ISSN 2462-2052 | eISSN 2600-8718
DOI: https://doi.org/10.37134/jsml.vol12.1.1.2024

Journal of Science and Mathematics Letters
Volume 12, Issue 1, 1-7, 2024

Research Article

Effects of Heuristic Problem-solving Strategies on Students' Achievement and Retention in Mathematics in Ogun State, Nigeria

Abiodun Taiwo Oluwadayo[1*], Oyedeji Opoola Aderibigbe[2], Ifamuyiwa Sunday Adebola[2] and Asanre Akorede Ayoola[1]

[1]Department of Mathematics, Tai Solarin University of Education, Ijagun, Ijebu-ode, Ogun State, Nigeria
[2]Department of Science and Technology Education, Olabisi Onabanjo Uuniversity, Ago-Iwoye, Ogun State, Nigeria
*Corresponding author: abiodunto@tasued.edu.ng

Received: 23 June 2023; **Accepted:** 7 August 2023; **Published:** 5 January 2024

ABSTRACT

The ability to solve problems is an important and integral part of learning Mathematics. Teaching students to use Heuristic Problem-Solving strategies can help them become expert problem solvers and assist them in transferring and applying their contextual knowledge to novel problems and situations. It is on this background that this study examines the effects of Heuristic Problem-Solving strategies on students' achievement in and retention in Mathematics in Ogun State, Nigeria. The research used quantitative and quasi-experimental design. A total of eighty students from two public secondary classes participated in the study. Three hypotheses guided the study. Mathematics Achievement Test (MAT) was used as an instrument to collect data. The reliability coefficient of MAT is 0.82. Data was analysed using independent t-test analysis. This finding revealed that the students that were exposed to Heuristic Problem Solving performed better than those in the conventional group. In conclusion, the results of the findings indicated that the Heuristic Problem-solving strategy enhances students' achievement and retention of knowledge in Mathematics, hence teachers should be encouraged to integrate student-centered teaching methods into their teaching methods so that students' misconceptions about Mathematics as a difficult subject in schools may be reduced.

Keywords: achievement, heuristic problem-solving, retention, strategies

1. INTRODUCTION

Secondary school students need to perform well in mathematics in order to attain future achievement in their academic and professional aspirations (Adiguzel & Akpinar, 2014). The National Policy on Education (NPE) has advocated the inclusion of problem-solving methods into the mathematics curriculum in Nigeria to offer students high-quality mathematical skills. This method of teaching Mathematics encourages students to actively engage in cognition and apply what they have learned in practical situations. However, students should learn and comprehend heuristic thinking and problem-solving techniques in order to improve as problem solvers (King, 2011). This will help students develop a kind of complex problem-solving skills

that will lead to much greater levels of mathematical accomplishment. Students will be better able to apply their knowledge and abilities to other aspects of life as they succeed more in the classroom. However, despite improvements in Mathematics education reform, there are still big gaps between how professionals utilize Mathematics in the workplace and how students learn it in school (Bottge et al., 2014).

According to the findings, students who use problem-solving techniques acquire rich and sophisticated schemata as well as linkages between the concepts they are learning (Owen & Sweller, 2015). One of the leading proponents of fostering the application of problem-solving strategies in the study of Mathematics was George Polya. His theories of heuristic thinking and Heuristic Problem-Solving Techniques were Polya's most important contributions to the problem-solving process. Heuristic reasoning should be viewed as temporary and plausible rather than final and rigorous (Polya, 2004). Heuristic reasoning aims to produce a set of useful principles for reasoning that are developed from the empirical experimental approach and guide thought in the directions most likely to produce success. Based on this, Polya identified four fundamental phases for problem-solving, which included comprehending the problem, coming up with a strategy, putting the plan into action, and looking back to assess the outcome (Marzano et al., 2001). These problem-solving guidelines were created using heuristic thinking, and they are effective for a wide range of issues.

