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# Effect of Polya Model Problem-Solving Instructional Strategy on Academic Achievement and Retention in Mathematics among Senior Secondary School Students in Akwa Ibom State

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## ABSTRACT

*The study examined the effects of Polya Model (PM) Problem-solving Instructional strategy on Academic Achievement and Retention in Trigonometry among Secondary School Students in Akwa Ibom State. A quasi-experimental pretest, posttest, control group design was used for the study. A sample of 200 (92 males, 108 females) senior secondary school two (SS2) students was drawn from the public schools in Ikot Ekpene. Two intact classes were used for the study; the experimental class was taught using PM, and the control class was taught using the lecture method. Two research questions and two hypotheses were formulated and tested at the 0.05 level of significance. The Mathematics Achievements test, with a reliability index of 0.83, was the instrument used for data collection. Data collected were analysed using mean, standard deviation, and analysis of covariance (ANCOVA). The study indicates that students taught using PM performed significantly better than those taught using the lecture method. There is no significant difference between the mean achievement scores of male and female students taught mathematics using the Polya problem-solving model instructional strategy. Female students taught mathematics using the Polya problem-solving model instructional strategy retained slightly higher than their male counterparts taught with the Polya problem-solving Model instructional strategy. It is recommended that female teachers should be employed and deployed to teach in order to encourage female students. Authors should use the steps of the PM strategy in worked examples to afford teachers and students the opportunity to use the strategy. Teachers should use PM for teaching trigonometric concepts in schools, and more attention should be given to female students. These will enhance students' academic achievement and retention.*

***Keywords:*** *Polya model, Achievement, Retention and Mathematics.*

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## INTRODUCTION

Mathematics is the study of the principles and patterns that govern numerical and spatial relationships, shapes, qualities and structures. It involves the use of logical reasoning, problem-solving skills, and mathematical abstractions to understand and describe the world (Ogunsola, Adelana & Adewale, 2021). Maruta and Magaji (2022) defined mathematics as a subject that encompasses all aspects of human endeavours and could be described as the life wire in the studies of various disciplines. Mathematics can be defined as a subject that encompasses all aspects of human endeavours. It could be described as the life wire in the studies of various disciplines. The importance of mathematics compelled the Federal Government of Nigeria to make mathematics a compulsory subject from primary school through to the end of secondary school education. Learning mathematics implies understanding symbols, language, relationships, identities, equations and other verbal problems (Bhat, 2017; Bakke & Igharo in Maruta & Magaji, 2022). Shear (2020) defined mathematics achievements as a construct used to represent the level or nature of demonstrated learning in relation to a specific domain of mathematics. Mathematics achievement can be assessed at either an individual or a group level and hence, can be described as a multilevel construct. The author further stated that, at the individual level, mathematics achievement represents the knowledge and skills a person has learned in particular areas of the subject. At a group level, mathematics achievement represents the demonstrated learning of a classroom, school, school district, state or country, and can serve as an indicator of educational opportunities. In research and policy contexts, mathematical achievements is usually measured with a test or assessment procedures. These tests can include multiple-choice and constructed response items.

Mathematics teaching enhances the students’ ability to recognise a problem and apply the knowledge in finding a solution to the problem. Learning trigonometry will remain ineffective without an appropriate teaching strategy. For this reason, the researcher opined that, if students are allowed to experience mathematics through the Polya model during mathematics lessons, their academic achievement and retention will improve and their fear of learning the subject will vanish, leading to greater positive productivity in all examinations.

According to Seun, Onocha & Oluwatoyin (2022), student achievement in mathematics measures the amount of academic content a student learns in a determined amount of time. Student achievement has become an important topic in education today because it is the outcome of the educational system. It is the extent to which a student, teacher or institution has their educational goals. Mathematics achievement has to do primarily with the performance of the student in their teacher-made test or standardized achievement test administered by examining bodies. However, the major goal of the teacher is to improve the ability level of the students and prepare them for adulthood. Each grade level has learning goals or institutional standards that teachers are required to teach.

