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Problem-Solving Pedagogy and Attitudinal Change in Mathematics: A Quasi-Experimental Study in Nigerian Secondary Schools

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ABSTRACT

This study examined the effect of a Pólya-based problem-solving instructional strategy on senior secondary students' attitudes toward mathematics in Kaduna State, Nigeria. Guided by constructivist learning theory, the study adopted a quasi-experimental pretest–posttest control group design involving 200 students purposively selected from public schools. The Mathematics Attitude Questionnaire (MAQ) was administered before and after a six-week intervention to measure enjoyment, anxiety, perceived competence, and perceived usefulness. The experimental group received instruction based on Pólya's four-step model, while the control group received conventional teaching. Data was analyzed using descriptive statistics and analysis of covariance (ANCOVA) to control baseline attitudes. Results revealed that although the problem-solving group achieved higher mean post-test attitude scores, the difference was not statistically significant ($p > .05$). Pre-attitude scores were the strongest predictor of post-attitudes, indicating that existing dispositions largely determined outcomes. These findings suggest that short-term problem-solving interventions may foster slight positive trends but require longer and more sustained implementation to produce significant attitudinal change. The study recommends integrating structured problem-solving with effective support strategies to enhance students' confidence and interest in mathematics.

INTRODUCTION

Attitudes toward mathematics represent one of the most influential affective factors determining students' academic success. A positive attitude promotes confidence, persistence, and engagement in solving mathematical problems, whereas a negative attitude often manifests anxiety, low self-esteem, and avoidance of participation. Prior research (Suleiman et al., 2020; Shah et al., 2023) has established a strong correlation between students' attitudes toward mathematics and their performance, as well as their long-term career choices in science and technology. In Kaduna State, Nigeria, declining interest and confidence in mathematics have contributed to low student achievement at the secondary school level. These challenges are compounded by teacher-centered pedagogies, limited instructional resources, and large class sizes, all of which restrict meaningful student–teacher interaction.

To address these issues, problem-solving approaches have been widely recognized as promising alternatives to traditional methods. In problem-solving instruction, students become active participants who construct understanding through direct engagement with contextualized mathematical tasks. This approach not only enhances cognitive outcomes such as critical and creative thinking but also nurtures affective domains such as motivation, confidence, and perseverance (Hmelo-Silver et al., 2007; Liljedahl et al., 2016). Among problem-solving models, Pólya's (1957) four-step framework understanding the problem, devising a plan, carrying out the plan, and looking back has proven particularly effective for guiding systematic reasoning and reflective learning. Rooted in constructivist theory, Pólya's model

views knowledge as actively constructed through interaction with meaningful tasks rather than passively received from teachers (Oduro, 2022). It encourages students to internalize mathematical processes, reflect on strategies, and develop ownership of their learning.

Empirical studies worldwide have confirmed that Pólya-based instruction enhances both cognitive and affective outcomes. Students engaged in problem-solving activities experience greater enjoyment and perceive mathematics as relevant to real-world problem contexts (Geiger et al., 2018; Hussein & Csíkos, 2023; Fülöp, 2021). Collaborative problem-solving further fosters social interaction and shared ownership of learning, creating a supportive classroom environment (Vygotsky, 1978; Hmelo-Silver, 2013). However, much of this evidence comes from well-resourced educational systems, whereas Nigerian classrooms particularly in Kaduna State face structural challenges, including overcrowding, resource scarcity, and a persistent reliance on teacher-centered instruction (Dauda et al., 2016; Olayinka & Olayinka, 2023). These contextual limitations raise questions about the effectiveness and adaptability of problem-solving pedagogy in such environments.

The theoretical foundation of this study integrates constructivist learning theory with the affective domain taxonomy of Krathwohl et al. (1964), which conceptualizes attitude as an interaction among beliefs, emotions, and learning experiences. Engagement in authentic problem-solving tasks can enhance self-efficacy, reduce mathematics anxiety, and strengthen perceived relevance of the subject (Zakariya et al., 2022). Thus, Pólya's model functions not only as a cognitive scaffold but also as an affective catalyst that encourages confidence, autonomy, and intrinsic motivation. When students experience success in solving challenging problems, they are more likely to view themselves as competent learners capable of mastering mathematics, thereby reshaping their emotional relationship with the subject.

