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IMPACT OF REALISTIC MATHEMATICS EDUCATION AND MATHEMATICAL MODELLING APPROACHES ON GEOMETRIC ACHIEVEMENT AND ATTITUDE AMONG SENIOR SECONDARY SCHOOL STUDENTS IN NORTH CENTRAL, NIGERIA

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Abstract

This study investigates the Impact of Realistic Mathematics Education (RME) and Mathematical Modelling (MM) approaches on geometric achievement and attitudes among senior secondary school students in North Central, Nigeria. A pretest and posttest control group factorial design were employed. four research questions were answered, and four hypotheses were tested in this study. The population of the study was made up of eight hundred and nineteen thousand nine hundred and eight (146,412) students in the Senior Secondary schools in North Central. Cluster sampling, purposive sampling and random sampling were used to select 361 students from twelve co-educational secondary schools in the North Central States of Nigeria that participated in the study. The schools were assigned to experimental groups; I, (RME), experimental group II (MM) and Control Group (Lecture Method). A Geometry Achievement Test (GAT) containing 20 – questions covering topics in Plane and Circle Geometry was used to collect data for both pre-tests and post-test while Mathematics Attitude Questionnaire (MAQ) was used for collecting data on attitude of students towards Geometry, experts validated the instruments. A Pearson product moment correlation and Crombach alpha formula were used to determine the reliability coefficient of GAT and MAQ which yielded 0.80 and 0.87 respectively, establishing the robustness of these instruments. The data were analyzed using descriptive statistics (mean and standard deviation), inferential statistics, analysis of variance (ANOVA), Analysis of Covariance (ANCOVA) and Scheff post hoc test was used. The hypotheses were tested at 0.05 level of significance. Results indicate significant differences in mean achievement scores among students taught Geometry using RME, MM approaches, and conventional lectures. In addition, both RME and MM approaches contribute to improved attitudes towards Geometry.Furthermore, an interaction effect between Realistic Mathematics Education, Mathematical Modelling approach, and conventional lecture methods on Students Geometry Achievement was observed. These findings have notable implications for the evolution of curricula and the enhancement of instructional strategies in mathematics education. The study provides valuable insights for educators seeking to improve geometry learning experiences and outcomes by employing effective instructional approaches.

Keywords; *Impact, Attitude, Achievement, Mathematical Modelling, Mathematics representation, Realistic Mathematics Education*

1.0 INTRODUCTION

1.1 Background to the Study

Science, Technology, and Mathematics Education (STME) are regarded as key indicators of a nation's socio-economic and geopolitical development. Studies have shown the significant impact of STME on countries like China, which has become a major economic power due to its emphasis on scientific and technological development. In Nigeria, the National Policy on Education and curriculum reforms have underscored the importance of Mathematics as a compulsory subject in basic education, reflecting its vital role in contemporary society.

Despite the importance of Mathematics, student performance in Senior Secondary School examinations remains discouraging. Various studies have consistently reported low achievement levels among Nigerian students in secondary school Mathematics. This trend has raised concerns about the future of Mathematics Education in the country.

To address this issue, new teaching methodologies have been introduced, including Realistic Mathematics Education (RME). RME, developed in the Netherlands, emphasizes math as a human activity connected to real-life situations. It aims to make math learning enjoyable and meaningful by using real-world contexts as a starting point for learning. RME involves problem-solving, discussions, and rational solution development, helping students understand mathematical concepts in practical contexts. This approach is believed to improve students' mathematical representation and problem-solving skills.

Mathematical modeling is another approach that makes math relevant by representing real-world problems mathematically. It helps students understand and solve real-life issues, particularly in areas like geometry. Modeling is seen as a central aspect of successful math teaching and learning, fostering a "culture of mathematizing" in schools.

These teaching approaches align with constructivist learning theory, which emphasizes the role of experiences and connections in student education. Constructivism suggests that students construct knowledge based on their experiences, and teachers should create problem-solving environments where students can construct their own knowledge.

The study aims to investigate the Impact of Realistic Mathematics Education and Mathematical Modeling on senior secondary students' achievement and attitudes toward Geometry in North Central Nigeria. It seeks to understand how these teaching approaches

impact students in a specific geographical context and differs in scope, content, sample size, data collection, and analysis from previous studies in the field.

