Effects of Polya's Problem-Solving Teaching Strategy on Students' Achievement in Bayelsa East Secondary Schools Mathematical Word Problems, Bayelsa State, Nigeria

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Abstract
The study investigated the effects of Polya's problem-solving teaching strategy on students' achievement in mathematical word problems in Bayelsa East Secondary Schools of Bayelsa State, Nigeria. Two research questions were raised and two corresponding null hypotheses that were tested at 0.05 level of significance guided the study. A pre-test post-test control group of quasi experimental design was adopted. The population of the study consisted of all Junior Secondary School 2 (JSS 2) mathematics students in the district. A purposive sampling technique was used to select 170 students from six (6) Mixed Junior Secondary Schools. Mathematical Problem-Solving Achievement Test (MPAT) was used to collect data from the students. The major finding showed that mathematics students taught with polya's model did significantly better than the students taught with the lecture method. Based on the finding, the study concluded that Polya's problem-solving strategy was effective for teaching mathematical word problems. Therefore, the researcher recommended that Polya's model should be adopted as a teaching strategy at the Junior Secondary Schools level in the Bayelsa East Senatorial District of Bayelsa State.

Keywords: *Achievement, Effects, Mathematics Students, Mathematical Word Problems, Polya's Teaching Strategy.*

INTRODUCTION

Problem-solving is one of the strategies of teaching and learning of mathematics. Woods et al (1975) quoted by Stice (2001), defined problem-solving as a process of obtaining a satisfactory solution to a novel problem, or at least a problem which the problem solver has not seen before. He saw problem-solving as a systematic procedure for finding solution to an identified mathematical problem. Here, the solver may be a teacher or a learner. Mathematical problem-solving can be defined as a modeling of a problem's numeric nature by formulating and testing hypotheses through collection and analysis of data, using path analysis, graphing, computers or calculators (Lajoie, 1992). Problem-solving strategy is thus viewed as a process that involves formulation, testing and confirmation of hypothesis as a scientific approach for solving mathematical problems.

Stice (2001) quoting Brownell (1942) gave a more general definition of problem-solving which he described in a number of ways including that:

(i) Problem-solving is a perceptual and conceptual task,
(ii) It has the nature of which the subject links the previous learning with the present task and organize the task in such ways to understand it, and
(iii) The subject experience perplexity in the problem situation, but he does not experience utter confusion. Then, problem-solving thus becomes the process by which the subject extricates himself from the problem.

Problem-solving teaching method can also be defined as "what you do when you don't know what to do" (Akers, 1981). By this definition, problem-solving involves critical and analytical examination of relevant variables of a problem of which the solution is not readily available. It involves the students searching deeply into the problem with a view to finding its solution. An improvement on this approach was suggested by Polya (1971) who outlined the following phases for problem-solving.

(i) Understanding the problem.
(ii) Devising a plan
(iii) Carrying out the plan
(iv) Looking back.

These stages were further amplified by Chamot, Dale, Malley and Spanos (1992) as follow:

(i) **Understand the Problem:** Activities include reading the mathematics problem aloud, discussing prior knowledge about the problem type, drawing a picture or image of the problem, rewriting the question as a statement with a blank for the answer, paraphrasing the question.

(ii) **Devising a plan:** Activities include deciding if one step or multiple steps are called for, choosing the mathematics question(s), make a table or other graphic representations, guessing and checking, write a mathematics sentence, or otherwise setting up the problem.

(iii) **Carrying out the plan:** Activities include working with pencil and/or calculator to compute the answer to the mathematic problem(s) set up in (ii).

(iv) **Looking back:** Activities include comparing the answer to the representation made in step (i) to see if it makes sense, reviewing the problem solving steps, looking for more information in the problem, estimating the answer, checking calculations. In some mathematical problems, solve from the answers back to the original problems or questions.

