Examining the Impact of Writing Strategies in Enhancing Pre-Service Teachers' Mathematical Problem-Solving Skills

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Abstract: Examining the Impact of Writing Strategies in Enhancing Pre-Service Teachers' Mathematical Problem-Solving Skills. **Objective:** This study investigated the impact of structured writing activities in enhancing the pre-service teachers' mathematical problem-solving skills and examined the challenges they encountered during the implementation of these strategies. **Method:** A mixed-method research design was employed using problem-solving pretest and posttest and interviews. The study involved 35 second-year pre-service teachers selected from 142 pre-service secondary teachers from a state university in the Philippines through purposive sampling. Quantitative data were analyzed using descriptive and inferential statistics, while qualiative data obtained from interviews were subjected to thematic analysis. **Findings:** The results underscored the notable impact of writing strategies in enhancing the pre-service teachers' problem-solving abilities. A pretest mean percentage score of 52.29 (developing) increased to 76.86 (proficient) on posttest. This yielded a moderate normalized gain {9} of 0.52 and a very large effect size (Cohen's d = 2.39). The paired t-test showed a significant effect (t = 14.2, p < .001). The ANCOVA and regression analysis showed that the academic background of the participants did not predict their posttest performance, unlike the pretest. The qualitative findings revealed the participants' challenges related to translating their thoughts in writing, limited content knowledge, emotional factors, difficulty in problem comprehension and analysis, and lack of problem-solving strategies. **Conclusion:** Despite the challenges encountered by the pre-service teachers, the results underscore the positive effect of the structured writing strategies in enhancing their problem-solving skills. This study suggests that structured writing strategies can be adopted in teacher training curricula to strenghten mathematical reasoning. It recommends integrating writing strategies in mathematics instruction whether in the development of the concept or assessment, through reflective writing prompts, logs, or metacognitive writing strategies to enhance students' problem-solving abilities.

Keywords: writing strategies, problem-solving, pre-service teachers, mathematics.

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■ INTRODUCTION

Mathematical problem-solving is a critical skill needed beyond the classroom that influences logical thinking and real-world decision-making. In an era where 21st century skills such as creativity, critical thinking, problem-solving, adaptability and communication skills are considered life skills, mathematical problem-solving ability is essential. Educational reforms and frameworks including that of the Philippines and other global mathematical curricula, consider problem-solving not just as a goal but also as a

means of learning mathematics. This highlights the role of problem-solving in fostering deeper understanding and lifelong learning.

Amidst the importance of problem-solving skills, the development of students' ability in mathematical problem-solving remains a great challenge to educators and students themselves (Liljedahl et al, 2016; Schoenfeld & Sloane, 2016). On the part of the students, the different constraints include difficulty in understanding the problem-solving process itself (Yu et al, 2015), problem representation and looking for appropriate problem-solving strategies (Sekaryanti et al, 2022). Also, students oftentimes focus on looking for specific answers which hinders them from exploring on the math problems at hand (Bradshaw & Hazell, 2017).

Classified as one of the higher-order thinking skills, the acquisition of an effective problem-solving skill requires an effective design of the students' learning experiences. Despite the recognized importance of problem-solving in mathematics education and in other fields, mathematics classrooms in the Philippines remains focused on computations or algorithms and very little of problem-solving (Panagdato et al, 2024). These problem-solving tasks are either routine or mere exercises to apply the concepts taught in the classroom, a description that disagrees with Polya's definition of problem-solving. One factor identified by Avila and Guzon (2020) includes teachers' challenges in integrating problem-solving in their instruction influenced by their beliefs related to mathematics and the types of tasks they employ in mathematics classrooms. Similarly, the assessment conducted by Dicdiquin, Mobo and Cotillas (2023) to identify the factors affecting the quality of mathematics instruction in the Philippines pointed out that although teachers displayed consistency in lesson planning and delivery, they need improvement in terms of instructional strategies to develop students' higher-order thinking skills such as problem-solving.

Several researchers (Gearing & Hart, 2019; Toker, 2021; Barham, 2020) explored on the different strategies on how to teach problem-solving. As a task that does not have a solution at hand, students need to be active sense-makers and engaged in the task. They claim that students need to talk and write mathematics to reason things through, to put their thoughts on paper, to build their own ideas and to make mathematics their own.

