retained because there is no significant difference between the students taught with the use of key concepts of quadratic equations using the graphical method with graph board and the conventional method.

Hypothesis 2: There is no significant difference effects' using its key concepts with graph board on the performance of male and female SS2 students taught quadratic equations using the graphical method in public and private schools.

Table 5: Summary of ANCOVA of mean performance scores of the male and female SS2 students taught quadratic equations by the graphical method using its key concepts with graph board.

Source	Type III Sum of Squares	Df	Mean Square	F	Sig.
Corrected Model	2078.940[a]	2	1039.470	7.788	.001
Intercept	2952.267	1	2952.267	22.120	.000
PREPTQEGM	1925.492	1	1925.492	14.427	.000
Gender	36.199	1	36.199	.271	.605
Error	7473.976	56	133.464		
Total	48326.750	59			
Corrected Total	9552.915	58			

*Significant (P < 0.05) and *not significant (P > 0.05)

The table 5 shows that F (1, 56) = 0.271 with p = 0.605, p > 0.05. Hypothesis two is retained for there is no significant difference between the male and female students taught quadratic equations by the graphical method using its key concepts with graph board.

Discussion of Findings

The result in table 1 showed the areas of students' misconceptions in solving quadratic equations using the graphical method. The areas based on the key concepts include table of values (inequalities, substitution, power of numbers, removing brackets and rules of signs), choosing scales/graduating the axes (mensuration, graduating the axes – multiplication table), plotting of graphs/joining points (coordinates of numbers, plotting graphs, joining of coordinate points) and reading graphs/solving related problems (root/truth set/solution of quadratic equations, derive root of equation by factorization, deduction of x from a given quadratic equation, to find the values of x when y is given, to find the values of y when x is given, range of values of x for which quadratic equation is positive, negative and less than zero, estimate the co-ordinates of the minimum point of y, find minimum/maximum values of y, line of symmetry of the graph, gradient of a curve). The finding is in agreement with Sam-Kayode and Salmon (2015) [22] who found out the misconceptions in many concepts and sub-concepts of geometry.

The lower order concepts of the key concepts of quadratic equations from table 1 showed that students have misconceptions within the range of 1.0 – 1.4, that is below 1.5. Based on the lack of understanding of lower order concepts, the key concepts of quadratic equations will be difficult to comprehend. Makonye and Maturu (2016) [17] opined that learners lack algebraic competency which encumbered their solutions to quadratic equations. Also, Gunawardena (2011) [10] reveals the number of error categories under each area of algebra. The present finding supports Ifamuyiwa (2014) [12], Oduah (2017) [19] and, Wonu and Zalmon (2017) [27] who looked at the topics that are difficult for students to learn. Hence, diagnosing the areas of students' misconceptions in solving quadratic equations using graphical methods will expose where Mathematics teachers need to do more work.

Table 2 showed the post-PTQEGM mean of the experimental groups of both private and public schools to be 37.9 and 22.8 respectively, while that of the control groups are 33.8 and 19.1. The mean gains for experimental groups are 11.3 and 7.8 and, control groups are 7.6 and 5.6 respectively. This implies that the experimental groups performed better than the control groups with the use of a graph board and the key concepts of quadratic equations. Iji, Abakpa and Takor (2015) [13], George and Charles Ogan (2015) [9], Beresibo (2016) [5], Yasha'u and Musa (2012) [28], Amadi and Charles Ogan (2015) [2], Usman and Musa (2015) [26], Galadima and Okogbenin (2012) [8], Ugwuanyi (2016) [24], Issau, Salman and Tiamiyu (2017) [14] and Egbe (2017) [6] supported the present study that the use of manipulatives, strategies and key concepts to teach will increase academic performance and minimized misconceptions. Though, table 4 revealed that there is no significant difference between the experimental and control groups based on the timeframe of researchers to carry out their work. This implies that when teachers put in more time to tackle/remediate the key concepts of quadratic equations using graphical method depending on the extent of the difficulties/misconceptions of students, certainly, there will be a maximum improvement.

The result revealed from Table 3 that male students perform better than the female students in the public schools with the gain mean of 8.0 as against 7.5 of the female. While the female students perform better than the male students in the private school with the gain mean of 12.6 against 9.0 of the male. The hypothesis result from table 5 showed that there is no significant difference between the male and female students taught with the key concepts of quadratic equations by the graphical method using graph board.($F(1,56) = 0.271$, $p > 0.05$). The null hypothesis was retained at 0.05 level of significance. The present study statistically is in line with Adaramola (2012) [1], Idris (2015) [11], Onwuka (2015), Galadima and Okogbenin (2012) [8], Beresibo (2016) [5], Attah and Guwam (2015) [4], Iji, Abakpa and Takor (2015) [13], Ifamuyiwa (2014) [12], and Ugwuanyi (2016) [24], Tiamiyu, Salmon and Issau (2017) [23], and Egbe (2017) [6], who found out that there is no significant difference between male and female students. Also, from the table 3, male students perform better than female students in the public schools which is in agreement with Anyor and Iji (2014) [3], Usman and Musa (2015) [26], and George and Charles–Ogan (2015) [9] that supported the claim. The divergent in results between the performance of male and female students may be due to some factor like interest, organizers of schools, sample size, the content of assessment against materials taught, class size.

Conclusion

The study confirmed the areas of students' misconceptions when solving quadratic equations using the graphical method. Also, as regards to gender, the appropriate measures of great efforts/inputs from the teacher in respect to the teaching of lower-order concepts of the key concepts will minimize misconceptions.

Recommendations

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

1. Students and teachers should be familiar with the lower-order concepts of the key concepts of a quadratic equation using graphical method for effective performance.
2. Mathematics teachers should diagnose students' misconceptions and lay more emphasis on those areas when teaching to minimize misconceptions which lead to errors.

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