Thompson (1992) observed that mathematics teachers with a problem-solving view tend to be more learner focused and constructivist in teaching style, actively involving students in exploring mathematical concepts, creating solution strategies, and constructing personal meaning in a problem-rich environment than teachers with lecture method view. From his opinion, problem-solving teaching strategy can be seen as a strong skill in mathematics teaching which mathematics teachers need to acquire in order to make their teaching more students-centred. In this case, problem-solving is a learner-centred approach of teaching and learning of mathematics. To improve on mathematics teaching in schools, Dirkes (1993) suggested that the mathematics teacher must makes his own paradigm shift, and this requires him to come face-to-face with deeply held personal beliefs about teaching and learning, and to face his own propensity for risk and initiative. According to Dirkes (1993), many mathematics teachers feel unprepared to take a problem-solving approach to the teaching of mathematics, instead, they opted to lecture method in the classrooms. According to the author, few mathematics teachers teach mathematics by using problem-solving strategy. Dirkes (1993) concluded by saying that even if mathematics teachers encountered problem-solving in their college methods courses, once in the classroom, they often conform to the conventional methods (e.g. lecture method) that hold sway in most secondary schools. In line with the work of Dirkes (1993), Secada (1991) reported that mathematics instruction in elementary and secondary schools is frequently limited to computation exercise and little or no time is spent on problem-solving. In addition, Ezenweani (2006) observed that many mathematics teachers have considered problem-solving strategy as being the act of solving mathematics problems on the chalk board.

Ezenweani (2006) further stated that such mathematics teachers considered problem-solving as a teacher-centred instead of student-centred. Lecture method as one of the common teaching methods used by mathematics teachers during teaching and learning of mathematics in the classroom has contributed to the poor achievement of students in mathematics. This necessitated the needs for the present study. In fact, the teaching of mathematics by mathematics teachers via lecture method made the learning of the subject looked abstract to the students.

Problem-solving is an experimental method of teaching mathematics which Polya (1971) saw as an art of inquiring and discovery. He emphasized that problem-solving question should be taught as a practical art, like playing the piano or swimming.

Krulik and Rudnik (1996) defined problem-solving as a process by which an individual uses previously acquired knowledge, skills and understanding to satisfy the demands of an unfamiliar situation. They asserted that problem-solving makes a relation among the events, the algorithm, and problems concerned with real life.

A study conducted by Silver and Marshall (1990) on Polya's problem-solving teaching strategy in relation to students' achievement, and discovered that Polya's problem-solving strategy process has improved performance of mathematics students at all grade levels, including college students in the developed countries. Also, problem-solving has been proved effective in the developed countries such as United States of America and United Kingdom, but teachers in Botswana Public Schools experience challenges of large class size, wide mixed ability classes and examined syllabus for the implementation of problem-solving strategy in the classroom (Garegae, n.d, Hyde & Bizar, 1989). The effect of problem-solving approach on students' achievement in mathematics was conducted by Perveen (2010). Perveen (2010) discovered that problem-solving approach based on Polya's model had significant effect on students' achievement in mathematics. The study according to Perveen (2010) employed pre-test post-test control group experimental research design. The study made use of two groups-experimental and control groups. Students in the experimental group were exposed to problem-solving teaching strategy based on Polya's model while mathematics students in the control group were taught without problem-solving teaching strategy. Perveen (2010) concluded that mathematics students in the experimental group performed significantly better than the students in the control group in the post-test.

Ali, Dad, Akhter and Khan (2010) did a study on the effect of using problem-solving method in teaching mathematics on the achievement of mathematics students. The study was conducted for elementary learners. Ali et al (2010) employed pre-test post-test design. At the end of the investigation, Ali et al (2010) discovered that there was significant difference between the effectiveness of problem-solving and traditional teaching methods on students' achievement in mathematics in favour of the problem solving teaching method. Ali et al (2010) concluded that problem solving teaching method enhanced the achievement of mathematics students at the elementary level.

On the achievement of male and female students that were exposed to problem-solving teaching strategy, Beller and Gafni (2000) discovered that male student's performances were better than the female students. In a related development, Orhun (2003) reported that girls tended to use more concrete strategies and boys tended to use more abstract strategies during the implementation of problem-solving teaching method in the classroom.

