Sapientia Foundation Journal of Education, Sciences and Gender Studies (SFJESGS), Vol.3 No.2 June, 2021; pg. 352 – 360
ISSN: 2734-2522 (Print); ISSN: 2734-2514 (Online)

EFFECTS OF THE PROBLEM-BASED LEARNING STRATEGY ON THE MATHEMATICAL REASONING OF SENIOR SECONDARY STUDENTS IN GEOMETRY IN KATSINA METROPOLIS, KATSINA STATE NIGERIA

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Abstract

This study investigated the effects of the Problem-Based Learning (PBL) strategy on the Mathematical Reasoning (MR) of senior secondary students in geometry in Katsina Metropolis, katsina State. The pretest-posttest quasi-experimental design was used. Intact classes were used for the study with a sample of 80. Purposive sampling technique was used to select two public co-educational senior secondary schools from the metropolis. One validated instrument: Mathematical Reasoning Inventory (MRI) was used for data collection with reliability index of 0.70. The treatment group was taught using problem-based learning while the control group was taught using the conventional teaching strategy. Mean scores and standard deviation were used to answer two research questions while Analysis of Covariance (ANCOVA) was used to test two hypotheses. The results showed significant differences in the Mathematical Reasoning (MR) mean scores of students taught geometry using Problem-Based Learning (PBL). The study recommended that problem- based learning strategy should be adopted by mathematics teachers for use in classroom instruction because they improve the male and the female students' mathematical reasoning.

Keywords: Effects, PBL strategy, Mathematical Reasoning, Geometry, Senior Secondary Students, Katsina State.

Introduction

There is no nation that has developed or that will ever develop without science technology, and there will not be scientific or technological advancement without mathematics. This is because mathematics is the science of quantity (arithmetic), structure (algebra), space (geometry) and change (calculus) is an indispensable tool for national development (Effiom, 2015). He further stressed that mathematics is indispensable because it has substantial use in all scientific activities. Moseri, Onwuka & Smart (2010), noted that there can be no real development scientifically and technology without the corresponding development in mathematics both conceived and practiced. Mathematics has a pervasive influence on our everyday lives contributes to the wealth of the nation. In recognition of the important mathematics to national development, the Federal Government of Nigeria mathematics a compulsory (core) subject for both primary and secondary school, FRN, (2013).

Accordingly, (Effiom 2016) described Mathematics as a creation of human mind concerned chiefly with ideas, processing and reasoning which is primarily a way of thinking and reasoning. As a way of reasoning, mathematics gives an insight into the power of human mind, which forms a very valuable discipline of teaching and learning. Afolabi,Yusuf & Idowu (2015) defined mathematical reasoning as the line of thought adopted to produce assertions and reach conclusions in solving mathematical task. Niss (2002) identified mathematical reasoning as one of the eight constituents of mathematical competence. The others are: mathematical thinking; posing and solving mathematical problems; mathematical modeling; representing mathematical entities; handling mathematical symbols and formalism; communicating in, with, and about mathematics as well as making use of al tools for mathematical activity. To support Niss's view, Ogunkunle and Charles Ogan (2012), stressed that the increasing number of mathematics educators believe that the internet could be used to assist students to think and work mathematically by improving their willingness and ability to pose questions, seek solutions, solve problems and communicate together applying mathematical ideas.

Odili as cited in Effiom (2015) stated that mathematics is man's most extensive and most profound effort to achieve precise and effective thinking and what it accomplishes measures the capacity of the human mind. He continued that it represents the superb and sublime product of human reasoning and this is the upper limit of what one hopes to attain in all rational domains. Adetula (2012) succinctly revealed that mathematics is not only the language of science; it is the essential nutrient for thought, logic and reasoning. Hence, it is not surprising to discover that the most effective and unparalleled accomplishments of human beings (e.g. electricity, mobile telephone, radio or TV, military arsenals, medical equipment, and even voyages to the sea, moon and other outer planets) are found in his effort to utilize his mathematical reasoning. In so far as making a living is concerned, many shrewd businessmen, boot licking civilians. Sycophantic politicians, aberrant civil servants, and crafty military men have amassed fortune, and sent majority of their fellowmen to slavery and poverty without knowing more than the rudiments of arithmetic.

Literature is replete with works showing the relationship between cooperative and collaborative strategies and achievements with students' attitude. But not much work is done in the area of finding the relationship between problem-based learning strategy and mathematical reasoning. Therefore, the researcher's interest is focused on determining the effect of problem based learning strategy on senior secondary students' mathematical reasoning.