Although numerous studies have examined problem-solving pedagogy, most Nigerian research has focused primarily on cognitive outcomes, such as academic performance and problem-solving skills (Krawec et al., 2013; Mazana et al., 2018), with limited attention to attitudinal or emotional changes. Moreover, few studies have statistically controlled pre-existing attitudes to determine whether any observed shifts result from instructional interventions or from students' initial dispositions. Previous evidence suggests that attitudes toward mathematics are relatively stable and resistant to short-term change (Hannula, 2002; Tobih et al., 2025). Consequently, the potential of short-term, structured problem-solving interventions to improve affective outcomes remains uncertain—particularly in under-resourced contexts like Kaduna State.

In this context, empirical evidence on the effect of Pólya-based problem-solving strategies on students' attitudes toward mathematics in Nigeria is scarce. This gap highlights the need for systematic investigation of whether and to what extent such instructional approaches can influence students' emotional engagement and perceptions of mathematics. The present study seeks to address this gap by employing a quasi-experimental design that compares students exposed to Pólya's problem-solving model with those taught using conventional methods, while statistically controlling for baseline attitudes through analysis of covariance (ANCOVA).

By integrating the principles of constructivism and affective learning theory, this research aims to contribute to both theory and practice in mathematics education. It extends existing scholarships by examining how structured problem-solving interventions can shape students' attitudes in a low-resource setting and by quantifying the relative influence of pre-attitude factors. Specifically, this study aims to determine whether there is a significant difference in students' attitudes toward mathematics between those taught using a Pólya-based problem-solving strategy and those taught using traditional teacher-centered methods, after controlling for initial attitudinal dispositions.

METHODOLOGY

This study employed a quasi-experimental pretest–posttest control group design to examine the effect of a Pólya-based problem-solving instructional strategy on students' attitudes toward mathematics. The design was chosen because it allows for the systematic comparison of groups in a natural classroom setting, where random assignment is often impractical. By incorporating both pre-intervention and post-intervention measures, this design enabled the researcher to control for initial differences in attitudes and isolate the specific effect of the instructional method.

Participants and Setting

The population of the study comprised Senior Secondary School Two (SSS II) students in public secondary schools across Kaduna State, Nigeria. This educational level was selected because students

at this stage are transitioning into more abstract mathematical concepts, and their attitudes can significantly influence subject choice and future academic pathways. Two public secondary schools were purposively selected to represent the diversity of Kaduna State in terms of geographical location, school size, and resource availability.

A total of 200 students participated in the study, consisting of 100 students in the experimental group and 100 in the control group. The experimental group received instruction through the Pólya-based problem-solving strategy, while the control group was taught using the conventional teacher-centered method. No random assignment was implemented due to institutional constraints; however, both groups were comparable in demographic composition and prior mathematics achievement, as confirmed through pretest analysis.

Instrument

Students' attitudes toward mathematics were measured using the Mathematics Attitude Questionnaire (MAQ) developed by Palacios et al. (2013). The MAQ is a standardized and psychometrically validated instrument designed to assess four dimensions of mathematical attitude: (1) enjoyment of mathematics, (2) mathematics anxiety, (3) perceived competence, and (4) perceived usefulness of mathematics. The instrument employs a five-point Likert scale ranging from strongly disagree (1) to strongly agree (5).

For the present study, the MAQ was adapted slightly to ensure contextual relevance and linguistic clarity for Nigerian students. A pilot test was conducted with 30 students from a similar population to establish reliability and content validity. Cronbach's alpha coefficient obtained was 0.87, indicating high internal consistency. The adapted instrument was then administered to both groups before and after the six-week instructional intervention.