Researchers have shown that many mathematics teachers teach without problem-solving teaching strategy in schools (Dirkes, 1993, Secada, 1991 & Ezenweani, 2006). The evidence available was that mathematics students performed poorly. Therefore, does Polya's problem-solving teaching strategy enhances students' achievement in mathematics in Bayelsa East Senatorial District of Bayelsa State?

Research Questions

1. Is there any difference between the mean achievement scores of mathematics students exposed to Polya's problem-solving teaching strategy and lecture method?
2. Is there any difference between the mean achievement scores of male and female mathematics students exposed to polya's problem-solving teaching strategy?

Research Hypotheses

The hypotheses below were tested at 0.05 level of significance.

Ho_1 There is no significant difference between the mean achievement scores of mathematics students exposed to Polya's problem-solving teaching strategy and lecture method.

Ho_2 There is no significant difference between the mean achievement scores of male and female mathematics students exposed to Polya's problem-solving teaching strategy.

Research Method

Design: The study employed the pre-test post-test control group of quasi experimental research design. The design was considered appropriate for the study because intact classes were used to avoid the sampled schools been distracted as a result of the study. The study made use of two groups – the experimental and control groups. Mathematics students in the experimental group were taught with Polya's Problem-Solving Teaching Strategy (PPTS) while the mathematics students in the control group were taught with Lecture Method (LM).

Population: The study was conducted for all public Junior Secondary School 2 (JSS 2) mathematics students in Bayelsa East Senatorial District of Bayelsa State, Nigeria.

Sample: One hundred and seventy (170) Junior Secondary School 2 (JSS 2) mathematics Students, made up of 67 for experimental group and 103 for control group were purposively selected from six (6) mixed public secondary schools.

Research Instrument/Validation

One instrument and format lesson plans based on Polya's model and lecture method were used for the study. The instrument was a Mathematical Problem-Solving Achievement Test (MPAT) and was constructed by the researcher. The instrument (MPAT) consisted of ten (10) multiple-choice objective questions. The ten (10) items were drawn from topics involving word problems in JSS 2 Mathematics Curriculum for which the students were exposed to using the Polya's model and the lecture method for one full academic term.

On the validation of the research instrument (MPAT), content validity and construct validity were used. For the content validity, table of specification in line with Bloom Taxonomy of objectives (knowledge, comprehension and application) based on the selected topics, was used. To carry out construct validity on the instrument (MPAT), the researcher drafted 23 items multiple-choice objective questions with five (5) options (A, B, C, D & E) and was administered to 30 JSS 2 mathematics students in a school not included in the sample. Items analyses were carried out on the data generated from the thirty (30) students. Under the items analyses, two (2) indices – item difficulty index and item discrimination index, were computed. For the item difficulty index, the percentages of students that got each question correctly were computed. To compute the item discrimination index, the scripts of the thirty (30) JSS 2 mathematics students were arranged based on merit-from highest scores down to the lowest scores. Twelve (12) scripts were counted from the top (upper scores) and twelve (12) scripts were also counted from the bottom (lower scores), leaving six (6) scripts in between. The six (6) scripts of the students were not used for the computation of the discrimination index. To calculate the discrimination index for each question, the number of students in the lower scores that got question one (1) correctly was subtracted from the number of students in the upper scores that got the same question one (1) (first question) correctly and the result was divided by twelve (12). The same procedure was applied to the remaining 22 questions of the instrument. Based on the computed results of the item difficulty index and discrimination index for each of the 23 questions and in conjunction with the experts in Mathematics Education, 13 questions were rejected while the remaining 10 questions were finally used for the study.

The ten (10) items harmonized instrument (MPAT) was further administered to twenty (20) JSS 2 mathematics students twice in another different secondary school. The scores generated were used to determine the reliability of the instrument (MPAT). The reliability coefficient of the instrument stood at 0.62 (test-retest method)

Treatment Procedure

Six (6) mathematics teachers were used to teach the students in the six (6) secondary schools. Out of these six (6) mathematics teachers, three (3) of them were used to teach the students in the experimental group while the remaining three (3) teachers were used to teach the students in the control group.