1.3 Purpose of the Study

The purpose of this study is to determine the Impact of Realistic Mathematics Education and Mathematical Modelling Approaches on Senior Secondary School Students' Achievement and Attitudes towards Geometry in North Central, Nigeria. Specifically, the study will be carried out to achieve the following objectives;

1. determine the main Impact of Realistic mathematics Education, Mathematical Modelling approaches and conventional lecture method on the student's geometry Achievement;
2. determine the attitude of students towards geometry when taught using Realistic mathematics education approach;
3. determine the attitude of students towards Geometry when taught using Mathematical Modelling approach;
4. determine the interaction effects of Realistic mathematics Education, Mathematical Modelling approach, conventional lecture method and Gender Geometry Achievement.

1.4 Research Questions

The following research questions were raised for the study.

1. What are the main Impact of Realistic mathematics Education, Mathematical Modelling approach and conventional lecture method on the student's Geometry Achievement?
2. What is the difference in the mean attitude of students towards Geometry before and after when taught using Realistic mathematics education approach?
3. What is the difference in the mean attitude of students towards Geometry before and after when taught using Mathematical Modelling approach?
4. Is there any interaction effects of Realistic mathematics Education, Mathematical Modelling approach, conventional lecture method and Gender Geometry Achievement?

1.5 Research Hypotheses

The following null hypotheses were formulated and will be tested at 0.05 alpha level of significance.

HO_1: There is no significant difference of Realistic Mathematics Education, Mathematical Modelling approach and conventional lecture method on the students' Geometry Achievement.

HO_2: There is no significant difference in the mean attitude scores of students towards Geometry before and after being taught using Realistic Mathematics Education approach.

HO_3: There is no significant difference in the mean attitude scores of students towards Geometry before and after being taught using Mathematical Modelling approach

HO_4: There is no significant interaction effect between Realistic mathematics Education, Mathematical Modelling approach, conventional lecture method and Gender Geometry Achievement.

METHODOLOGY

The study employed a pretest and posttest control group factorial design, utilizing a three by two (3 × 2) factorial design. This design involved three treatment levels (Realistic Mathematics Education (RME) and Mathematical Modelling (MM)) and two levels of gender (Male and Female) to test the study's hypotheses. The target population consisted of Senior Secondary school students in North Central Nigeria for the 2021/2022 academic session, with a total population of 146,412 senior secondary school Mathematics students in SSII. The selection of SSII was based on the focus of the study on challenging Mathematics concepts within the SSII syllabus. The sample for the study included 361 Mathematics students from 12 co-educational public senior secondary schools in the North-Central Geopolitical Zone of Nigeria. These schools were selected using purposive sampling based on similar environmental conditions, including manpower, gender composition, and school type (public schools). Within each sampled school, an intact class of SS 2 was randomly selected from each arm, resulting in three groups: experimental group I (107 students), experimental group II (126 students), and a control group (128 students). Data collection instruments included the Geometry Achievement Test (GAT) and the Mathematics Attitude Questionnaire (MAQ). GAT comprised 20 subjective items with a total score of 100 marks, covering plane and circle geometry content. MAQ was used to assess students' attitudes toward geometry and consisted of two parts: part one collected student bio-data, while part two included 50 items assessed on a 5-point Likert scale. The items covered four subscales: personal confidence in the subject matter, the usefulness of the subject's content, perception of the subject as a male domain, and perception of teachers' attitude. Scoring for positive and negative items differed, with positive items scored SA = 5, A = 4, U = 3, D = 2, and SD = 1, while negative items were scored SA = 1, A = 2, U = 3, D = 4, and SD = 5. The instruments underwent face, construct, and content validation by specialists in the field of Pure Mathematics and Science Education. Reliability analysis yielded a coefficient of 0.80 for GAT and 0.87 for MAQ. Data collection occurred in two stages: the first stage involved training mathematics teachers and administering pretests, while the second stage involved four weeks of exposing the experimental group to RME and MM activities using treatment instruments (worksheets), while the control group received traditional lectures. Posttests

were administered to both groups to assess their achievement in mathematical RME and MM. Data analysis was conducted using mean and standard deviation for research questions and dependent t-tests and ANCOVA statistics for hypothesis testing, with a significance level of 0.05.