Instructional Procedures

The intervention was designed around Pólya's (1957) four-step problem-solving model, which served as a cognitive and affective framework for learning mathematics. Each lesson explicitly followed the four stages:

- Understanding the Problem – Students identified known and unknown variables, rephrased the problem in their own words, and clarified goals through guided questioning.
- Devising a Plan – Students collaboratively proposed multiple solution strategies, discussed their feasibility, and selected the most appropriate mathematical approach.
- Carrying Out the Plan – Students executed their chosen strategies, performed computations, and verified their results through peer discussion.
- Looking Back – Students reflected on the effectiveness of their solutions, considered alternative methods, and related their findings to real-life contexts.

The teacher acted primarily as a facilitator, encouraging exploration, reasoning, and discussion. Problems were selected from the national mathematics curriculum and contextualized in everyday Nigerian scenarios (e.g., budgeting, measurement, and data interpretation) to enhance relevance.

In contrast, the control group received traditional instruction characterized by direct explanation, teacher demonstration, and individual seatwork. Both groups were taught by teachers of comparable qualification and experience to reduce instructor-related bias. The intervention was conducted over six consecutive weeks, with two 45-minute sessions per week, within the regular academic calendar.

Data Collection and Analysis

Data was collected at two points: prior to the commencement of the intervention (pretest) and immediately after the six-week program (posttest). Students' scores on the MAQ provided quantitative measures of their attitudes toward mathematics.

Descriptive statistics, including means and standard deviations, were used to summarize students' attitude scores for both the experimental and control groups. To examine whether there was a significant difference in post-intervention attitudes while accounting for initial differences, an Analysis of Covariance (ANCOVA) was conducted. In this analysis, the posttest attitude scores served as the dependent variable, the type of instructional strategy (problem-solving vs. conventional) as the independent variable, and the pretest scores as the covariate. This allowed for adjustment of baseline differences and provided a more accurate estimation of the treatment effect.

All assumptions of ANCOVA—including linearity, normality, and homogeneity of variances—were checked prior to analysis. Levene's test confirmed the equality of error variances, and scatterplots supported the assumption of linearity between covariate and dependent variable. Statistical significance was determined at $p < .05$. Effect sizes were reported using partial eta squared (η^2) to indicate the

magnitude of observed effects. Data were analyzed using the Statistical Package for the Social Sciences (SPSS) version 26.

Ethical Considerations

Ethical approval for the study was obtained from the Kaduna State Ministry of Education. School principals provided institutional consent, and all participants were informed about the purpose of the study, confidentiality of responses, and voluntary participation. No identifying information was collected, and students were assured that their participation or responses would not affect their academic grades.

RESULT AND DISCUSSION

Result

Research Question

Would there be a difference between the attitude of students taught mathematics using a problem-solving strategy and those taught using the conventional method?

To address this research question, the descriptive statistics for students' attitude scores on the Mathematics Attitude Questionnaire (MAQ) under the conventional teaching method and the problem-solving strategy are presented in Figure 1.

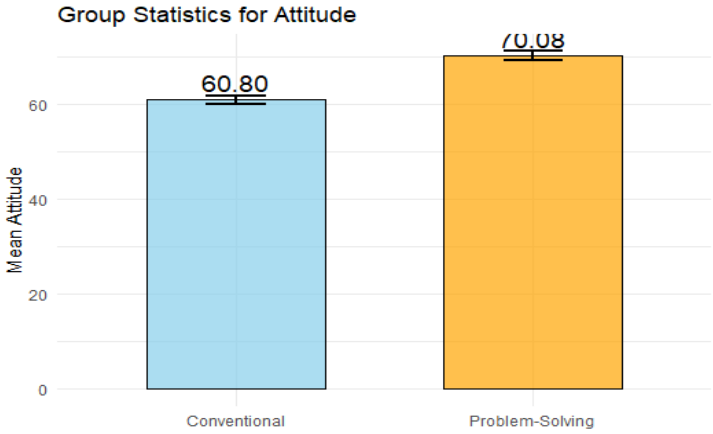

Figure 1. Comparison of Mean Attitude Scores for Conventional Teaching Method and Problem-Solving Strategy

