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EFFECTIVENESS OF THE POLYA STRUCTURED PROBLEM-SOLVING FRAMEWORK: AN EXPERIMENTAL STUDY IN 21ST-CENTURY LEARNING CONTEXTS

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ABSTRACT

This quasi-experimental study examined the effectiveness of the Pólya Structured Problem-Solving Framework in improving the problem-solving and critical-thinking skills of pre-service teachers majoring in Filipino at Capiz State University, Roxas City Campus. Forty junior undergraduate students were assigned to an experimental group (n = 20) and a control group (n = 20). The experimental group received structured instruction using Pólya's four-step problem-solving model, while the control group was taught through traditional instruction. Pre-test and post-test measures were administered to assess students' problem-solving and critical-thinking performance. Descriptive statistics, Wilcoxon signed-rank tests, independent-samples t-tests, and analysis of covariance were used to examine within-group improvement and between-group differences. Results indicated that both groups improved from pre-test to post-test; however, the experimental group obtained higher post-test outcomes in problem-solving and critical-thinking skills. The findings suggest that explicit, structured problem-solving instruction may provide stronger cognitive support for learners than traditional instruction alone. The study contributes to teacher education by showing how a guided and reflective instructional framework can support higher-order thinking development in 21st-century learning contexts.

KEYWORDS: Teacher Education; Guided Discovery; Higher-Order Thinking; Instructional Scaffolding; Quasi-Experimental Design; Reflective Learning; Cognitive Skills; 21st-Century Education.

1. INTRODUCTION

The 21st century has seen rapid changes in educational practices and pedagogy due to globalization, technological advances, and the intricate challenges of the modern world. With these changes, the importance of higher-order cognitive skills, including problem solving and critical thinking, continues to grow. Agencies such as UNESCO and the World Economic Forum advocate for these skills as foundational for creativity, sustainability, and responsible decision-making. The United Nations Sustainable Development Goal (SDG) 4 advocates for the right to quality education and aims to instill critical thinking and the spirit of global citizenship. This creates an expectation for universities to find evidence-based ways to integrate these skills into their curricula. In recent years, one such framework that has gained traction is George Pólya's Four-Step Problem-Solving Model, which includes understanding the problem, making a plan, carrying out the plan, and looking back. Overall, Pólya’s framework is often cited in the mathematics education literature, while its effectiveness in developing critical thinking and cognitive skills in other disciplines is not well understood. The current research attempts to address this gap. It seeks to empirically evaluate the effectiveness of the Polya Structured Problem-Solving Framework on the development of problem-solving and critical thinking skills of pre-service teachers. The results will provide insights to refine curricula, improve pedagogical practices, and assist in making evidence-based choices in teacher education. Important to note, the researcher was motivated to investigate the Effectiveness of the Polya Structured Problem-Solving Framework: An Experimental Study in 21st-Century Learning Contexts. This study aims to establish, in a general sense, the effectiveness of the guided-discovery approach to problem solving. More specifically, it attempts to answer the questions listed below.

1. What are the levels of problem-solving skills and critical thinking skills of the students involved, in the pre-test and post-test, after being taught using Polya Structured Framework Instruction and after being taught using traditional instruction?
2. What are the significant differences, if any, within each group in the pre-test and post-test analysis?

2. MATERIALS AND METHODS

2.1. Research Design

The study employed a quasi-experimental pre-test-post-test control group design. Specifically, it followed a matching-only design, in which participants in the experimental and control groups were made comparable using prior academic performance and then assigned to two instructional groups (Fraenkel and Wallen, 2010).

2.2. Participants

The study consisted of 40 pre-service teachers majoring in Filipino at Capiz State University, Roxas City Campus, who were randomly assigned to the Experimental group (n=20) and the control group (n=20). Two groups were created based on their academic performance from high to low. Upon ranking, all the odd numbers were assigned to the first group, whereas the even numbers were assigned to the second group. Following this, the researcher flipped a coin to decide which group would be the experimental and which would be the control group. Each group was assigned a separate schedule for the instructions. Participants were junior undergraduate students from the College of Education majoring in Filipino, who had no previous exposure to the Polya Structured Problem-Solving Framework.

Table 1: Distribution of Participants.