RESULTS

Research Question One

What are the Impact of Realistic mathematics Education, Mathematical Modelling approach and conventional lecture method on the student's Geometry Achievement?

Table 1: Mean and Standard Deviation of Pre-test and Post-test achievement Scores of Experimental Group I, II and the Control Group

Group	N	Pretest $\bar{X}$	SD	Post-test $\bar{X}$	SD	Mean difference
Experimental Group I	128	32.69	12.93	83.39	8.97	50.70
Experimental Group II	107	38.23	10.77	79.60	8.21	41.37
Control Group	126	38.11	12.35	66.51	15.23	28.40

Table 1 shows the mean and standard deviation achievement scores of experimental groups I, experimental group II and control groups at pre-test and post-test. From the result, it can be deduced that the mean and standard deviation scores at pre-test and post-test for Experimental Group I (RME) as = 32 .69, SD= 12.93 and $\bar{X}$= 83.39, SD= 8.97 respectively. This gives the mean difference of 50.93 in favour of post-test. Similarly, the mean and standard deviation scores at pre-test and post-test for Experimental Group II (MM) are $\bar{X}$= 38.23, SD= 10.77 and $\bar{X}$= 79.60, SD= 8.21 respectively. This gives the mean difference of 41.37 in favour of post-test. On the other hand, the mean and standard deviation scores at pre-test and post-test for the Control Group (lecture methods) are $\bar{X}$= 38.11, SD= 12.35 and $\bar{X}$= 66.51, SD= 15.23 respectively. This gives the mean difference of 28.40 in favour of post-test. The table also reveals that Experimental Group I, II and control group had a mean difference of 50.93, 41.37 and 15.23 respectively and with experimental group I having the highest mean gain of 50.93. As a result of this identified difference in mean achievement scores, hypothesis I was tested at 0.05 level to determine if the observed difference was significant. To determine if the difference is significant, ANCOVA was used as presented in Table 3.

Research Question Two

What is the difference in the mean attitude of students towards Geometry when taught using Realistic mathematics education approach?

Table 2: Mean and Standard Deviation of Experimental Group 1 students' attitude towards Geometry.

Groups	N	Mean	S. D	Mean difference
Before	128	67.09	12.72	15.99
After	128	83.08	14.01	

Table 2 reveals that experimental group 1 has (Mean = 67.09 and S. D= 12.72.); at pre-test while at post- test experimental group 1 has (Mean = 83.08 and S. D= 14.01). This indicates that students had better attitude towards Geometry when exposed to Realistic Mathematics Education approach than before they were exposed to Realistic Mathematics Education with a mean difference of 15.99. To determine if the difference in the attitude is significant, ANOVA was used as presented in Table 4

Research Question Three

What is the difference in the mean attitude of students towards Geometry before and after when taught Geometry using Mathematical Modelling approach?

Table 3: Mean and Standard Deviation of Experimental Group 2 students' attitude towards Geometry.

Groups	N	Mean	S. D	Mean Difference
Before	107	61.35	7.73	15.16
After	107	76.51	6.64	

Table 3 reveals that experimental group 2 has (Mean = 61.35 and S. D= 7.73.); at pre-test while at post- test it has (Mean = 76.51 and S. D= 6.64). This indicates that students had better attitude towards Geometry when exposed to Mathematical Modelling approach than before they were exposed to Mathematical modelling with a mean difference of 15.16. To determine if the difference in the attitude is significant, Dependent sample t-test was used as presented in Table 5

Research Question Four

Is there any interaction effects of Realistic mathematics Education, Mathematical Modelling approach and conventional lecture method on the students' Geometry Achievement?