Figure 1 presents a comparison of mean post-test attitude scores between students taught using the problem-solving strategy and those taught using the conventional method. As shown, the problem-solving group recorded a higher mean score (M = 70.08) compared to the conventional group (M = 60.80). The error bars, representing the standard error of the mean, illustrate the degree of variability within each group's scores. Although the visual pattern suggests a more favorable disposition toward mathematics in the problem-solving group, inferential statistical analysis was necessary to determine whether this observed difference was statistically significant. This figure provides an initial descriptive insight into the data, setting the stage for the ANCOVA results reported subsequently, which assess the difference while controlling pre-intervention attitudes.

Null Hypothesis

There is no significant difference between the attitude of students taught mathematics using a problem-solving strategy and those taught using the conventional method.

To test this hypothesis, A one-way analysis of covariance (ANCOVA) was conducted to examine the effect of the teaching method (Problem-Solving vs. Conventional) on students' attitudes while controlling for pre-test scores. The results are shown in Table 1.

Tabel 1. Analysis of Covariance (ANCOVA) for the Difference in Attitude between Problem-Solving and Conventional Groups

Source	Type III Sum of Squares	Df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	10002.113[a]	2	5001.057	1272.773	.000	.951

Source	Type III Sum of Squares	Df	Mean Square	F	Sig.	Partial Eta Squared
Intercept	276.016	1	276.016	70.246	.000	.351
Pretest	7146.999	1	7146.999	1818.917	.000	.933
Group	5.084	1	5.084	1.294	.257	.010
Error	510.804	130	3.929			
Total	575823.000	133				
Corrected Total	10512.917	132				

a. R Squared = .951 (Adjusted R Squared = .951)

The univariate ANCOVA results (Table 1) revealed that the instructional strategy, problem-solving versus conventional, did not have a statistically significant effect on students' post-test attitudes toward mathematics after controlling pre-test attitudes, $F (1, 130) = 1.294$, $p = .257$, partial $\eta^2 = .010$. Given that the p-value exceeds the conventional alpha level of 0.05, the null hypothesis could not be rejected. This means that there was no statistically reliable evidence that the problem-solving strategy produced different post-intervention attitudes compared to conventional teaching once initial attitudes were taken into account. The partial eta squared value of 0.010 indicates a small effect size, with the instructional method explaining only 1.0% of the variance in post-test attitudes. In contrast, the corrected model was highly significant, $F (2, 130) = 1272.773$, $p < .001$, largely because of the very strong predictive influence of pre-test attitudes, $F(1, 130) = 1818.917$, $p < .001$, partial $\eta^2 = .933$. This suggests that students' initial attitudes explained an overwhelming 93.3% of the variance in their post-test scores, underscoring the central role of baseline dispositions in shaping how learners respond to instruction. The R^2 value of 0.951 (adjusted $R^2 = 0.951$) further confirms that the model accounted for 95.1% of the variance in post-test attitudes, with nearly all of this explanatory power attributable to pre-test attitudes rather than to the instructional method. Before interpreting these findings, the assumption of homogeneity of error variances was evaluated using Levene's test, $F (1, 131) = 0.490$, $p = .485$. The non-significant result indicates that the assumption was met, meaning the variance in post-test attitudes was statistically equivalent across both instructional groups. Meeting this assumption supports the validity of the ANCOVA results and suggests that the non-significant group difference is not due to unequal variability between groups. While descriptive statistics indicated that students in the problem-solving group achieved a higher mean post-test score ($M = 70.08$, $SD = 7.654$) than those in the conventional group ($M = 60.80$, $SD = 7.638$), the ANCOVA results clarify that this difference is largely attributable to pre-existing attitudes rather than the intervention itself. This finding is consistent with prior research suggesting that students' affective dispositions toward mathematics are often deeply rooted and resistant to short-term change (Hannula, 2002; Fülöp, 2021). The small effect size observed here further suggests that short-term pedagogical changes, while potentially meaningful in other domains, may require longer and more sustained implementation to yield measurable changes in affective outcomes.