Problem-solving requires the use of mental processing, prior knowledge, logic, and methods, and it is a mental activity. Because of this, a problem-solving methodology should be used in the majority of mathematical content. Heuristic reasoning's objective is to research the procedures and principles of creation and discovery (Polya, 2004). It must be adaptable enough to operate well with a variety of issues and support students in steering their ideas in the directions most likely to result in a workable solution. Understanding the problem, coming up with a plan, carrying out the plan, and looking back to assess the solution found are the four fundamental steps in the Polya method for solving mathematical problems (Marzano et al., 2001). Polya also created Heuristic Problem-Solving techniques. They are tools that help students narrow their search for a solution within a broad problem area. They are particularly useful when students run into issues that they are unfamiliar with or have never seen before. Additionally, studies have demonstrated that students' achievement and retention levels increased noticeably when Heuristic Problem-Solving Techniques were explicitly taught to them (Novotna et al., 2014). Heuristic Problem-Solving Techniques can be applied individually or in combination, and they offer basic recommendations for resolving various kinds of situations. Since it is difficult for them to attempt to work through all strategies, students need to be taught to choose the most appropriate strategy for the type of problem that they are given. Instructing students to look for similar difficulties or problems with similar characteristics and apply the strategies that were most successful for solving them in the past is a method to do this. This calls for those problem-solving techniques to be taught with the same emphasis as every other mathematical idea (Novotna et al., 2014). It is crucial to investigate how Heuristic Problem-Solving Techniques affect students' mathematical performance and retention.

Three statements of hypotheses that guide this study are (i) There is no significant difference in Mathematics achievement scores of students in Heuristic Problem-Solving class and control class before the intervention (ii) There is no significant difference in Mathematics achievement scores of the students in Heuristic Problem-Solving and control strategies after the intervention, and (iii) There is no significant difference in Mathematics retention scores of the students in Heuristic Problem -Solving and Control strategies after the intervention.

2. MATERIALS AND METHODS

This study examined the effects of Heuristic Problem-Solving strategies on student achievement and retention in Mathematics in Ogun State, Nigeria, using a quantitative and quasi-experimental approach. According to Ary et al. (2010), a quasi-experimental study applies independent variables to a specific sample to observe their impact on the dependent variable. The achievement and retention of students are the dependent variables in this study, while the method of Heuristic Problem-Solving is the independent variable. The implementation of the research is secondary schools. Based on the hypotheses, two groups and three tests (pre-test, post-test, and delayed post-test) were used in an experimental group and a control group.

2.1. Participants

The study involved a total of 80 students from two public secondary schools. A total of 40 students were selected to each of the experimental and control groups. from each of the schools. The students consisted of 38 males and 42 were female. The students who took part were all in Senior Secondary School one (SSS1). Four Mathematics teachers were also used as research assistants. These teachers had over twenty years of experience teaching Mathematics in senior secondary schools.

2.2. Administration of pre-test, post-test, and delayed post-test

All students were required to complete pre-test, post-test, and delayed post-test in both the control group and the intervention group. Before the five weeks of intervention, the researchers with the help of research assistants, administered the pre-test to the students in both experimental and control groups. The post-test was given immediately after the five-week intervention. Three weeks after the intervention, a delayed post-test was given to determine how well the students could retain mathematical concepts.

2.3. Procedures for the study

The study did not affect the usual school teacher's established work schedule, classroom procedures, or assessments. The teacher's instructions in Mathematics were based on the topics covered in Senior Secondary School One 1 (SSS 1) mathematics. The teachers who were used as assistants for three days received training from the researchers. The Heuristic Problem-Solving intervention class was taught Mathematics contents by the researchers for five weeks in the experimental group with the assistance of the research assistants. Four research assistants were used in the study.

2.4. Instruments for data collection

The Mathematics Achievement Test (MAT) consists of 40 multiple-choice questions, each with four possible answers. The researchers created the MAT to measure students' learning and retention of Mathematics topics. The questions chosen were from Senior School Certificate Examination of the West African Examination Council (WAEC) and National Examination Council (NECO). The knowledge, understanding, and application levels are all covered by the Mathematics Achievement Test (MAT). The instrument measured the students' entering behavior prior to treatment exposure, their achievement level immediately after treatment, and their capacity to remember three weeks later. The reliability and validity of MAT were keenly scrutinized for their appropriateness and correctness. By creating a table of specifications, the

reliability of the content was verified. The researchers initially prepared a 120 item objective question which were administered to 100 students outside the sample selected, this was used as the pilot test. Item analysis was performed using the students' responses.

