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Effect of Problem-Solving Approach on Students' Mathematics Achievement in Enugu Education Zone, Enugu State, Nigeria

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ABSTRACT

This quasi-experimental study examined the effect of a structured problem-solving approach, operationalized through Pólya's four-step model, on senior secondary students' mathematics achievement in Enugu Education Zone, Enugu State, Nigeria. The study also tested the moderating influences of gender and school location. A pretest, posttest non-equivalent control-group design in a 2 × 2 × 2 factorial arrangement (instructional approach, gender, school location) was adopted. The sample comprised 246 Senior Secondary Two students drawn from eight intact classes in four co-educational public secondary schools (two urban and two rural). The experimental group (n = 124) was taught algebraic word problems, quadratic equations, and applied mensuration for six weeks using Pólya's understand, plan, carry out, look back cycle. The control group (n = 122) received the same content through the conventional lecture method. A 40-item Mathematics Achievement Test (KR-20 = .81) provided pretest and posttest data. Two-way analysis of covariance, with pretest scores as covariate, tested the hypotheses at the .05 level. Students taught with the problem-solving approach obtained a higher adjusted posttest mean (M = 27.38) than those taught by lecture (M = 21.41). The main effect of instructional approach was statistically significant, $F(1, 237) = 72.16$, $p < .001$, partial $\eta^2 = .23$. Gender had no significant main effect. School location favored urban students. A significant approach × location interaction indicated that the advantage of the problem-solving approach was larger in urban schools. The findings support systematic use of Pólya's model in SS2 mathematics and targeted support for rural classrooms.

Keywords: *problem-solving approach, Pólya's model, mathematics achievement, gender, school location, Enugu Education Zone, ANCOVA*

1. INTRODUCTION

Mathematics occupies a central place in Nigeria's secondary curriculum because it supplies the language and tools of science, technology, engineering, and quantitative citizenship (Federal Republic of Nigeria, 2013). Despite that policy status, achievement in public examinations remains uneven. WAEC Chief Examiners' reports have for many years identified poor translation of word problems into mathematical statements, weak application of algebraic processes, and limited capacity to interpret real-life quantitative situations (WAEC, 2019). Those weaknesses point to instruction that

privileges demonstration and recall over the disciplined practice of solving non-routine problems (Charles & Lester, 1984).

Enugu State is not exempt from this pattern. Studies in Enugu Education Zone and neighbouring zones have documented modest mean achievement in algebra and mensuration when teaching is dominated by the lecture method, and they have shown that structured problem-solving techniques can raise those means (Nneji, 2013; Nneji & Udabah, 2020; Unodiaku, 2013). A problem-solving approach treats the solution process as the object of teaching. Pólya's (1957) four-phase heuristic, understanding the problem, devising a plan, carrying out the plan, and looking back, remains the most widely taught explicit model in school mathematics. Schoenfeld (1985, 1992) showed that school students often possess adequate resources yet fail because they do not monitor their own plans.

1.1 Problem, purpose and hypotheses

If students in Enugu Education Zone continue to meet algebraic and mensuration tasks mainly through teacher demonstration, they will keep failing items that require them to interpret a situation, choose a representation, execute a plan, and check reasonableness. The study compared the mean achievement of students taught with the problem-solving approach and those taught with lecture, compared male and female students within the problem-solving condition, and tested approach × gender and approach × location interactions. H01 to H04 corresponded to these four questions.

2. LITERATURE REVIEW

Problem solving in school mathematics is both a goal and a method (NCTM, 2000). Lester (2013) cautioned that merely assigning word problems does not constitute problem-solving instruction. Teachers must model heuristic moves and require students to articulate plans. Ali et al. (2010) found that elementary students taught with an explicit problem-solving method outscored a traditional group.

Nneji (2013) taught SS2 algebra in Ebonyi State with Pólya's model and obtained higher achievement and retention than an expository comparison, with no significant gender difference. Olofin and Kolawole (2020) reported a significant posttest advantage for Kolawole's Problem-Solving strategy. Badru (2022) found a significant main effect of a problem-solving approach on cognitive performance.

Gender differences in mathematics achievement in Nigeria are inconsistent. Several problem-solving experiments have found no significant gender main effect once prior achievement is covaried (Nneji, 2013; Nwigwe & Osuafor, 2023). School location is a more stable source of variance in Enugu State. Urban schools typically have more qualified teachers, fuller timetables, and greater access to textbooks (Nneji & Udabah, 2020; Unodiaku, 2013). Nneji and Udabah (2020) found both a location main effect and a method × location interaction when a reduction problem-solving technique was used in Enugu Education Zone. The present study keeps Pólya's four steps intact, uses SS2 content that WAEC flags, and includes both gender and location.

3. METHODOLOGY

The study adopted a quasi-experimental pretest, posttest non-equivalent control-group design arranged as a 2 × 2 × 2 factorial: instructional approach, gender, and school location. It was conducted in Enugu Education Zone. Schools were stratified into urban and rural. Two urban and two rural co-educational public schools were selected. Two intact SS2 classes were drawn from each school. Within each school, one class was assigned by coin toss to the experimental condition and the other to the control condition. The sample was 246 students (experimental n = 124; control n = 122), of whom 128 were male and 118 were female, and 126 attended urban schools and 120 attended rural schools.

The Mathematics Achievement Test contained 40 four-option items on algebraic word problems, quadratic equations, and mensuration applications. A table of specification distributed items across

knowledge (10), comprehension (10), application (14), and analysis (6). Three specialists reviewed the items. A pilot in Agbani Education Zone yielded KR-20 = .81. Regular mathematics teachers implemented the treatments after a two-day workshop. Instruction lasted six weeks, three periods of 40 minutes each week. Experimental lessons required students to state knowns and unknowns, name a strategy, execute in pairs, and verify by substitution or estimation. Control lessons used teacher explanation, chalkboard examples and seatwork. ANCOVA in SPSS 27 used pretest scores as covariate.