The three (3) mathematics teachers in the experimental group were trained on how to use the lesson plan structured based on polya's 4 steps (understanding the problem, devising a plan, carry out the plan and looking back) by the researcher in each of the topics. The teachers in this group were trained in their respective schools. The mathematics teachers in the control group did not received any training from the researcher but they were directed to use the lesson plan prepared based on the lecture method in each of the same topics.

Before the commencement of the training and the experiment, the Mathematical Problem-solving Achievement Text (MPAT) was administered to the students in both groups as pre-test. The answer scripts and the instrument were immediately retrieved from the students by the researcher and his team at the end of the test. During the course of the teaching, the researcher visited each school twice to assess the levels of teaching by the teachers. The experiment which lasted for one full academic term, two times per week was conducted during the normal school periods following the normal time table of each school. The post-test on achievement which reserved the same content and format as pre-test (MPAT) was administered by the researcher and his team simultaneously immediately after the weeks of teaching.

Data Analysis

The scoring of students' responses was on the scale of 0 to 10 marks. The two research questions were answered by the use of mean and standard deviation. The null hypothesis (Ho_1) was tested by ANCOVA while the null hypothesis (Ho_2) was tested by t-test. The pre-test scores were used as covariates.

Results

Research Question 1

Is there any difference between the mean achievement scores of mathematics students exposed to polya's problem-solving teaching strategy and lecture method? This research question was answered with the data in Table 1.

Table 1: Mean and Standard Deviation of Mathematics Students Taught With PPTS and LM

Types of Test	Experimental Group (PPTS)		Control Group (LM)	
	Mean ($\bar{x}$)	**SD**	**Mean ($\bar{x}$)**	**SD**
Pre-test	1.67	0.98	1.86	1.27
Post-test	3.75	2.31	2.06	1.32
No. of Subjects	**67**		**103**	

From Table 1 shown above, the pre-test mean and standard deviation scores of mathematics students in the experimental group were 1.67 and 0.98, respectively. Also the pre-test mean and standard deviation scores of mathematics students in the control group stood at 1.86 and 1.27, respectively. 0.19 was the difference between the pre-test mean scores of mathematics students in the experimental and control groups. 3.75 and 2.31 were the post-test mean and standard deviation scores of students in the experimental group, respectively. In the control group, the post-test mean score was 2.06 and standard deviation score was 1.32. In addition, 1.69 was the difference between the post-test mean scores of students in the experimental and control groups.

Research Question 2

Is there any difference between the mean achievement scores of male and female mathematics students exposed to polya's problem-solving teaching strategy? Data in Table 2 were used to answer this research question.

Table 2: Mean and Standard Deviation of Male and Female Mathematics Students in the Experimental Group.

Types of Test	Male		Female	
	Mean ($\bar{x}$)	**SD**	**Mean ($\bar{x}$)**	**SD**
Pre-test	1.70	1.09	1.65	0.89
Post-test	3.73	2.23	3.76	2.40
No. of Subjects	**30**		**37**	

From Table 2, it was observed that male mathematics students had a mean score of 1.70 and standard deviation of 1.09 in the pre-test. In the pre-test, female students had a mean score of 1.65 and standard deviation of 0.89. A 0.05 was the difference between the mean pre-test scores of male and female students in the experimental group. In the post-test, male students scored a mean achievement of 3.73 and a standard deviation of 2.23. For the female students, it was revealed that they had a mean score of 3.76 and a standard deviation of 2.40 in the post-test. A 0.03 was the difference between the post-test mean scores of male and female mathematics students in the experimental group.

Hypothesis (Ho_1)

There is no significant difference between the mean achievement scores of mathematics students exposed to polya's problem-solving teaching strategy and lecture method. This hypothesis was tested with the data in Table 3 shown below.