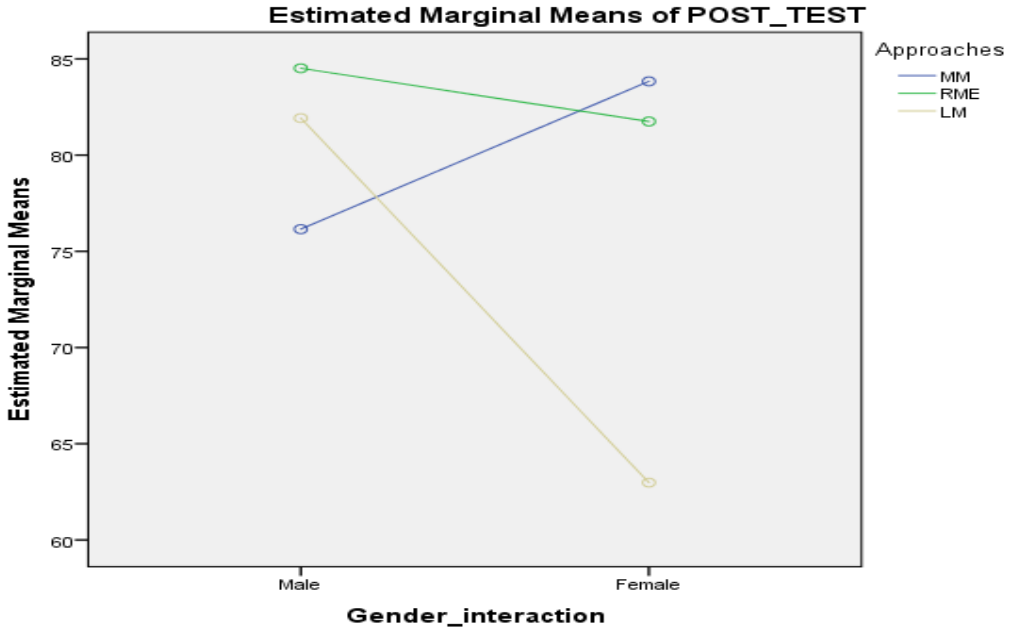
Table 4:Mean and Standard Deviation of Experimental Group I, Experimental Group II and Control Group Geometry Achievement.

Items	**N**	**Mean**	**Std. Deviation**

MM	107	79.60	8.974
RME	128	83.39	8.213
LM	126	66.89	15.232

Table 4 shows the Experimental Group I (RME) with $\bar{X}$= 83.39, SD= 8.213, Experimental Group II (MM) has $\bar{X}$= 79.60, SD= 8.21 respectively and Control Group (lecture methods) has $\bar{X}$= 66.51, SD= 15.23 respectively. The table also reveals that Experimental Group I had a higher mean of 83.39, follow by Experimental Group II with 79.60 and control group had a mean of 66.89 respectively. As a result of this identified difference in mean achievement scores, hypothesis 12 was tested at 0.05 level to determine if there are interaction effects among the three approaches in order to observed if interaction effects were significant. Figure1 shows the Interaction effect three approaches to learning geometry.

Figure 4.2 Interaction effect of gender and three approaches to learning geometry



Hypotheses One

There is no significant difference between the mean achievement scores of senior secondary school students towards Geometry when taught using Realistic Mathematics Education, Mathematical Modelling approaches and conventional lecture.

Table 5: Summary of Analysis of Covariance (ANCOVA) Scores of Experimental groups and control group

Source	Type III Sum of Squares	Df	Mean Square	F	P
Corrected Model	18753.327[a]	3	6251.109	48.416	.000
Intercept	207708.592	1	207708.592	1608.750	.000
Covariate	9.727	1	9.727	.075	.784
Treatment	18459.443	2	9229.721	71.486	.000

Error	46092.906	357	129.112
Total	2177891.000	361	
Corrected Total	64846.233	360	

*: Significant at P < 0.05

Table 5 showed the ANCOVA result of the comparison of posttest scores of students in Experimental groups and the control group. An examination of the table shows (F (2, 360) = 9229.721, P < 0.05). On this basis, hypothesis one was rejected. Therefore, there was significant difference between students' Geometry Achievement when taught using Realistic Mathematics Education, Mathematical Modelling approach than those taught using conventional lecture. Scheffe post- hoc test was carried out to find out where the differences lie as shown in table 3(a).