Group	Total number of students	Percent (%)
Group A (Experimental group)	20	50
Group B (Control group)	20	50
Total	40	100

2.3. Intervention

The treatment group was given a 6-week Polya Structured Problem-Solving Framework intervention, which is broken down into the following: Understanding the problem: the problem, the goal, and the constraints; Devising a plan: alternatives, evaluation, selection; Implementing: execution and monitoring; Reflective evaluation: outcome, process, and improvement.

The control group was taught problem-solving through traditional methods. Both groups had the same instructor.

2.4. Research Instruments

Problem-Solving Skills. The problem-solving skills of students were assessed using a test modified from the Problem-Solving Strategies book by Ted Herr and Ken Johnson (1994). The test consisted of 10 extended-response items. The items were based on the topics and strategies discussed during the intervention period, such as guess and check, draw a picture, make a systematic listing, look for a pattern, look for a formula, use a variable(s) (one and two variables), draw a diagram, solve a simpler problem, work backward, and make a logical deduction. In the problem-solving skills test, the total score was 100 points. Each item was worth 10 points and will be scored based on a rubric taken from the Problem-Solving Strategies book by Ted Herr and Ken Johnson (1994).

Critical Thinking Skills. The critical thinking skills of the students were assessed using a test adopted from Learning Express, LLC (2010). This test consists of 20 items and is divided into four categories: inference, analysis, interpretation, and evaluation.

Inference consisted of 5 items. In this section, the students were required to identify and extract components to draw reasonable conclusions, conjure, hypothesize, evaluate the situation, work with relevant data, and infer the outcomes of data, statements, or questions.

Both assessment tools were reliable and valid.

2.5. Procedure

Matching only a pretest-posttest control group design, as described by Fraenkel and Wallen (2010) is a design in which the researcher tries to make the participants in the experimental and control groups comparable by using previous semesters of two (2) intact groups. The groups were randomly classified as Group A (Experimental instruction) and Group B (Control instruction). The participants of Group A were compared to the students-participants of Group B. A pre-test was given to both groups prior to the intervention. After the pre-test, each group was subjected to different teaching strategies. For Experimental instruction, the time schedule was set from 9:30 to 10:30 in the morning, while the control instruction was from 10:30 to 11:30 in the morning, for a duration of six (6) weeks.

2.6. Data Analysis

IBM SPSS Statistics Version 27.0 was used for data analysis. Students' achievements in mathematics, problem-solving, and critical thinking skills were evaluated through descriptive statistics that included means and standard deviations. These were determined based on participants' pre-and post-test scores. Mean gain scores were computed to assess improvement after the given interventions.

An independent samples t-test was used to assess baseline equivalence for the traditional and explicit instruction groups. The t-test was also used to assess differences in post-test outcomes between the instructional groups.

Assuming normality, differences between pre-test and post-test scores were evaluated in each group using the Wilcoxon Signed-Rank Test. If normality assumptions were not met, then paired-samples t-tests were used to assess improvement in problem-solving and critical thinking skills in each instructional group.

Furthermore, to control for initial differences in pre-test scores, Analysis of Covariance (ANCOVA) was applied, with post-test scores as the outcome variable, instructional approach as the independent variable, and pre-test scores as the covariate. The level of significance was set at $\alpha = 0.05$, and partial eta squared (η^2) was used to quantify effect sizes.

Descriptive statistics and mean (M) values were used to describe each student's achievement in mathematics, and problem-solving and critical thinking skills at pre and post-test assessments..

Before taking any inferential steps, the required data screening steps were done. Shapiro-Wilk tests were used to check normality, along with the calculation of skewness and kurtosis. Levene's test was used to check for equal variances across groups. For ANCOVA, the homogeneity of regression slope assumption was tested by looking at the interaction of the covariate (pre-test scores) with the group.

Using independent sample t-tests, it was established that the baseline equivalence of the groups receiving traditional instruction and explicit instruction was. Differences at the group level were assessed via paired sample t-tests for pre-test and post-test scores, provided the data were normally distributed. In the absence of normality, the Wilcoxon signed-rank test was used.

ANCOVA was used to evaluate the instructional intervention group while accounting for the initial differences between groups. For this, post-test scores were taken as the dependent variable, the instructional approach (either traditional or explicit instruction) was the fixed factor, and the pre-test scores were used as the covariate. The adjusted means for the post-test scores were compared to assess the group differences. The effect sizes were computed using partial eta squared (η^2) with 0.01, 0.06, and 0.14 as the thresholds for small, medium, and large effect sizes, respectively. An alpha level of ($\alpha = 0.05$) was used to measure statistical significance.