The result of the analysis was used to pick items that were neither too difficult nor too easy (difficulty index between 40% and 60% was fixed) and which discriminate positively between strong and weak students. The Mathematics Achievement Test (MAT) was composed of 40 objective items that made it through the item analysis process. A sample of forty SSS1 students not included in the main study were given the 40-item MAT. The test-retest reliability method was used to measure the reliability of the Mathematics Achievement Test (MAT). MAT was administered twice within the time interval of one week between the first and second administration. After the data was collected, it was examined, and the results showed that the MAT had a reliability index of 0.82. The items on the test were reshuffled and re-administered to the learners to measure students' retention in Mathematics.

3. RESULTS AND DISCUSSION

3.1. Hypothesis 1: There is no significant difference in the mathematics achievement scores of students in Heuristic Problem-Solving classes and control class before the intervention

In order to assess the effectiveness of Heuristic Problem-Solving as an intervention in educating Senior Secondary School students in Ogun State, Nigeria, this study examined the students' Mathematics achievement and retention. The data were analyzed by the researchers using SPSS 27.0 in accordance with the research hypotheses. The analysis of the academic performance of the students in the experimental class (HPS) and control class before the intervention is displayed in Table 1.

Table 1. Independent t-test analysis of students' achievement scores in Heuristic Problem-solving (HPS) classes and control class before the intervention

Strategies	Mean	Std. Dev.	df	Mean-Diff.	95% confidence interval of the difference		T	Sig.
					Lower	Upper		
HPS	24.38	9.198	78	-.125	-4.551	4.301	0.056	0.189
CONT	24.50	10.636		-.125	-4.553	4.303		

Before the intervention, the experimental class's Mathematics students' achievement (Mean = 24.38; Std. Dev = 9.198) was quite comparable to that of the control class (Mean = 24.50; Std. Dev = 10. 636). Additionally, the experimental group class's mean difference was -0.125, 95% CI [-4.551 to 4.301]. Similar to this, there was no difference in the means before treatment when it compared to the control class, where the mean difference was -0.125, 95% CI [-4.553 to 4.303]. Additionally, Table 1 results ($t = 0.056$, $df = 78$; $p<0.05$) revealed that there was not a significant difference in the students' Mathematics achievement levels before the intervention.

3.2. Hypothesis 2: There is no significant difference in Mathematics achievement scores of students in Heuristic Problem-Solving classes and control class after the intervention

The analysis of the academic performance of the students in the experimental class (HPS) and control class after the intervention is displayed in Table 2. After the intervention, students'

Mathematics achievement in the experimental class was significantly higher than that of the control class (Mean = 31.08; Std. Dev = 8.689). Additionally, the experimental group class's mean difference was 1.750, 95% CI [-1.476 to 4.876]. Similar to this, there was a difference in means ($p>0.05$) after the treatment, as shown by the mean difference in the control class, which was 1.700, 95% CI [-1.488 to 4.888]. Additionally, Table 2 ($t = 1.066$, $df = 78$; $p<0.05$) revealed a significant difference in the student Mathematics achievement levels after the intervention.

Table 2. Independent t-test analysis of students' achievement scores in Heuristic Problem-solving (HPS) classes and control class after the intervention

Strategies	Mean	Std. Dev.	df	Mean-Diff.	95% confidence interval of the difference		T	Sig.
					Lower	Upper		
HPS	31.08	8.689	78	1.750	-1.476	4.876	0.001	1.066
CONT	29.38	5.128		1.700	-1.488	4.888		

3.3. Hypothesis 3: There is no significant difference in Mathematics retention scores of students in Heuristic Problem-Solving classes and control class after the intervention

The analysis of the retention of students in the experimental class (HPS) and control class after the intervention is displayed in Table 3. After the intervention, students' retention in Mathematics was significantly higher in the experimental class than in the control class (Mean = 30.18; Std. Dev = 6.857). Additionally, the experimental group class's mean difference was 2.30, with a 95% confidence interval of [-0.513 to 5.113]. Similarly, there was a difference in means after the treatment, as seen by the control class's mean difference of 2.300, 95% CI [-0.514 to 5.114]. Additionally, Table 3 ($t = 0.202$, $df = 78$; $p>0.05$) revealed a significant difference in the students' retention levels after the intervention.