Table 6: Scheffe Post-hoc Analysis of Mean score of students in Experimental groups and control group

Treatment	Experimental I (RME)	Experimental II (MM)	Control (LM)
Experimental I (RME)	-	3.79*	16.50*
Experimental II (MM)	-3.79*	-	12.71*
Control (LM)	-16.50*	-12.71*	-

*: Significant at P < 0.05

Table 6 showed the Scheffe post- hoc analysis of mean score of students in Experimental groups and control group. The table indicate that significant difference exists between RME vs MM, RME vs LM, MM vs LM and LM vs MM with mean difference of 3.79, 16.50 and 12.71 respectively indicating those taught using RME and MM had a higher mean score when taught Geometry than those taught using LM.

Hypotheses two

There is no significant difference in the mean attitude scores of students towards Geometry before and after taught using Realistic Mathematics Education approach.

Table 7: Summary of Dependent t-test Analysis of students' attitude towards Geometry when taught using RME approach

Groups	N	Mean (x)	SD	Df	t	P	Remark
Before	128	67.09	12.72	127	8.821	0.000	Significant
After	128	83.08	14.01				

Table 7shows the analysis of dependent sample t-test of mean attitude scores of students towardsGeometry before and after exposure to Realistic Mathematics Education Approach. It reveals that the calculated t–value = 8.821, df = 127, p = 0.000 indicating P < 0.05. Hence, Hypothesis two was rejected. This mean, there was significant difference in the mean attitude scores of students taught Geometry before and after exposure to Realistic Mathematics Education.

Hypotheses Three

There is no significant difference in the mean attitude scores of students towards Geometry before and after taught using Realistic Mathematics Education approach.

Table 8: Summary of Dependent t-test Analysis of students' attitude towards Geometry when taught using MM approach

Groups	N	Mean (x)	SD	Df	t	P	Remark
Before	107	61.35	7.73	106	14.641	0.000	Significant
After	107	76.51	6.64				

Table 8shows the analysis of dependent sample t-test of mean attitude scores of students towardsGeometry before and after exposure to Mathematical Modelling Approach. It reveals that the calculated t–value = 14.641, df = 106, p = 0.000 indicating P < 0.05. Hence, Hypothesis three was rejected. This mean, there was significant difference in the mean attitude scores of students taught Geometry before and after exposure to Mathematical modeling.

Hypotheses Four

There is no significant interaction effect between Realistic mathematics Education, Mathematical Modelling approach, conventional lecture method and Gender on the students' Geometry Achievement.

Table 9: Summary of Analysis of Covariance (ANCOVA) showing interaction effect between Realistic mathematics Education, Mathematical Modelling approach and conventional lecture method on the students' Geometry Achievement.

Source	Type III Sum of Squares	Df	Mean Square	F	P	Partial Eta Squared
Corrected Model	27945.396[a]	5	5589.079	53.769	.000	.431
Intercept	1871190.095	1	1871190.095	18001.556	.000	.981
Approaches	5734.044	2	2867.022	27.582	.000	.134
Gender	1658.169	1	1658.169	15.952	.000	.043
CODESA * Gender	8246.635	2	4123.318	39.668	.000	.183
Error	36900.837	355	103.946			

Total	2177891.000	361
Corrected Total	64846.233	360

*: Significant at P < 0.05

Table 9 shows the summary of ANCOVA (F(2,361) = 39.67, p = 0.000 with partial eta squared of 0.183. Thus, Null hypothesis 4 was rejected. Hence, there is enough evidence to support the claim that there was an interaction effect between Realistic mathematics Education, Mathematical Modelling approach and conventional lecture method on the students' Geometry Achievement when compared to gender. Turkey HSD post- hoc test was carried out to find out where the differences lie as shown in table 10.

Table 10: Summary of Turkey HSD post- hoc test interaction effect between Realistic mathematics Education, Mathematical Modelling approach and conventional lecture method on the students' Geometry Achievement when compared to gender

(I) Approaches	(J) Approaches	Mean Difference (I-J)	P
MM	RME	-3.79*	.013
	LM	12.71*	.000
RME	MM	3.79*	.013
	LM	16.50*	.000
LM	MM	-12.71*	.000
	RME	-16.50*	.000

*: Significant at P < 0.05

Table 10 shows Turkey HSD post-hoc test. It indicates that significant difference exists between RME vs LM, MM vs LM and LM vs MM with mean difference of -3.79, 12.71, 3.79, 16.50, -12.71 and -16.50 respectively indicating there was significant difference in the mean score of those taught using RME vs LM, MM vs LM, LM vs RME and LM vs MM.