A link between problem-solving and writing has been established in various studies. Gillespie et al (2014) assert that writing to learn in content areas such as mathematics enhances students' learning by helping students to comprehend, think critically and construct new understandings about what they are learning. Through writing in mathematics classrooms, students are encouraged to articulate and clarify their thinking, and develop a deeper understanding of mathematical concepts.

In this digital age where information and answers are instantly accessible, writing remains a significant skill for deep thinking, organization and communication. With this, this study explored the integration of writing strategies in problem-solving activities of pre-service teachers specializing in mathematics education to look into its effectiveness in improving their problem-solving skills. As future mathematics educators, they are expected to possess this higher-order thinking skill to facilitate the same to their future learners in the field. By engaging them in writing activities while doing problem-solving tasks, they are expected to articulate their thinking, to justify their solutions and to reflect on their strategies.

While extensive studies exist on problem-solving heuristics, strategies and procedural fluency, there is limited exploration of how writing strategies support students' reasoning and thinking in mathematical problem-solving. Similarly, limited integration of writing has been explored in research as a strategy in developing students' problem-solving skills, unlike in developing

students' literacy skills. The potential of writing as a structured instructional strategy for facilitating students' problem-solving skills has not been explored much in research in mathematics classrooms. Mostly, writing in mathematics classrooms focuses on the use of learning logs, journals and exit tickets as writing tools to look into students' mathematical thinking. In this paper, the use of writing as a structured instructional and assessment strategy is explored by analyzing how students understand the problem, plan and justify their solutions, analyze errors, and explain their problem-solving strategies. Specifically, it shifts the focus from procedural fluency to reflective reasoning through writing. Additionally, the study by Lee et al (2020), Sekaryanti, et al (2022) and Seo (2019) on high school students did not investigate the effectiveness of structured writing strategies for pre-service teachers. This is the gap that this study tried to address.

This study is grounded on constructivist theories which recognize learning as an active and constructive process (Piaget, 1970) and social constructivism, which emphasizes the role of language and social interaction in learning (Vygotsky & Cole, 1978). Through writing, students are able to facilitate internal reflection and communication allowing them to reflect on their own metacognitive processes (Flavell, 1979) and experiences, making their own learning more meaningful. Writing in this study, serves as a cognitive tool, encouraging the students to articulate their reasoning, evaluate their heuristics and deepen their mathematical understanding.

Specifically, this study tried to investigate how the structured writing strategies effectively facilitated the development of the pre-service secondary teachers' mathematical problem-solving skills. It tried to answer the following questions:
1. To what extent does problem-solving ability improve after intervention?
2. What are the main challenges participants face in applying writing strategies?

METHOD
Participants

The study involved 35 pre-service teachers (27 females and 8 males) enrolled in mathematics education program in a state university in the Philippines during the second semesster of AY 2023 – 2024. The participants came from four different academic backgrounds, Accountancy and Business Management (ABM), General Academic Strand (GAS), Science, Technology, Engineering and Mathematics (STEM) and Humanities and Social Sciences (HUMSS). The participants were chosen using purposive sampling from a study population consisting of 142 pre-service secondary teachers taking the same program The use of purposive sampling was appropriate because it allowed for the intentional selection of the participants who possessed specific characteristics, knowledge and experiences relevant to the research objectives. As this study tried to look into the pre-service teachers' problem-solving skills, this necessitates participants who were directly engaged in a coursework mostly consisting of problem-solving. This also ensures that rich, relevant and context-specific data were obtained which would not be possible through random sampling.

Research Design and Procedures

This study employed a mixed-methods research design to comprehensively examine the effectiveness of structured writing activities in enhancing the particpants' problem-solving abilities. The quantitative component, specifically the one-group pretest-posttest design, examined the extent of improvement of the participants' problem-solving performance after the intervention. The qualitative component explored the challenges that the participants encountered using structured writing activities during problem-solving. The research was conducted over a period of three months from January 2024 to March 2024. The procedures included the following:

1. Identifying of the research participants through purposive sampling.
2. Collecting data through pretest.
3. Implementing the intervention for three months.
4. Gathering data through test, written works and interviews.
5. Triangulating data to ensure reliability and validity.
6. Analyzing quantitative data using descriptive and inferential statistics and qualitative data using thematic analysis.
7. Subjecting the qualitative data to peer review to ensure reliability and validity.