All tests were two-tailed

2.7. Institutional Review Board Statement

This research follows the ethical standards of Helsinki's declaration and has gained approval from the University Research Ethics Committee (UREC) of Capiz State University (Approval Code: 2023-001; Date of Approval: [February 18, 2026]. The research protocol assured participants of the right to voluntary participation, informed consent, and confidentiality, along with secure data handling.

2.8. Informed Consent Statement

All participants involved in the study provided informed consent. Participants were briefed on the study's objectives, the confidentiality measures, the right to withdraw without any repercussions, and anonymity. For participants who were under 18 years, both student assent and parental or guardian consent were obtained.

2.9. Data Availability Statement

As per the data protection policy of the institution, the raw data from this study cannot be released publicly; however, data from this study can be made available to other researchers upon approval from the corresponding author. The university's Intellectual Property Office must review and approve any instructional materials, intervention protocols, and other related instruments to ensure they align with the university's policies on ownership and research dissemination.

3. RESULTS AND DISCUSSION

3.1. Pre-intervention and Post-intervention Levels

Table II presents the pre-test and post-test levels of students' problem-solving and critical-thinking skills in the experimental and control groups. Before the intervention, both groups demonstrated poorly developed problem-solving skills. The experimental group obtained a pre-test mean of 28.70, while the control group obtained a pre-test mean of 26.10. These scores suggest that both groups initially needed structured support in approaching problems systematically.

After instruction, the experimental group obtained a post-test mean of 87.00 in problem-solving skills, interpreted as highly developed. The control group also improved, with a post-test mean of 58.50, interpreted as developed. In critical thinking, the experimental group improved from a challenge-thinker level to a practicing-thinker level, while the control group improved from a challenge-thinker level to a beginning-thinker level. These findings indicate improvement in both groups, with stronger descriptive gains in the experimental group.

Table 2: Pre-test and post-test levels of students' problem-solving and critical-thinking skills.

Group	Skill	Pre-test mean	Pre-test interpretation	Post-test mean	Post-test interpretation
Experimental	Problem-solving skills	28.70	Poorly developed	87.00	Highly developed
Experimental	Critical-thinking skills	3.95	Challenge thinker	8.70	Practicing thinker
Control	Problem-solving skills	26.10	Poorly developed	58.50	Developed
Control	Critical-thinking skills	3.40	Challenge thinker	6.90	Beginning thinker

Note: Interpretations follow the scale used in the study.

The pre-intervention results show that learners had not yet fully developed advanced higher-order thinking skills. From Pólya's perspective, effective problem solving requires learners to understand the problem, develop a strategy, implement the strategy, and review the solution. The low baseline results suggest that many students had difficulty applying these stages independently. Thus, a structured instructional approach may be necessary to help learners organize their reasoning and verify the quality of their solutions.

The higher post-test performance of the experimental group may be attributed to the explicit cognitive support provided by Pólya's structured model. The result is consistent with literature suggesting that guided and problem-based approaches can enhance students' reasoning, problem-solving, and critical-thinking performance (Chacón-Castro et al., 2023; Liu and Pásztor, 2022).

3.2. Within-group Differences

Table III shows the results of the Wilcoxon signed-rank tests for the pre-test and post-test scores of the experimental and control groups. Significant differences were observed in both problem-solving and critical-thinking skills within each group. These findings indicate that both instructional approaches were associated with learning gains from pre-test to post-test.

Table 3: Test of difference in pre-test and post-test scores within instructional groups.

Instructional group	Variable	z-value	p-value	Remarks
Experimental	Problem-solving skills	-3.92	< .001	Significant

Experimental	Critical-thinking skills	-3.94	< .001	Significant
Control	Problem-solving skills	-3.92	< .001	Significant
Control	Critical-thinking skills	-3.53	< .001	Significant

Although both groups improved significantly, within-group comparisons alone do not establish that one instructional method was superior to the other. Stronger claims about comparative effectiveness require between-group analysis, particularly post-test comparisons or ANCOVA controlling for pre-test scores.

3.3. Between-group Post-test differences

Table IV presents the independent-samples t-test results comparing the post-test outcomes of the experimental and control groups. The results show statistically significant differences in both critical-thinking and problem-solving skills. These findings suggest that students exposed to the Pólya Structured Problem-Solving Framework performed better than those who received traditional instruction.

Table 4: Post-test differences in critical-thinking and problem-solving skills between instructional groups.