Table 3. Independent t-test analysis of students' retention scores in Heuristic Problem-solving (HPS) classes and control class after the intervention

	Strategies	Mean	Std. Dev.	df	Mean-Diff.	95% confidence interval of the difference		T	Sig.
						Lower	Upper		
Delayed Post-Test	**HPS**	30.18	6.857	78	2.300	-0.513	5.113	0.009	0.202
	CONT	27.88	5.730		2.300	-0.514	5.114		

First of all, this is the first field study to examine whether the student-oriented teaching method (Heuristic Problem-Solving) affects the Senior Secondary school one (SSS1) in Ogun state, Nigeria. Second, as it enhances student achievement and retention in Mathematics learning, the intervention has been shown to be effective and efficient in teaching Mathematics in senior secondary schools. The reason for the achievement and retention ability of the student in Mathematics when the student-centered teaching method (Heuristic problem-solving) was used in this research cannot be unconnected to the fact that most of the student-centered teaching methods have some influence on non-intellectual factors such as learning habits, interest, value, enjoyment, motivation, and students' characteristics. For instance, Li (2020) noted that secondary school students' use of student-centered teaching strategies provides a significant interest in and excitement for learning Mathematics. Liu (2018) agreed that using student-centered teaching strategies can increase Mathematics learning initiatives and increase interest among students. The finding that Heuristic Problem-Solving (HPS) strategy improved students' achievement and retention in Mathematics is consistent with that of Novotna et al. (2014) and

that Heuristic Problem-Solving method increases students' achievement and retention in Mathematics.

The fact that Heuristic Problem-Solving involved student-centered learning methods, where the students worked cooperatively in groups in a meaningful environment with little guidance from the facilitator during the teaching and learning process, can also be attributed to the significant difference in the mean achievement and retention scores of the students in the experimental group. Additionally, during the teaching and learning process, students in the experimental groups collaborated to interpret mathematical concepts and synthesize these notions into new mathematical values. The intervention helped the learners comprehend Mathematics conceptually and equipped them with the skills needed to answer mathematical questions. A student who has a deep comprehension of a concept can use the idea or concepts in problem solving to deal with new and even unfamiliar situations (Gagnon & Maccini, 2010). This is in sharp contrast to the conventional teaching methods as observed, where the lessons were teacher-centered and the students learnt abstract mathematical concepts with no evidence of incorporation of group learning or the integration of meaningful authentic real-life problems.

Collaborative teaching is an important variable for improving and enhancing student learning in science and Mathematics (Ogunkunle, 2011). The students that were exposed to Heuristic Problem-Solving have opportunities for collaborative learning. According to (Abonyi & Umeh, 2014), HPS can make Mathematics less abstract. Many students struggle with Mathematics because of the abstractness of the concept. Concrete manipulatives that used in the HPS have been shown to increase students' understanding of these abstract concepts. Furthermore, the higher achievement and retention of students in the experimental groups also shows that the strategy is effective in the teaching of Mathematics. The strategy also provided students with clear expectations and scaffolding, which led to an increased understanding of the concepts behind solving mathematical problems. This was in line with Maccini & Hughes' (2010) assertion that the use of a student-centered teaching method by Mathematics teachers during the teaching and learning process was responsible for the Senior Secondary School students' high Mathematics achievement.

Additionally, improvements in achievement and retention scores of the students in the experimental groups showed that they actively participated and learned by doing. This supported the findings of Obodo (2017) and the recommendations made in the West African Examination Council (WAEC) Examiner report (2018) that the teaching of Mathematics should be student-centered and not dogmatic.