Instruments

This study employed the following instruments: 1. Problem-Solving Tests: developed to measure the extent of problem-solving abilities of the pre-service teachers before and after the intervention. Items underwent modifications and content validation by mathematics and pedagogical experts resulting to CVI of 0.81 for pretest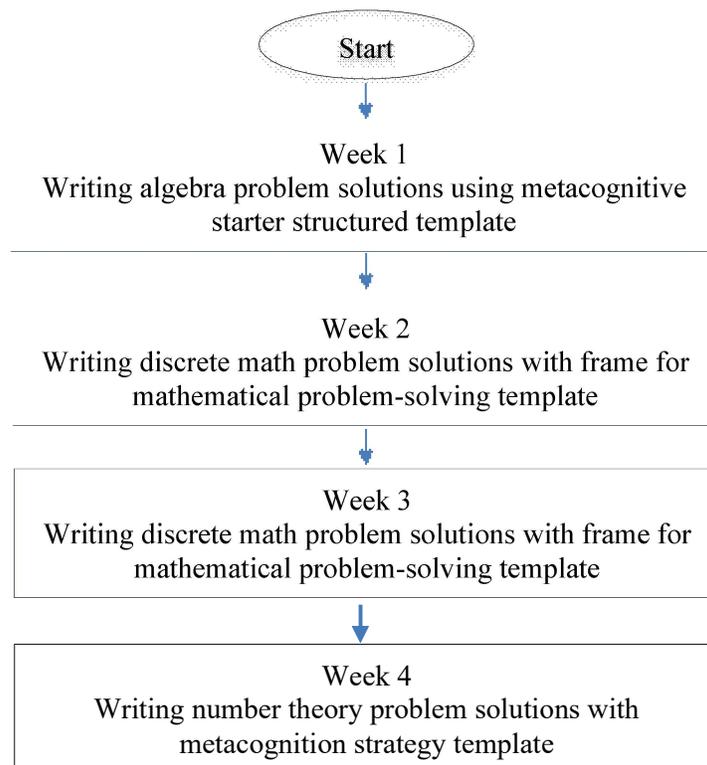 and 0.84 for posttest. Participants' responses to these tests were treated using structured rubric which were reviewed by field experts. 2. Interview Guide: used to determine the challenges faced by the pre-service teachers in applying writing strategies during problem-solving. Questions were reviewed by field experts before the actual utilization.
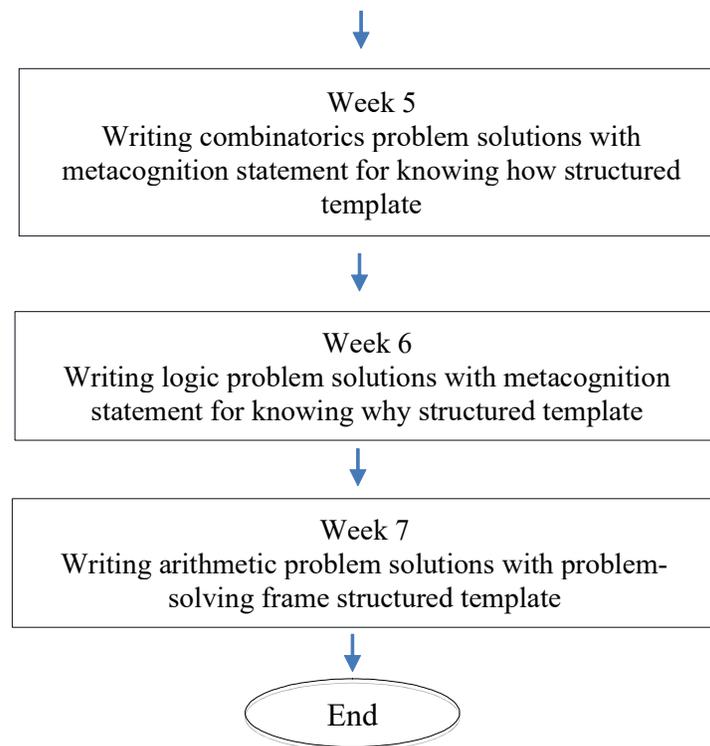
Intervention

The intervention involved the implementation of structured writing activities during problem-solving. The writing strategies were integrated into the instruction as part of the discussions and assessments. Each session lasted for 90 minutes, once each week for seven weeks from January 2024 to March 2024. The sequence of the intervention is presented in the flow diagram below.