Nneji in Maruta, Mohammed and Magagi (2023) contended that for the improvement of retention of learned materials in mathematics, activity-based learning is indispensable. Retention depends on the teaching strategy adopted by the teacher. He further pointed out that research evidence has consistently indicated teaching method as a major factor determining achievement and retention of students in mathematics. Hence, the search for better methods and newer innovations is a great challenge facing science educators. In the same vein, Maruta (2018) stated that the lecture method does not allow students to participate actively in the learning process and discourages them to have both inductive and deductive reasoning.

Gender differences in mathematics teaching, learning, achievement and retention have also been explained on the basis of gender differences in cognition and brain internalisation (Egara & Mosimege, 2023). In a similar argument, Allahnana, Akande Vintesh, Alaku and Alaku (2018) argued that male and female students do experience the world in different ways. Firstly, they are positioned differently in society. Secondly, their learning styles are different and how they perceive and process reality. Oribhabor (2020) emphasise that most mathematics classroom discourse is organised to accommodate male learning patterns, hence their high achievement in mathematics. Also, the idea that mathematics is for boys may result in low motivation in girls and could widen the gender gap in mathematics achievement and retention in favour of boys. Boaler in Ajai and Imoko (2015) is of the view that the different learning goals of girls and boys leave girls at a disadvantage in competitive environments. Boys and girls preferred a mathematics curriculum that enables them to work at their own pace, as their reasoning is different. Girls value experiences that allow them to think and develop their own ideas, as their aim is to gain understanding. In the same vein, boys emphasise speed and accuracy and see these as indicators of success. Boys are able to function well in a competitive environment of textbook-based mathematics learning.

Many people do not know that mathematics is more than what is taught at school, and different from what most people think it is. Many students have a wrong image of mathematics; that mathematics has many formulas to learn without knowing why; mathematics is a never-changing, not lively subject; something for nerds and loners, and also, maybe, something for boys and men and not for girls and women. Gender is a set of characteristics distinguishing between male and female, particularly in the case of men

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and women. The discriminating characteristics vary from sex to social life to gender identity. Gender differences in mathematics achievement and ability has been a source of concern as scientists seek to address the under-representation of women at the highest levels of education (Asante in Ajai &Imoko, 2015). Through PM, learners are given free rein and exposed to different strategies for solving problems. PM is made up of four stages: (i) understanding the problem, (ii) making a plan, (iii) executing the plan, (iv) looking back and reflecting.

The persistent poor performance of senior secondary school students in mathematics has become a recurring concern for educators, policymakers, and stakeholders in the education sector. Despite the significance of mathematics in science, technology, engineering, and mathematics (STEM) fields, many students struggle to grasp mathematical concepts, leading to low academic achievement and poor retention in the subject. Conventional teaching methods, which often emphasize rote memorization and procedural fluency, have been criticized for failing to equip students with the critical thinking and problem-solving skills required for success in mathematics. This approach can lead to a superficial understanding of mathematical concepts, making it difficult for students to apply them to real-world problems. Furthermore, the teaching of mathematics often focuses on transmitting knowledge rather than developing problem-solving skills, creativity, and critical thinking. This can result in students becoming passive learners, relying heavily on memorization rather than developing a deep understanding of mathematical concepts. The consequences of poor mathematical skills are far-reaching, with implications for students' future careers, economic opportunities, and societal development. In an increasingly technological and data-driven world, mathematical literacy is essential for individuals to make informed decisions, think critically, and solve complex problems. Given the limitations of conventional teaching methods, there is a need to explore innovative approaches that can enhance students' problem-solving skills, academic achievement, and interest in mathematics. A problem-solving model that has shown promise in improving mathematical skills is Polya's Problem-Solving Model. However, despite the potential benefits of these models, there is a need for empirical research to investigate their effectiveness in the context of senior secondary school mathematics education. This study aims to address this gap by examining the effects of Polya's Problem-Solving Model on academic achievement and retention among senior secondary school students in mathematics.

## Hypotheses

The following hypotheses were formulated and tested at 0.05 level of significance:

$H_0$1: There is no significant difference between the mean achievement scores of male and female students in mathematics taught using Polya problem-solving model instructional strategy.

$H_0$2: There is no significant between the mean retention scores of male and female students in mathematics taught using Polya problem-solving model instructional strategy.