4. RESULTS

Table 1. Pretest and posttest MAT scores by instructional approach

Approach	n	Pre M	Pre SD	Post M	Post SD
Problem-solving	124	18.46	4.71	27.42	5.18
Lecture	122	18.21	4.88	21.36	5.64
Total	246	18.34	4.79	24.41	6.17

The groups were comparable at pretest. Mean gain was 8.96 for problem-solving and 3.15 for lecture.

Table 2. Posttest means by approach and gender

Approach	Gender	n	Post M	Post SD
Problem-solving	Male	64	27.81	5.02
Problem-solving	Female	60	27.00	5.36
Lecture	Male	64	21.58	5.71
Lecture	Female	58	21.12	5.60

Table 3. Posttest means by approach and school location

Approach	Location	n	Post M	Post SD
Problem-solving	Urban	64	29.16	4.61
Problem-solving	Rural	60	25.57	5.22

Lecture	Urban	62	22.19	5.48
Lecture	Rural	60	20.50	5.71

Table 4. ANCOVA of posttest MAT scores

Source	SS	df	F	p	ηp²
Pretest	1846.22	1	86.41	<.001	.27
Approach	1541.73	1	72.16	<.001	.23
Gender	24.18	1	1.13	.288	.01
Location	218.64	1	10.23	.002	.04
Approach × Gender	8.06	1	0.38	.539	.00
Approach × Location	91.47	1	4.28	.040	.02
Error	5063.88	237	,	,	,

Assumptions of linearity, homogeneity of regression slopes and homogeneity of variances were satisfied. H01 was rejected: adjusted means were 27.38 for problem-solving and 21.41 for lecture, a large effect. H02 and H03 were not rejected. H04 was rejected. The problem-solving advantage was 6.97 points in urban schools and 5.07 points in rural schools.

5. DISCUSSION

A six-week implementation of Pólya's four-step model produced a large improvement in SS2 mathematics achievement relative to lecture. The adjusted mean difference of nearly six points on a 40-item test is educationally non-trivial. The result aligns with Nneji (2013), Olofin and Kolawole (2020) and Badru (2022), and with Schoenfeld's (1985) claim that making control decisions explicit improves performance. Phase 1 forces students to write given and required before they reach for a formula, attacking the translation failure that WAEC (2019) documents. The look-back phase builds a habit of checking units and substituting answers.

The absence of a gender main effect and of an approach × gender interaction is consistent with Nneji (2013) and Nwigwe and Osuafor (2023). School location behaved differently. Urban students scored higher in both conditions, and the problem-solving advantage was larger in urban schools, reproducing Nneji and Udabah (2020). Rural students still gained more than five raw points under Pólya's model. The interaction is a warning about implementation intensity, not a reason to withhold the method from rural schools.

Harbor-Peters (2001) long argued that Nigerian students' difficulties are as much pedagogical as cognitive. Methods that do not require students to generate representations leave them unable to start non-routine items. Process-oriented programmes that teach students how to plan and monitor solutions have a long record of reducing that deficit (Charles & Lester, 1984). A problem-solving approach targets that deficit directly because Phase 1 of Pólya's cycle is precisely the work of restating the problem, identifying unknowns, and choosing a representation.

Vygotsky's (1978) zone of proximal development supplies a social reading of the same process. The teacher and more capable peers first regulate the four steps. The student later internalizes them. Together these accounts predict that students who practice an explicit cycle will outperform students who only observe worked examples, and that the advantage should appear most clearly on items that demand translation and planning rather than recall.

Teacher quality was addressed by using only graduate mathematics teachers and by training both groups for equal time. Content was identical. Testing effect was reduced by rearranging posttest items. Hawthorne effects were limited by presenting both treatments as ordinary scheme-of-work coverage. Intact-group nonequivalence was statistically managed with the pretest covariate. Schools were far enough apart to make student discussion across conditions unlikely.

Intact classes were used. ANCOVA reduces but does not eliminate selection bias. The treatment lasted six weeks and measured immediate posttest achievement, not delayed retention. Only public co-educational schools were sampled. The MAT was multiple-choice and therefore captured recognition of correct solutions more readily than written planning. Future studies should add a delayed posttest, include single-sex and private schools, score students' written plans as a process measure, and compare Pólya's model with other named heuristics inside the same zone.

6. CONCLUSION AND RECOMMENDATIONS

A Pólya-based problem-solving approach significantly improved SS2 students' mathematics achievement in Enugu Education Zone compared with the lecture method. The improvement did not depend on gender. It was present in both urban and rural schools but was larger in urban schools. Mathematics teachers should adopt Pólya's four-step cycle as the default structure for lessons on word problems, quadratic equations and mensuration applications. The Ministry of Education and PPSMB should incorporate supervised practice of the four steps into cluster workshops. Teacher-education programmes should require micro-teaching of Pólya-structured lessons. Rural schools should receive additional coaching visits during the first weeks of implementation. Textbook authors and NERDC reviewers should include explicit understand, plan, carry out, look back prompts beside worked application items.

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Taken together, the evidence presented in this article is intended to inform classroom practice, teacher education and education-office supervision in Enugu State. The recommended actions are feasible with existing staff, existing compounds or devices, and existing scheme-of-work time, provided that school leaders protect the instructional routine long enough for teachers and students to internalize it.

The findings reported above should be read alongside school-level constraints of power, class size, teacher preparation and examination pressure that structure STEM teaching in Enugu State. Implementation will succeed where those constraints are named and managed rather than ignored.

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