Analysis of Data

For quantitative data, both descriptive and inferential statistics were used. Before conducting parametric tests, prerequisite tests such as

Start

Week 1
Writing algebra problem solutions using metacognitive starter structured template

Week 2
Writing discrete math problem solutions with frame for mathematical problem-solving template

Week 3
Writing discrete math problem solutions with frame for mathematical problem-solving template

Week 4
Writing number theory problem solutions with metacognition strategy template

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                    ↓
┌─────────────────────────────────────┐
│              Week 5                  │
│   Writing combinatorics problem      │
│   solutions with metacognition       │
│   statement for knowing how          │
│   structured template                │
└─────────────────────────────────────┘
                    ↓
┌─────────────────────────────────────┐
│              Week 6                  │
│   Writing logic problem solutions    │
│   with metacognition statement for   │
│   knowing why structured template    │
└─────────────────────────────────────┘
                    ↓
┌─────────────────────────────────────┐
│              Week 7                  │
│   Writing arithmetic problem         │
│   solutions with problem-solving     │
│   frame structured template          │
└─────────────────────────────────────┘
                    ↓
              (    End    )
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Shapiro-Wilk tests for data normality and Levene's test for homogeneity were conducted. Analysis of covariance (ANCOVA) was used to control confounding variable which is the academic background of the pre-service teachers considering that the participants came from four different specializations in their senior high school and to strenghten the validity of the findings. Additionally, an average normalized gain $\langle g \rangle$ was also computed to determine the extent of improvement in problem-solving skills of the participants from the results of their pretest and posttest using this formula and interpretation adapted from Hake (2010). For <0.30 – low improvement, 0.30 0.70 – moderate improvement and >0.70 – strong improvement. To examine the influence of the participants' initial performance and specializations in their posttest scores, a multiple linear regression analysis was also conducted after performing and satisfying the different assumptions required. The posttest scores served as the dependent variable while pretest scores and specializations served as the predictors. This was conducted to determine whether the participants' academic background (specialization) significantly predicted their learning gains or posttest and to control the effect of their initial performance or pretest.

For the qualitative data, thematic analysis technique as described by Terry, Hayfield, Clarke and Braun (2017) was employed. This technique includes the following phases:

1. Data familiarization: knowing the dataset, reading, rereading and keeping notes into the dataset.
2. Generating codes: creating meaningful labels to specific segments of the dataset.
3. Constructing themes: pattern formation and identification, examining codes, combining, clustering or collapsing codes.
4. Reviewing potential themes: reviewing themes alongside datasets, making adjustments to themes, checking whether themes capture the research objectives.
5. Defining and naming themes: telling a story,

writing the analysis that is based on the dataset which makes sense of the patterns

6. Producing the report: writing of the final analysis to answer the research questions and linking to scholarly literature.

■ **RESULT AND DISCUSSION**

The results of this study are presented and discussed according to the research objectives, namely, the extent of pre-service teachers' problem-solving skills after the intervention and challenges faced by pre-service teachers in utilizing writing strategies during problem-solving. The data were obtained through problem-solving tests and interviews and supported by captured written works by the participants.

Extent of Improvement in Pre-Service Teachers' Problem-Solving Skills after Intervention

To determine the extent of improvement in pre-service teachers' problem-solving skills after the implementation of the structured writing activities, descriptive and inferential statistics were used. The following shows the results of the problem-solving tests given before and after the intervention:

Results from the problem-solving tests indicate that the mean score after the implementation (M = 26.9, SD = 4.14) of the structured writing activities during problem-solving was significantly higher than the pretest mean score (M = 18.3, SD = 4.20). The average

Table 1. Results of problem-solving tests before and after the intervention of the structured writing activities

	N	Mean	SD	MPS	$\langle g \rangle$
A	35	18.3	4.20	52.29	0.52
B	35	26.9	4.14	76.86	

A – pretest; B – posttest; maximum score - 35

normalized gain $\langle g \rangle$ = 0.52 suggests a moderate improvement of the participants' problem-solving skills after the intervention suggesting a meaningful improvement which can be attributed to the intervention. To statistically validate this improvement, inferential analyses were performed.

Prior to subjecting the results to an appropriate inferential treatment, these were

subjected to tests for normality using Shapiro-Wilk test to decide whether to use parametric or its equivalent non-parametric test. The results are presented in table 2.