Problem-Based Learning (PBL):

Problem-Based Learning (PBL) is a classroom instructional strategy that organizes mathematics instruction around problem solving activities and affords students more opportunities to discover important concepts. PBL which began over 25 years age has since been implemented in elementary and secondary schools as well as various undergraduate and graduate programs around the world, Padmavathy and Moseri (2013). PBL is described as a learning environment where problems drive the learning. That is, learning begins with a problem to be solved, and the problem i posed in such a way that students need to gain new knowledge before they can solve the problem. Rather than seeking a single correct answer,

students interpret the problem, gather need information, identify possible solutions and evaluate option; and present conclusions.

Emmanuel (2009) outlined four major features of PBL as follows; focusing groups of students on specific problem(s), developing their critical thinking, analytical thinking or high order thinking, promoting team work through group discussion and presentation, and facilitating instruction. Hmelo-Silver (2004) stated that PBL was designed to help students construct an extensive and flexible knowledge base develop effective problem-solving skills, develop self-directed lifelong learning skills, becomes effective collaborators and intrinsically motivated to learn. Padmavathy and Mareesh (2013) revealed that PBL had effect in teaching mathematics and improved male and female students' understanding (cognitive achievement), creative mathematical reasoning and problem solving skills equally PBL was also found to improve student mathematical comprehension level, problem solving and science process skills, Sule and Derya, (2013). Further findings indicate a treatment effect on secondary school student critical reasoning (thinking) ability and content knowledge using PBL, Scott and Bryan, (2007).

Mathematical Reasoning

Azuka (2015) extensively presented an extended; theoretical framework concerning mathematical reasoning. Reasoning is the line of thought adopted to produce assertions and reach conclusions in task solving. It doesn't have to be formal logic, and it may even be incorrect. The choice is to see product that appears in the form of a sequence, starting with a task (example tests etc.) and ends with an answer. For organization of data, a four step reasoning structure is used:

A Problematic Situation (PS) is met where it is not obvious (for the individual) how to proceed. Strategy Choice (SC): try to choose (in a wide sense: recall, construct) that can solve the problematic situation. This could be supported by pi argumentation.

Strategy Implementation (SI) that can be supported by a verifiable argumentation A Conclusion (C) is obtained.

There are two main types of reasoning: imitative and creative reasoning. Rote learning reasoning is an imitative reasoning, and the opposite creative reasoning. Creative Reasoning (CR) is reasoning that is novel, plausible has a mathematical foundation, all of which Imitative Reasoning (IR) does require. Imitative reasoning is a family of different types of superficial reasoning, from a mathematical point of view, with two head categories: memorized and algorithmic reasoning Lithner (2008). He also defined creative reasoning as Creative Mathematically Founded Reasoning (CMFR), if it fulfills the following conditions:

Novelty: A new (to the reasoner) sequence of solution reasoning is created, or a forgotten sequence is re-created. To imitate an answer or a solution procedure is not seen as novel.

Plausibility: There are arguments supporting the strategy choice and/or strategy implementation, motivating why the conclusions are true or plausible. Guesses, vague intuitions and affective reasons are not considered.

Mathematical Foundation: The argumentation is founded on intrinsic mathematical properties of the component involved in the reasoning. Purely experience-based reasons as in keyword strategy are not valid. Intrinsic is considered being central (in comparison to surface properties which have no or little relevance). Mathematical is what is accepted by the mathematical society as being correct. Property is part of a component: objects (fundamental entity, e.g. numbers, functions, graphs); transformations (operations on an object, e.g. calculate a determinant); and concepts (central mathematical idea built on a related set of objects, transformations and their properties, e.g. concept of infinity). Creative mathematical reasoning is not restricted to people with an exceptional ability in mathematics, but might be difficult to produce without sufficient key competencies and a supporting environment. Imitative reasoning can be thought of as highly productive in the sense that you can solve lots of task in a short amount of time as long as you have the correct algorithms required for problematic situations where the imitative reasoning can no longer from a mathematical standpoint. Nevertheless, according to upper secondary school teachers, creative reasoning is only for high-ability students (Boesen, 2006).

Statement of the Problem

Students' academic performance appears to be one of the key criteria for educational standard and quality. Literature is replete with statistics and assertions indicating students' general poor academic achievement in mathematics and geometry in particular. Uwadiae (2010) revealed that 42% of registered candidates for the school certificate mathematics examination consistently obtain credit pass in mathematics, indicating 58% passes below credit level. Worst still, the West African Examination Council (WAEC) Chief Examiners' report on students' areas deficiency in school certificate examinations, showed that students least understood geometry concepts as shown by their achievement and attitude as they a geometry questions or haphazardly attempt them (WAEC,2007).

Many factors are responsible for students' low achievement in geometry and on achievement in annual national examinations. Inappropriate earlier instruction strategy could be one of them. Ogunkunle & Charles Organ (2012) established that school teacher Port Harcourt were ineffective in teaching mathematics as they apply convention teaching method in almost all the topics they taught. It is the researcher's view students' reasoning abilities could be a factor as well. Therefore, this study wants to determine the effects of problem-based learning strategy on the mathematical reasoning abilities of students in geometry in senior secondary school in Katsina metropolis, Katsina State.