Variable	t-value	df	p-value	Remarks
Critical-thinking skills	-2.987	38	.005	Significant
Problem-solving skills	-6.773	38	< .001	Significant

The findings suggest that the Pólya problem-solving framework supports the development of higher-order thinking by guiding students through a structured process of analysis, planning, implementation, and reflection. This approach encourages students to thoroughly examine the problem, identify relevant information, select strategies, monitor their reasoning, and evaluate their solutions, which may explain why the experimental group showed stronger post-test performance compared to the control group. These results align with several theoretical perspectives in problem-solving pedagogy. Piaget's Theory of Cognitive Development emphasizes problem-solving as a key element of cognitive growth, and the Pólya framework supports this by promoting logical thinking and higher-order cognitive skills. This structured process mirrors Piaget's concepts of assimilation and accommodation, where learners adjust their understanding based on new challenges. Vygotsky's Social Constructivism also supports the findings, highlighting the role of scaffolding in cognitive development. The Pólya framework serves as a scaffold, providing students with guided support that fosters independent problem-solving, which is in line with Vygotsky's Zone of Proximal Development (ZPD). Furthermore, the Pólya framework promotes metacognition by encouraging students to reflect on their problem-solving strategies, which is supported by metacognitive theory that suggests such reflective practices improve the transfer of problem-solving skills to new contexts. Bloom's Taxonomy of Higher-Order Thinking also reinforces the findings, as the Pólya framework requires students to engage in higher-order cognitive tasks such as analysis, evaluation, and creation, rather than simply recalling or applying knowledge. This progression aligns with Bloom's model of cognitive development. Finally, prior studies on problem-solving pedagogy, including those by Schoenfeld (1985), suggest that structured problem-solving strategies lead to better problem-solving outcomes, as they promote deep thinking, reflection, and the application of multiple strategies. The findings of this study support these claims, demonstrating that the use of the Pólya framework resulted in stronger performance and enhanced cognitive development in the experimental group.

3.4. Theoretical Contribution

The study contributes to the literature on higher-order thinking by showing that problem solving and critical thinking may be developed through a common instructional structure. Pólya's framework does not merely support procedural problem solving; it also encourages reflective, analytical, and evaluative thinking. This extends the conceptual use of Pólya's model beyond a problem-solving heuristic and situates it as a broader cognitive development framework.

3.5. Empirical Contribution

Empirically, the study shows that students with initially underdeveloped higher-order thinking skills can improve when provided with structured instruction. Both groups improved from pre-test to post-test, but the experimental group demonstrated stronger outcomes. This supports the claim that explicit instructional design is an important factor in developing students' cognitive skills.

3.6. Methodological Contribution

Methodologically, the study highlights the importance of distinguishing within-group improvement from between-group comparative effectiveness. Significant pre-test and post-test improvement in both groups indicates that learning occurred; however, the stronger basis for claiming intervention effectiveness comes from the between-group post-test comparisons and the planned use of covariate control.

4. CONCLUSIONS

The study found that the Pólya Structured Problem-Solving Framework was associated with improved problem-solving and critical-thinking skills among pre-service teachers. Both the experimental and control groups showed significant improvement from pre-test to post-test, but the experimental group achieved stronger post-test outcomes. These findings suggest that structured, explicit, and reflective problem-solving instruction can provide the cognitive support needed for learners to develop higher-order thinking skills.

Overall, the results support the use of Pólya's framework as a pedagogical tool in teacher education. By guiding students through understanding, planning, implementation, and reflection, the framework can help learners become more systematic, analytical, and evaluative in dealing with complex tasks.

5. RECOMMENDATIONS

Teachers are encouraged to integrate structured problem-solving models, such as Pólya's framework, into classroom instruction to help students develop systematic reasoning and reflective thinking.

Curriculum designers should include problem-based, inquiry-based, and guided-reasoning activities that promote higher-order thinking. Scaffolding tasks, case-based activities, and real-world problem-solving exercises may be used to strengthen students' reasoning and decision-making skills.

Future researchers should conduct retention studies to determine whether gains in problem-solving and critical-thinking skills are sustained over time. Additional studies may also use larger samples, randomized experimental designs, and ANCOVA-based analysis to estimate the effect of structured instruction more precisely across disciplines and grade levels.

Students should be encouraged to participate actively in problem-solving and reflective thinking activities. They may use Pólya's method as a guide for organizing their reasoning and evaluating the quality of their solutions.

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