Results of the Shapiro-Wilk tests supported the normality of data obtained from pretest (W = 0.958, p = 0.195) and posttest (W=0.980, p = 0.755). Both p-values are greater than 0.05, the use of parametric test which is paired t-test for

Table 2. Results of the test for normality of pretest and posttes

				Shapiro-Wilk	
	N	Mean	SD	W	P
A	35	18.3	4.20	0.958	0.195
B	35	26.9	4.14	0.980	0.755

A – pretest; B – posttest; H€ : p > 0.05.

further analysis was justified. A paired t-test was conducted to determine whether the improvement in the pre-service teachers'

problem-solving performance was statistically significant. The result is presented in table 3.

Table 3. Results of paired samples t-test for pretest and posttest

			statistic	df	P	Mean difference		Effect Size
B	**A**	**Student's t**	14.2	34.0	<.001	8.57	Cohen's d	2.39

Note. H $_i$ $_{Measure 1 - Measure 2}$ 'e 0; B- posttest, A – pretest

Results show that the posttest mean score (M = 26.9, SD = 4.14) was significantly higher than the pretest mean score (M = 18.3, SD = 4.20), t = 14.2, p <.001. This shows a significant improvement in the pre-service teachers' problem-solving abilities before and after the implementation of the intervention. Additionally, the effect size using Cohen's d was calculated to determine the magnitude of the effect of the intervention. Cohens d of 2.39 shows a very large effect size (Cohen, 1988) of the intervention in the improvement of the problem-solving abilities of the participants. This suggests that the structured writing activities had a substantial impact on the pre-service teachers' problem-solving performance.

Additionally, Levene's test for homogeneity of variances with pretest as the dependent variable and specializations as the fixed factor (independent variable) was conducted to determine whether ANCOVA was appropriate for further analysis of the increase in posttest scores, ensuring that the academic background (e.g. specializations) of the participants did not significantly affect their performance. The result is presented in table 4.

Table 4. Result of homogeneity of variances test (Levene's)

F	df1	df2	p
2.30	3	31	0.097

H_0 : *variance was equal across groups (specializations)*

The Levene's test conducted using Jamovi software showed that the significance level (p) of 0.097 was higher than 0.05 thus we fail to reject the null hypothesis that variation in each group was homogeneous. This supports the appropriateness of using ANCOVA for further analysis. Since both tests for normality and homogeneity were satisfied, an ANCOVA test was conducted with the posttest scores as the dependent variable, specialization as the fixed factor or independent variable and pretest scores as the covariate. This was conducted to determine whether the specializations of the participants had a significant impact on their posttest scores while controlling for their pretest scores. The result is presented in table 5.

Table 5. Result of ANCOVA – Posttest

	Sum of Squares	df	Mean Square	F	p	η^2
Specialization	31.9	3	10.6	0.983	0.414	0.054
Pretest	233.1	1	233.1	21.547	<.001	0.395
Residuals	324.6	30	10.8			

The results of the ANCOVA test showed that the specializations of the participants do not have a statistically significant effect on their posttest scores F(3, 30) = 0.983, p = .414, ç²=0.054, which indicates small effect size. Conversely, the pretest scores were significant

covariate, $F(1, 30) = 21.547$, $p < .001$, $ç^2 = 0.395$, which suggests that 39.5% of the variances in posttest scores can be explained by their performance in the pretest. The results suggest that the intervention had consistent effect on participants' regardless of their specialization, as explained by the non-significant effect of specialization on posttest scores, after controlling for the pretest scores. However, the result of the pretest as a strong covariate indicates that the participants' prior knowledge or ability has a strong influence on their performance after the intervention.

Moreover, a multiple linear regression analysis was performed after ensuring that the assumptions were met to examine the influence of pretest scores and specializations to the participants' posttest scores. The regression model ($R^2 = 0.443$) in table 6 accounted for 44.3% of the variance in the posttest scores, suggesting a moderately strong explanatory index.

Table 6. Model fit measures

Model	R	R²
1	0.665	0.443

Note. Models estimated using sample size of N=35

In table 6, the multiple correlation coefficient ($R = 0.665$) suggests that the predictors, pretest and academic background are linearly related to the posttest (outcome). This value indicates a moderate to strong positive relationship between the predictors and the outcome. However, consistent with the previous discussions, table 7 shows that the specialization was not a significant predictor of the posttest.