DISCUSSION OF THE FINDINGS

The study's results highlight the advantages of utilizing Realistic Mathematics Education (RME) and Mathematical Modeling(MM) approaches in teaching Geometry, demonstrating their superiority over traditional lecture-based methods. RME's hands-on approach immerses students in interactive and practical learning experiences, significantly improving their academic performance. This experiential approach helps students establish meaningful connections between mathematical concepts and real-world scenarios, enhancing their understanding of Geometry concepts. Furthermore, MM complements RME by facilitating personalized support and a constructivist learning style, empowering students to construct their knowledge through problem-solving and critical thinking. This not only deepens their Geometry understanding but also equips them with transferable skills for real-world challenges.An interaction effect was observed between Realistic Mathematics Education, Mathematical Modelling approach, conventional lecture method, and Gender Geometry Achievement.

These findings align with earlier research by Effandi et al. (2017), Zakaria and Syamaun (2017), Nicola (2011), Baskan and Alev (2013), and Sokolowski (2015), all supporting the positive impact of RME and MM on students' mathematics achievement. This collective evidence suggests that these teaching approaches have the potential to revolutionize mathematics education.

Regarding students' attitudes towards Geometry, the study shows a significant improvement in mean attitude scores after being taught using the RME approach. This finding corresponds with Verschaffel et al.'s (2019) research, which also found that RME positively influenced students' attitudes by connecting mathematics to real-world situations. Leung and Wong (2017) found similar positive changes in primary school students' attitudes toward math with RME. However, Henningsen and Stein (2017) found that while RME improved problem-solving skills, it did not consistently change attitude scores, suggesting that attitude change may not always accompany skill improvement.

Concerning the MM approach, there was a significant difference in mean attitude scores before and after instruction, aligning with Blum and Leiss (2020), who found a positive attitude change toward Geometry through MM. Gravemeijer et al. (2017) also emphasized MM's potential in improving attitudes through active participation and inquiry-based learning. However, Chen et al.'s (2017) study provides a counter-perspective, suggesting that the MM approach may not uniformly lead to positive attitude changes in students.

CONCLUSION

Based on the findings of this study, it can be deduced that the use of Realistic Mathematics Education (RME) approach for teaching and learning of secondary schools' Geometry is more effective than Mathematical Modeling (MM) approach and lecture method though both Realistic Mathematics Education (RME) and Mathematical Modeling (MM) approaches has positive effect on students' academic achievement and attitude of students towards geometry. The two approaches improve students Geometry representation and problem-solving skills. Through the use of this approaches in teaching and learning of difficult concepts in Mathematics most especially in Geometry, lessons can be easily delivered to learners in inspiring, understandable and exciting ways. This will undoubtedly positively improve students' achievement and attitude towards geometry. If these approaches are adopted by teachers and students, RME can therefore be used to complement classroom instruction in Mathematics. Consequently, the use of MM could be regarded as one of the veritable approaches for enhancing achievement and attitude of students towards geometry in North Central Nigeria.

RECOMMENDATIONS

Based on the major findings of this study, the following recommendations are proffered as follows:

1. Incorporate targeted activities within Realistic Mathematics Education (RME) and Mathematical Modelling (MM) approaches to specifically enhance students' geometry representation skills. Visual aids, diagrams, and real-world examples should be employed to facilitate understanding.

2. Craft structured problem-solving exercises aligned with the principles of RME and MM. Encourage students to apply mathematical concepts in real-life scenarios, fostering improved problem-solving abilities.

3. Regularly evaluate students' attitudes towards Geometry before and after exposure to the Realistic Mathematics Education approach. This assessment can track attitude improvements and identify areas for further development.

4. Advocate for the incorporation of both Realistic Mathematics Education (RME) and Mathematical Modelling (MM) approaches into the senior secondary school syllabus. These innovative trends have global significance and should be embraced in Nigeria's education system.

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