Purpose of the study

This study generally determined the effects of problem-based learning strategy on mathematical reasoning of senior secondary students in geometry in Port Harcourt metropolis Rivers State, Specifically; it is the objectives of this study to:

I. determine if there is any difference in the Mathematical Reasoning (MR) mean scores of students taught geometry using Problem-Based Learning (PBL) strategy and Conventional Teaching Strategy (CTS).

2. Ascertain whether differences exist in the overall MR mean scores of the male and the female students taught geometry with PBL and CTS.

Research Questions

Based on the objectives of this study, the following research questions have been formulated to guide the study:

1. What are the differences in the Mathematical Reasoning (MR) mean scores of students taught geometry using Problem-Based Learning (PBL) Strategy and Conventional Teaching Strategy (CTS)?

2. What are the differences in the male and the female students MR mean scores in geometry when taught with PBL and CTS?

Research Hypotheses

To achieve the objectives of this study, the following null hypotheses were tested at 0.05 level of significance:

Ho_1: There is no significant difference in the Mathematical Reasoning (i') mean scores of students taught geometry using Problem- Based Learning (PBL) strategy and Conventional Teaching Strategy CTS..

Ho_2: There is no significant difference in the MR mean scores of the male and the female students taught geometry with PBL and CTS.

Methodology

The pretest-posttest quasi-experimental design was used for the study. non randomized pretest, post-test experimental and control groups research design were employed with the purpose of observing the relative effectiveness of the independent variable which is the teaching strategy. Intact classes were assigned as treatment control groups with students in the treatment group receiving instruction by Problem Based Learning (PBL) strategy only. Students in the control group continued their normal lessons using Conventional Teaching Strategy (CTS). The design is a 2x2 factorial design involving two independent variables: Instructional strategies and gender. The two instructional strategies were PBL and CTS while gender denotes male and female students. The dependent variable of this study was mathematical reasoning.

The population of this study was all the Senior Secondary Class 2 (SSC2) students in Katsina State. The SSC2 was chosen because it is considered a class of higher levels of Mathematics teaching and learning.

A sample of 80 students was used for the study indicating 40 students in a class in two schools. A class size of 40 students is normal for effective instructions. Purposive sampling technique was used to select Katsina Metropolis of Katsina State. Then simple random sampling technique was used to select two public senior secondary schools from the area. One of the schools was used for Pilot testing which was from the population

Mathematical Reasoning Inventory (MRI) was the instrument for data collection MRI was used to assess the mathematical reasoning abilities of the students in geometry. The MRJ contained 50 items. Each correct option had a score of two (2) marks with zero (0) mark for wrong option.

To assess the mathematical reasoning abilities of the students, they were asked to solve each Geometry Achievement Test (GAT) questions and indicate either correct, incorrect, self corrected as or did not answer for a given suggested answer to the 50 GAT questions. Each correct option had 2 marks with zero mark for wrong option.

The reliability of the instrument MRI was determined using test-retest method (measure of stability) with a reliability index of 0.80. Simple random sampling technique was used to draw a sample of 40 students who did not participate in the main study. Copies of the instruments were administered to the sample. They were requested to attempt all the items of GAT and MRI.

Data analysis

The students pre-test and post-test scripts in both groups were marked and scores recorded. Mean and standard deviation were used to answer research questions while Analysis of Covariance (ANCOVA) was used to test the hypotheses at 0.05 alpha level because the pre-test scores were used as covariance or control measure to the post-test scores.

Results

Research question 1: What are the differences in the Mathematical Reasoning (MR)mean scores of students taught geometry using Problem-Based Learning (PBL) strategy and CTS?

Table1: Mean differences in the MR scores of students taught geometry using PBL and CTS.

		N	PRETEST		POSTTEST			
Variable	Strategies		Mean score	SD	Mean score	SD	Mean Score	SD
Math Reasoning	PBL	40	28.75	7.94	59.20	7.40	30.45	4.99
	CTS	40	19.25	6.89	44,45	11.58	25.20	6.54

Table 1 shows that the mathematical reasoning mean scores of the student in the PBL group (M = 30.45, SD=4.99) was higher than those of the CTS group (M=25.20, SD=6.51). It means that students in the PBL group had higher mathematical reasoning skills than those in the CTS group.

Research question 2: What are the differences in the male and the female students MR scores in geometry when taught with PBL and CTS?

Table2: Gender differences in the MR mean score in geometry when taught with PBL and CTS.