## METHOD

The design used for this study was the quasi-experimental pretest, posttest, control group design. The target population of the study was all secondary school students in Akwa Ibom State. Two (2) public secondary schools were the sample for the study to guarantee uniformity because of the same scheme of work and curriculum, learning conditions of the students, and period of work coverage are the same. The sample of the study comprised 200 students drawn from Senior Secondary School Two (SS2) in Ikot Ekpene Town. Only co-education schools were considered. Two out of 20 schools were selected using simple random sampling techniques; one was assigned the experimental group and the other the control group, using a coin tossing method. The Mathematics Achievement Test (MAT), comprising 50 multiple-choice objective questions with options A-D, developed by the researchers, was used for data collection. MAT items were adapted from WAEC and NECO past questions and the New General Mathematics textbooks.

The MAT was used for pretest and posttest. To determine Retention, MAT was reshuffled and administered to the students two weeks after the posttest. MAT underwent content validation by three experts, two in measurement and evaluation, and one from mathematics education in the Department of Science Education, Michael Okpara University of Agriculture, Umudike. The validity index was computed by taking the average of the indices by various experts, which yielded a 0.83 coefficient of internal consistency. A trial test was given to students in one of the co-education schools that is not among the sampled schools. The reliability coefficient of the TAT was determined using the Kuder-Richardson 20 (KR–20) formula, which yielded an internal consistency index of 0.83. The data collected from the pretest, posttest, and retention test were analyzed using mean and standard deviation to provide answers to the research questions, while the hypotheses were tested at a 0.05 significance level using Analysis of Covariance (ANCOVA), where the pretest scores served as the covariates.

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## RESULTS AND DISCUSSION

Test of hypotheses and answers to research questions are presented below:

**Table 1:** Mean achievement score and standard deviation of male and female students taught using Polya problem-solving model instructional strategy

| Variable | | Pre-test | | Post-test | | Achievement |
|---|---|---|---|---|---|---|
| Gender | N | $\bar{X}$ | SD | $\bar{X}$ | SD | mean gain |
| Male | 32 | 18.41 | 6.54 | 53.69 | 10.30 | 35.28 |
| Female | 38 | 18.84 | 7.39 | 56.16 | 5.10 | 37.32 |

Table 1 shows the mean achievement score and standard deviation of male and female students taught mathematics using the Polya problem-solving model instructional strategy. Male students had a pretest score of 18.41 with a standard deviation of 6.54 and a posttest score of 53.69 with a standard deviation of 10.30 and an achievement gain of 35.28, while female students had a pretest mean score of 18.84 with a standard deviation of 7.39 and a posttest mean score of 56.16 with a standard deviation of 5.10 and an achievement gain of 35.28. The standard deviations were not closely spread, which indicates high variability in scores. This indicates that female students taught using the Polya problem-solving model instructional strategy achieved more than their male counterparts taught with the Polya problem-solving model instructional strategy.

**Table 2:** Analysis of Covariance (ANCOVA) of male and female students mean achievement scores when taught mathematics using Polya problem-solving model instructional strategy

| Source | Type III Sum of Squares | Df | Mean Square | F | Sig. | Decision |
|---|---|---|---|---|---|---|
| Corrected Model | 213.137[a] | 2 | 106.569 | 1.723 | .186 | NS |
| Intercept | 21756.305 | 1 | 21756.305 | 351.687 | .000 | S |
| PRETEST | 107.122 | 1 | 107.122 | 1.732 | .193 | NS |
| GENDER | 86.731 | 1 | 86.731 | 1.402 | .241 | NS |
| Error | 4144.806 | 67 | 61.863 | | | |
| Total | 216328.000 | 70 | | | | |
| Corrected Total | 4357.943 | 69 | | | | |

a. R Squared = .049 (Adjusted R Squared = .021)

Table 2 shows an F-ratio of 1.402 for groups with a P-value of 0.241, which is greater than the significance value of 0.05. The null hypothesis that there is no significant difference between the mean achievement scores of male and female students taught mathematics using the Polya problem-solving model instructional strategy is therefore not rejected, which indicates that there is no significant difference between the mean achievement scores of male and female students taught mathematics using the Polya problem-solving model instructional strategy.