Compared to participants from the ABM specialization, those from GAS scored .902 lower ($p = .600$), participants from HUMSS

Table 7. Model coefficients – posttest

Predictor	Estimate	SE	t	p
Intercept[a]	16.506	2.771	5.957	<.001
Pretest	0.633	0.136	4.642	<.001
Specialization:				
GAS– ABM	-0.902	1.703	-0.530	0.600
HUMSS- ABM	-0.845	1.658	-0.510	0.614
STEM– ABM	-2.551	1.591	-1.603	0.119

scored .845 lower ($p = .614$) and those from STEM scored 2.551 lower ($p = .119$) which are all not statistically significant indicating that the specialization was not a predictor of the posttest performance when controlling for the pretest. The pretest on the other hand indicates a significant predictor of the posttest performance, $b = 0.633$, $p < .001$, signifying that for every point increase in the pretest, an increase of 0.633 was observed in the posttest. These results suggest that the initial ability of the participants, not their specialization, influenced their posttest performance, and the observed increased may be attributed to the intervention-the structured writing activities, which indicates its potential effectiveness.

These findings are consistent with several studies which found that the use of mathematical writing helped enhance students' problem-solving abilities. Toker (2021) examined student' mathematical problem-solving processes evident in their writing through formative feedback and stated that different dimensions were addressed

in writing while students were engaged in problem-solving process. Students were, according to him, visually communicating their understanding of the problem and expressing their thinking about possible solutions. Lee et al's (2020) study had similar view affirming that mathematical writing had positive impact as students were observed to visualize, made aware and recognize their problem-solving behaviors.

Similarly, the study of King, et al (2016) confirmed that writing helps students think critically and reflect on their own experiences and learning while doing problem-solving. They also mentioned that students were able to explain their reasoning more effectively and make connections of abstract mathematical concepts in the content of the problem. Similarly, Kunseeda, et al (2018) who examined students' writing skills in a mathematical problem-solving task using a lesson study concluded that students who engaged in writing interventions were better in organizing their thinking, presenting their ideas and evaluating their own solutions, thus helping them improve their problem-solving skills. Accordingly, students who engaged in writing tasks in mathematics such as explaining the problem-solving process and analyzing misconceptions and errors demonstrated improvements in their mathematics achievement, and that writing aided students in improving their conceptual understanding (Raquid & Litao, 2023). Petersen et al (2017) also affirmed that through writing in a mathematics classroom, students are able to reflect critically through their strategies and explanations which helped them develop their problem-solving strategies. This is in consonance with the study conducted by Bicer et al (2018) who suggested that integrating writing activities in mathematics instructions can bring forth positive impact on students understanding of mathematics.

The results of this study have practical and theoretical implications in improving mathematics education. Practically, although at present, information can be obtained instantly because of

technology and AI, writing still plays a significant role in learning and universities and all levels of education should recognize the strong connection between writing and thinking. Theoretically, this study enriches the studies and literature related to the advantages of writing in learning. The significant improvement observed on the performance of the students after the intervention supports the constructivists view that emphasizes the active roles of learners in constructing their own learning (Vygotsky, 1978). Through writing, the participants articulated their own thinking processes, consistent with the role of metacognition in problem-solving.

Generally, the findings strongly suggest that structured writing activities significantly enhance pre-service teachers' mathematical problem-solving skills as evidenced by the moderate normalized gain, the statistically significant improvement in test scores and the large effect size. Additionally, the improvement was regardless of the academic background of the participants which highlight the universal applicability of the writing strategies in mathematical instruction . These results add to the growing body of literature emphasizing the benefit of integrating writing in mathematics education, grounded in constructivist and metacognitive learning theories.

Challenges Faced by the Participants in Applying Writing Strategies in Problem-Solving

Although the structured writing activities resulted to notable improvement in the pre-service teachers' problem-solving performance after the intervention, several challenges in applying the strategy were identified during the interview. These challenges were of two types: challenges related to applying writing strategies and challenges related to problem-solving itself which directly affected their writing. The challenge faced by the pre-service teachers in applying writing strategies consisted of their struggle in translating

their thoughts to writing (43%), while those related to problem-solving which affected their writing are the following: limited content knowledge (54%), limited problem comprehensin and analysis (40%), emotional factors (34%) and limited problem-solving strategies (31%). Table 8 shows the proportion of these challenges faced by the pre-service teachers. These challenges were not unique to the participants as several aired the same challenges.