Discussion

This study examined the impact of a structured problem-solving instructional strategy, grounded in Pólya's four-step model, on the attitudes of senior secondary school students toward mathematics in Kaduna State, Nigeria. Using a quasi-experimental pretest–posttest design, the research sought to determine whether embedding problem-solving tasks into classroom instruction could yield improvements in student attitudes compared to conventional methods.

Although descriptive statistics indicated that students in the problem-solving group achieved a higher mean post-test attitude score ($M = 70.08$, $SD = 7.654$) than those in the conventional group ($M = 60.80$, $SD = 7.638$), the ANCOVA results revealed that this difference was not statistically significant, $F(1, 130) = 1.294$, $p = .257$, partial $\eta^2 = .010$. The effect size was small, suggesting that the instructional method explained only 1.0% of the variance in post-test attitudes. While such modest effects are easily overlooked, even small improvements in confidence or reductions in mathematics anxiety can be educationally meaningful in under-resourced classrooms where participation and persistence are often fragile. Over longer periods or at scale, such incremental changes may accumulate into more substantial motivational benefits.

A key finding was the strong predictive influence of students' pre-test attitudes, which accounted for 93.3% of the variance in post-test outcomes ($F(1, 130) = 1818.917$, $p < .001$, partial $\eta^2 = .933$). This underscores the entrenched nature of affective dispositions toward mathematics and echoes international research showing that beliefs, anxieties, and self-perceptions strongly shape learners' responses to instructional innovations (Hannula, 2002; Schoenfeld, 2013; Rotgans & Schmidt, 2019). Studies confirm that attitudinal change typically requires prolonged exposure to supportive, student-centred environments, while shorter interventions often show only trends rather than statistically

significant effects. Conversely, sustained use of problem-solving strategies has been shown internationally to build confidence and resilience (Fülöp, 2021; Wang, 2021), suggesting that the relatively short six-week duration of this study may have limited observable gains.

The non-significant results observed here should therefore be interpreted cautiously as indicative rather than conclusive. Nevertheless, the positive direction of the findings aligns with international evidence that problem-solving pedagogy enhances engagement, collaboration, and the perceived relevance of mathematics (Hmelo-Silver et al., 2007; Jonassen, 2010). The structured exploration, collaborative reasoning, and reflective evaluation inherent in Pólya's framework, particularly when tied to real-world applications (Geiger et al., 2018; Inganah et al., 2023), remain promising as part of a broader, long-term instructional reform strategy.

The Nigerian educational context also presents systemic challenges that likely influenced the outcomes. Kaduna State classrooms are often characterised by overcrowding, scarce instructional resources, and reliance on teacher-centred methods (Dauda et al., 2016; Olayinka & Olayinka, 2023). In addition to instructional methods, external influences such as teacher quality, classroom climate, and parental support exert powerful effects on students' mathematical attitudes (Frenzel et al., 2007). These factors, though not directly measured in the present study, may partly explain the dominance of pre-test attitudes and the limited short-term impact of the intervention. This underscores the need for comprehensive approaches that integrate pedagogical reform with systemic support for teachers, families, and school environments.

In conclusion, while no statistically significant differences were observed between instructional groups, the results indicate a trend consistent with prior international findings on the potential of problem-solving pedagogy to foster gradual attitudinal improvements. This highlights the critical role of pre-existing attitudes and contextual factors in shaping outcomes. Future research should adopt longitudinal, mixed methods designs to capture both statistical effects and students lived experiences, while also addressing broader systemic factors that constrain the effectiveness of instructional innovations.