4. CONCLUSION

This study examined how students' achievement and retention in Mathematics in Ogun State, Nigeria, were affected by Heuristic Problem-Solving methods. Three research hypotheses were developed and tested in accordance with the study's objectives using independent t-test analysis, with a 0.05 level of significance. Based on the quantitative analysis of the data from the respondents, the following were the main findings of the study. Firstly, there was no significant difference in the mathematics achievement scores of students in Heuristic Problem -Solving class and control class before the intervention. Secondly, there was a significant difference in Mathematics achievement scores of students in Heuristic Problem-Solving classes and control class after the intervention, and thirdly, there was a significant difference in Mathematics retention scores of students in Heuristic Problem -Solving class and control class after the intervention. In conclusion, the results of the findings indicated that the Heuristic Problem-solving strategy enhances students' achievement and retention of knowledge in Mathematics, hence teachers should be encouraged to integrate student-centered teaching

methods into their teaching methods in so that students' misconceptions about Mathematics as a difficult subject in schools may be reduced.

Declaration of Interest
The authors hereby declare that there is no conflict of interest.

Acknowledgement
We acknowledge the principals of Ogbogbo Community High School and Adeola Odutola Grammar School for allowing us to use their schools for the study. Moreover, the Mathematics' teachers in the sampled schools for their support. Lastly, we acknowledge the students that willingly volunteered to be used as respondents.

REFERENCES

Abonyi OS, Umeh VO. (2014). Effects of heuristic method of teaching on students' achievement in algebra. *International Journal of Scientific and Engineering Research*, 5(2), 1735-1740.

Adiguzel T, Akpinar Y. (2014). Improving school children's mathematical word problem solving skills through computer-based multiple representations. *Association for Educational Communications and Technology*, 27(1), 19-25.

Ary D, Jacobs LC, Sorensen C. (2010). *Introduction to Research in Education*, Wadsworth. Canada.

Bottge B, Heinrichs M, Mehta Z, Hung Y. (2014). Teaching mathematical problem solving to middle school students in math, technology education, and special education classrooms. *Research in Middle Level Education*, 27(1), 43-68.

Gagnon JG, Maccini P. (2010). Teacher-reported use of empirically validated standards-based instructional approaches in secondary Mathematics. *Remedial and Special Education*, 28(1), 43-56.

King A. (2011). Effects of training in strategic questioning of children's problem-solving performance. *Journal of Educational Psychology*, 83(3), 307-317.

Li WZ. (2020). A case study of the effect of problem-solving on mathematical problem-solving ability of junior high school students. PhD Dissertation, Xinjiang Normal University.

Liu WR. (2018). A practical study of students' talking Mathematics activities in junior high school Mathematics classroom. PhD Dissertation, Inner Mongolia Normal University.

Maccini P, Hughes C A. (2010). Effects of a problem-solving strategy on the introductory algebra performance of secondary students with learning disabilities. *Learning Disabilities Research & Practice*, 15(2), 10-21.

Marzano R, Pickering D, Pollock J. (2001). Classroom instruction the works: Research based strategies for increasing student achievement. Upper Saddle River, NJ: Pearson Education, Inc.

Novotna PJ, Eisenmann J, Pribyl J, Ondrušová M, Brehovsky J. (2014). Heuristic strategies in problem solving in school Mathematics. Proceedings of the 10th International Conference on Efficiency and Responsibility in Education, Nigeria.

Obodo GC. (2013). Mathematics-A language for computer in the new millennium: Implication to the Society. Proceedings of the 37th Annual conference of MAN, Nigeria.

Ogunkunle RA. (2011). Teaching of Mathematics in Schools-The Laboratory Approach. *International Journal Educational Development*, 8(1), 180-184.

Owen E, Sweller J. (2015). Should Problem solving be used as a learning device in Mathematics? *Journal for Research in Mathematics Education*, 20(3), 322-328.

Polya G. (2004). How to solve it: a new aspect of mathematical method. Princeton, NJ: Princeton University Press.

West African Examinations Council's Senior School Certificate Examination Chief Examiner's Report on Biology (Genetics). (2015, 2016, 2017, 2018 and 2019). Statistics Section, West African Examination Council (WAEC) National Office, Onipanu, Lagos, Nigeria.