Table 3: ANCOVA Summary Table For Experimental and Control Groups on Students' Achievement in Mathematics

Source	Type III Sum of Square	Df	Mean Square	F	Sig.
Corrected Model	137.411[a]	2	68.706	22.649	. 000
Intercept	278.212	1	278.212	91.713	. 000
Pretest	21.742	1	21.742	7.169	.008
Groups	123.161	1	123.161	40.600	.000
Error	506.595	167	3.034		
Total	1905.000	170			
Corrected total	644.006	169			

$P<.05$

The result presented in Table 3 reveals that there was a significant difference between the achievement of mathematics students taught with polya's problem-solving teaching strategy and students taught with lecture method. The calculated F value (F=40.600) was greater than the critical $Fo_{.05}$ (1,168), which is 3.91. Based on this result, the null hypothesis (Ho_1) is hereby rejected. The mathematics students taught with polya's problem-solving teaching strategy had a mean score of 3.75 and those students taught with lecture method had a mean score of 2.06. The result showed that mathematics students taught with polya's model did significantly better than their counterparts taught with lecture method.

Hypothesis (Ho_2)

There is no significant difference between the mean achievement scores of male and female mathematics students exposed to polya's problem-solving teaching strategy. Data in Table 4 were used to test this hypothesis.

Table 4: T-test Summary Table Showing the Achievement of Male and Female Mathematics Students (Post-Test).

Gender	N	$\bar{x}$	SD	DF	t Calculation	t Critical	Decision
Male	30	3.73	2.23				Ho_2
Female	37	3.76	2.40	65	0.053	1.960	Accepted

$p>0.05$

From Table 4, the t-calculated value of 0.053 was less than the t-critical ratio of 1.960. Based on this, the null hypothesis (Ho_2) was accepted. This implies that there was no significant difference between the mean scores of male and female students taught with polya's model.

Discussion of Results

In discussing the first finding of this study, data indicated that the polya's problem-solving teaching strategy had a significant effect on the achievement of mathematics students. This implies that the experimental group with the mean score of 3.75 and standard deviation of 2.31 scored significantly higher than the mean and standard deviation scores of students in the control group. The researcher further stated that the first finding corroborates the findings of earlier researchers who discovered polya's model as an effective approach to teaching of mathematics. Examples of such researches were given as Garegae (n.d), Silver and Marshal (1990), Hyde and bizar (1989), Perveen (2010), and Ali et al (2010).

The study also discovered that there was no significant difference between the mean achievement scores of male and female mathematics students taught with polya's problem-solving teaching strategy. Although, the achievement mean score of the female students was little higher than that of the male students but the difference was not significant. This second finding was in contrary view to the finding by Beller and Gafni (2000). Beller and Gafni (2000) reported that male students performed better than female students in a problem-solving teaching approach as implemented by the mathematics teachers. The simple reasons for the discrepancy in this finding might be due to schools' location difference, levels of the students used, and among others.

This study ensured that nearly all the variables, apart from the polya's problem-solving teaching strategy, that might have effects on the study, to some extent, were technically controlled by the researcher. Variables such as teachers' factor, schools' location factor, students' factor and among others were technically controlled by the researcher. The researcher ensured that the six (6) mathematics teachers that were used to teach the students possessed the same qualification in mathematics and at the same time were employed by the Bayelsa State Government the same year.

Conclusion

Having examined all the research findings, the researcher arrived at the following conclusions:

1. Polya's problem-solving teaching strategy was effective for teaching mathematical word problems to junior secondary school 2 mathematics students in Bayelsa East Senatorial District.

2. Polya's problem-solving teaching strategy improved the achievement of male and female mathematics students in Bayelsa East Senatorial District.

Recommendations

Based on the above conclusions, the study recommended the following:

(1) Polya's problem-solving model should be adopted as a mathematics teaching strategy at the Junior Secondary Schools in Bayelsa East Senatorial District.

(2) Mathematics teachers in the Bayelsa East Senatorial District of Bayelsa State at the Junior Secondary Schools level, should encourage their students to develop critical and logical thinking through their questioning styles while using the polya's model.

(3) Male and female mathematics students should be encouraged to learn mathematics by their teachers, if possible, at equal rate.

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