**Table 3:** Mean retention score and standard deviation of male and female students taught mathematics using Polya problem-solving model instructional strategy

| **Variable** | | **Posttest** | | **Retention** | | **Retention** |
|---|---|---|---|---|---|---|
| **Gender** | **N** | $\bar{X}$ | **SD** | $\bar{X}$ | **SD** | **mean gain** |
| Male | 32 | 53.69 | 10.30 | 55.50 | 8.47 | 1.18 |
| Female | 38 | 56.16 | 5.10 | 56.53 | 5.07 | 0.37 |

Table 3 shows the mean retention score and standard deviation of male and female students taught mathematics using the Polya problem-solving model instructional strategy. Male students had a posttest score of 53.69 with a standard deviation of 10.30 and a retention score of 55.50 with a standard deviation of 8.47 and a retention gain of 1.18, while female students had a posttest mean score of 56.16 with a standard deviation of 5.10 and a retention mean score of 56.53 with a standard deviation of 5.07 and a retention gain of 0.37. This indicates that female students taught using the Polya problem-solving model instructional strategy retained slightly higher than their male counterparts taught with the Polya problem-solving model instructional strategy.

**Table 4:** Analysis of Covariance (ANCOVA) of male and female students mean retention scores when taught mathematics using Polya problem-solving model instructional strategy

| Source | Type III Sum of Squares | Df | Mean Square | F | Sig. | Decision |
|---|---|---|---|---|---|---|
| Corrected Model | 2730.419[a] | 2 | 1365.210 | 198.263 | 0.000 | |
| Intercept | 203.899 | 1 | 203.899 | 29.611 | 0.000 | |
| POSTTEST | 2712.121 | 1 | 2712.121 | 393.868 | 0.000 | |
| GENDER | 15.190 | 1 | 15.190 | 2.206 | 0.142 | NS |
| Error | 461.352 | 67 | 6.886 | | | |
| Total | 223160.000 | 70 | | | | |
| Corrected Total | 3191.771 | 69 | | | | |

a. R Squared = .855 (Adjusted R Squared = .851)

Table 4 shows an F-ratio of 2.206 for groups with a P-value of 0.142, which is greater than the significance value of 0.05. The null hypothesis that there is no significant difference between the mean retention scores of male and female students taught Mathematics using the Polya problem-solving model instructional strategy is therefore not rejected, which implies that there is no significant difference between the mean retention scores of male and female students taught mathematics using the Polya problem-solving model instructional strategy.

The results show that both male and female students in the experimental group had higher achievement in Mathematics than those in the control group, but the male students scored a little higher than their female counterparts in the experimental group. This agrees with the work cited by Effiom and Abdullahi (2021) that boys generally achieve higher than girls on standardized mathematics tests. Furthermore, the results show that the mean retention scores of the students in the experimental group were significantly higher than those of the control group. Thereby, agreeing with the findings of Ajai and Imoko (2015), Egora and Mosumege (2023), and Mahaweruimana and Mutarutinya (2023). Male students had a higher mean retention than their female counterparts among those taught mathematics using PM.

The mean Achievement scores of male and female students taught Trigonometry using the PM show that there was no significant difference between gender and strategy since the probability level 0.241 was greater than the significance level of 0.05. The result of the retention showed no significant difference between gender and strategy. Since the P-level of 0.142 is greater than the significance level of 0.05.

## CONCLUSION AND RECOMMENDATIONS

Based on the findings of the study, it was concluded that the Bransford-Stein problem-solving model has a more positive effect on students' achievement and retention in trigonometry than the traditional (Lecture) method. This positive effect on students' achievement is higher for male students than their female counterparts, even though the difference in their achievements for both groups was not significant. The overall results obtained from this study agree with the general expectation of educators that activity-based teaching strategies, which are student-centered, are more educationally rewarding than the traditional (Lecture) method, which is more teacher-centered.

The following recommendations were made from the study:

- Female teachers should be employed and deployed to teach in order to encourage female students.

- Authors should be encouraged to use the steps of PM strategy in their worked examples in order to afford teachers and students the opportunity to use the strategy.
- Teachers should be encouraged to use PM for teaching their students Mathematics concepts in school, and more attention should be given to the female students.
- Mathematics curricula developers, educators and teachers should incorporate the Polya models among others in the curriculum, in training and teaching of mathematics at senior secondary school levels.

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