Implications for Practice and Policy

The findings of this study offer several implications for practice, teacher development, and policy in low-resource contexts such as Nigeria. First, the strong influence of pre-existing attitudes underscores the importance of early diagnostic assessments that capture students' anxiety, interest, and self-efficacy. Such assessments can guide teachers in tailoring instruction to learners' affective needs. Second, although immediate affective gains were not statistically significant, the consistent trend toward improvement supports a shift away from didactic instruction toward student-centred, problem-based learning environments. Third, professional development programmes should prepare teachers not only in technical problem-solving strategies but also in creating supportive classroom climates that address motivation and emotional regulation. Finally, policymakers should invest in systemic supports such as contextualised curricular resources, smaller class sizes, and continuous mentoring for teachers, to sustain the implementation of inquiry-based pedagogies.

Limitations of the Study

This study, while rigorous in its design and execution, is subject to several limitations that should be considered when interpreting its findings. First, although the sample size was relatively large for the context, no formal a priori power analysis was performed. The absence of such a calculation limits our ability to determine whether the study was adequately powered to detect small-to-moderate effects. Given the small observed effect size (partial $\eta^2 = .010$), future studies should conduct pre-study power analyses to establish appropriate sample sizes.

Second, the duration of the intervention, limited to six weeks, may not have been sufficient to produce enduring attitudinal change. Affective dispositions typically evolve gradually and often require prolonged exposure to alternative instructional approaches before significant differences can emerge. Third, the study relied on self-reported data through the Mathematics Attitude Questionnaire (MAQ). While the instrument has strong psychometric validity, self-report measures are inherently subjective and may be influenced by social desirability or students' test-taking disposition. Fourth, the quasi-experimental design, though suitable for school contexts, did not permit random assignment, meaning that potential selection bias cannot be entirely ruled out. Although pre-test scores were statistically controlled using ANCOVA, other unmeasured covariates may have influenced the outcomes.

In addition, the findings are context-specific to Kaduna State, Nigeria, where cultural, infrastructural, and pedagogical conditions may differ from those in other Nigerian regions or international contexts. Consequently, the results should be interpreted with caution when considering broader applicability. Replication in other geographical and educational settings is necessary to strengthen the generalisability of these findings.

Finally, the study did not directly assess external factors such as teacher quality, classroom climate, or parental support, all of which are known to shape students' attitudes toward mathematics. The absence of these variables restricts explanatory scope. Future research should therefore incorporate these contextual dimensions, adopt longitudinal and mixed methods designs, and extend intervention duration to provide a more holistic understanding of the complex factors influencing students' mathematical attitudes.

CONCLUSION

This study investigated the effects of a structured problem-solving instructional strategy, grounded in Pólya's model, on the attitudes of senior secondary school students toward mathematics in Kaduna State, Nigeria. Although the intervention group recorded a higher mean post-attitude score than the control group, the difference was not statistically significant after controlling pre-existing attitudes. The small observed effect underscores that while problem-solving approaches may encourage more positive attitude toward trends, their short-term impact is limited when prior dispositions are not simultaneously addressed.

The results highlight the significant predictive power of pre-attitude scores, suggesting that students' initial beliefs, anxieties, and levels of confidence strongly shape how they respond to instructional innovations. These findings echo international research showing that affective change is typically resistant to short-term interventions and requires sustained, student-centred learning environments to become more evident. Thus, innovative pedagogies such as problem-solving may be most effective when embedded within longer-term, systemic reforms that integrate cognitive and affective supports.

While the direction of the results aligns with broader evidence that problem-solving instruction fosters engagement, confidence, and perceived relevance of mathematics, these findings should be interpreted with caution. The study was limited to Kaduna State, and contextual factors, including large class sizes, resource constraints, and reliance on teacher-centred methods, may have shaped outcomes in ways not generalisable to other Nigerian regions or international settings. Additionally, the absence of qualitative data, such as classroom observations or student interviews, restricted the ability to capture learners lived experiences, which would have enriched the interpretation of the quantitative results.

Future research should therefore adopt longitudinal and mixed methods designs that combine statistical analyses with qualitative insights, explore comparative studies across regions and countries, and incorporate external factors such as teacher quality, classroom climate, and parental support. Such approaches will provide a more comprehensive understanding of the complex interplay between instructional strategies, context, and students' attitudes toward mathematics.

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