				Pretest		Posttest		Gain score	
Variable	Strategy	Gender	N	Mean	SD	Mean	SD	Mean	SD
	PBL	Male	21	32.57	7.41	62.19	6.95	29.62	5.39
		Female	19	24.53	6.32	55.89	6.55	31.37	4.47
	CTS	Male	20	20.40	8.30	45.70	14.43	25.30	7.71
MR		Female	20	18.10	5.09	43.20	7.98	25.10	5.33

Table 2 shows that the female students in the PBL group (M=3l.37, SD=4.47) had the highest mean score in mathematical reasoning. This was followed by the male students of the same group (M=29.62, SD= 10.02). The least mean score in mathematics reasoning was obtained by the female students of the CTS group (M=25.10, SD=5.33). This indicated that the female students of the PBL group had better mathematical reasoning ability in geometry when compared with the male students.

Hypotheses Testing

Ho_1: There is no significant difference in the Mathematical Reasoning (MR) mean scores of students taught geometry using Problem- Based Learning (PBL) strategy and Conventional Teaching Strategy CTS.

Table3: summary of ANCOVA on the different MR mean scores of students taught geometry using PBL and CTS.

Source of variation	Type iii sum of squares	DF	Mean square	F	Sig.
Corrected model	9080.753[a]	2	4540.377	132.790	.000
Intercept	4882.738	1	4882.738	142.803	.000
PRMR	4729.503	1	4729.503	138.321	.000
Strategy	325.459	1	325.459	9.519	.003
Error	2632.797	77	34.192		
Total	226580.000	80			
Corrected total	11713.550	79			

Table 3 shows that there is significant difference in the mathematical reasoning (F1,77=9.5 19, p>.05) scores of students taught geometry using Problem- Based Leaning. (PBL)strategy and CTS.

Ho_2: There is no significant difference in the MR mean scores of the male and lilt female students taught geometry with PBL and CTS.

Table4: Summary of ANCOVA on the difference MR mean scores of the male and the female students taught geometry using PEE and CTS.

Source of variation	Type iii sum of square	DF	Mean square	F	Sig.
Corrected model	9056.962	6	1509.494	29.113	.000
Intercept	7833.399	1	7833.399	151.079	.000
PRMR	4030.623	1	4030.623	77.737	.000
Gender	10.107	1	10.107	.195	.660
Strategy	626.384	2	313.192	6.040	.003
Gender* strategy	20.766	2	10.383	.200	.819
Error	5859.005	113	51.850		
Total	345876.000	120			
Corrected total	14915.967	119			

a. R Squared = .607 (Adjusted R Squared = .586)

Table 4: shows that there is no significant difference in the mean MR scores of male and female students taught geometry with PBL and CTS (FI.113.195, p>0.05). The interaction effect between gender and strategy was not significant (F2, 113=.200.P>0.05). There was a significant difference in the MR mean scores of the students based on the strategy (F2, 113=6.040, p<.0.05).

Discussion of Findings

The result shows that the mean score in mathematical reasoning was higher in the PBL group (M30.45, 5D4.99), than that in the CTS (M=25.20, SD=6.54). When put to statistical test, the result was that there is significant difference in the mean Mathematical Reasoning (Fl, 77=9.519, p<0.05) scores of students taught geometry using the PBL strategy and the CTS. The result also shows that the female students in the PBL group (M31.37, SD4.47) had higher mean gain in Mathematical Reasoning. When put to statistical test, the result was that there is no significant difference in the mean MR scores of the male and the female students taught geometry with PBL and CTS (Fl, 113.195, p>0.05). These findings are in agreement with an earlier study by Padmavathy and Mareesh (2013) who re that problem-based learning had effect in teaching mathematics and improved and female students' understanding (cognitive achievement), creative mathematical reasoning and problem solving skills equally.

Summary of Findings

The following findings were made:

1. The gain mean scores in mathematical reasoning of students were found higher among PBL group than their CTS counterparts.
2. Female students in the PBL group had the highest mean score Mathematical Reasoning.
3. There was significant difference in the mathematical reasoning mean score students taught geometry using PBL and CTS.
4. There was no significant difference in the (MR) mean scores of the female students taught geometry with PBL and CTS. The interaction between gender and strategy was not also significant.

Conclusion

Problem-based learning strategy was found to be a better instructional strategy compared with the traditional or conventional teaching strategy. Problem-I learning is preferred to conventional teaching strategy for developing still mathematical reasoning skill. Finally, PBL was found to promote gender in academics.

Recommendations

Based on the findings of this study and in view of the above conclusion following recommendations are made:

1. Mathematics teachers should adopt problem-based learning strategy ii classroom to enhance students' mathematical reasoning.
2. Problem-based learning strategy should be adopted for use in mathematical classes so as to eliminate gender inequity in mathematical reasoning.

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