Table 8. Challenges faced by the pre-service teachers in applying writing strategies in problem-solving

Challenges	Number or Respondents	Percentage
difficulty in translating thoughts to writing	15	43%
limited content knowledge	19	54%
limited problem comprehension and analysis	14	40%
emotional factors	12	34%
limited problem-solving strategies	11	31%

Of the challenges identified by the participants, one was their difficulty in translating their thoughts to writing (43%) as they expressed their struggle of converting their inner thoughts to written language. Some of the factors identified as contributory to this challenge were organizing ideas, use of vocabulary appropriate to the problem-solving tasks, and grammatical structures which are necessary for translating thoughts into written form (Harmawan, et al, 2023). These difficulties can affect the effective communication of their reasoning and solutions in written form. Research indicates that the processs of converting these inner thoughts to written language requires strong cognitive and language abilities (Fernyhough & Borghi, 2023). Sweller's (2011) cognitive load theory explains this phenomenon that when students are exposed to complex tasks such as problem-solving, their cognitive demand of writing their reasoning and solutions increases their working memory load. This suggests that providing scaffold such as externalizing their thoughts, providing time where students can discuss their reasoning with their peers before writing may help address this identified challenge.

The second challenge which was common to more than half of the participants (54%) was their acknowledgment of their limited content knowledge necessary for problem-solving. They admitted that their lack of prior knowledge, limited conceptual understanding, and their limited exposure to similar tasks before affected their performance. This was consistent with the study of Baki and Arslan (2017) which highlighted the difficulty of mathematics teachers in developing students' mathematical writing skills due to students' limited content knowledge which greatly affects their ability to write mathematical reasoning effectively.

The third challenge which emerged from the participants' responses was that of limited problem comprehension and analysis (40%). Participants admitted that they had difficulty understanding the mathematical problems which made them struggle to write or explain their reasoning and solutions. With this, their difficulty lies on the initial stage of problem-solving which greatly affected their overall performance in the task. Patty (2024) recognized that these cognitive factors including working memory capacity and comprehension skills positively impact students' writing abilities in problem-solving contexts.

Emotional factors (34%) such as anxiety, lack of self-confidence and self-efficacy also

emerged as challenge for participants in applying writing strategies during problem-solving. A research conducted by Graham (2022) confirmed that students' self-efficacy plays an important role in their writing performance. Those with low confidence lead to reduced engagement and achievement.

The last challenge which emerged was the lack of problem-solving strategies (31%). Some participants solely relied on memorized procedures, routine works and formulas and could according to them, rarely think of strategies not explicitly taught to them. This limits their flexibility and development of their creativity and critical thinking and also influences their ability to write their mathematical reasoning and solutions. Singh, et al. (2024) suggested that this over-reliance on procedural knowledge can impede the development of their higher-order thinking.

These findings clearly mirror the broader and current context of mathematics education in the Philippines. The studies and international assesssments conducted like PISA in 2022 reflect the gaps both in content knowledge and higher-order thinking skills among learners (OECD, 2023). Although the K to 12 curriculum places critical thinking and problem-solving at the center of the framework, the implementation often falls short due to traditional teaching practices that focus more on rote memorization and procedural fluency rather than development of these higher-order skills and reflective thinking. This may partly explain the participants' reliance to memorized procedures and their struggle to write their mathematical thinking.

These findings also align with Vygotsky's (1978) socio-cultural theory which provides explanations of the participants' difficulty in translating their thoughts into written form which reflect a lack of scaffolding or assistance. This suggests integrating strategies like collaborative writing and peer discussions that could provide the needed support. This could also help address the emotional challenges expressed by the participants in highlighting the effect of affective domains which is oftentimes a big factor which is overlooked in learning mathematics. This is linked to Bandura's theory of self-efficacy (1982) which suggests that learners who have low self-efficacy or self-confidence in mathematical tasks may avoid doing writing tasks which lead to weaker performance. With this, effective strategies or support may be employed to support students' development.

While the structured writing strategies helped improve participants' problem-solving performance, the challenges identified underscore the need for a more supportive approach in mathematics education. Such approach must help develop students' conceptual knowledge, assist them in their writing process, develop their problem-solving strategies and most importantly, help build their confidence and affective aspects. This may help future educators to communicate their mathematical reasoning effectively.

■ CONCLUSION

This paper highlighted the impact of the structured writing strategies on the mathematical problem-solving skills of the pre-service teachers and identified the challenges they encountered during the implementation of the strategy. The findings revealed a significant improvement in their problem-solving performance as evidenced by the pretest and posttest results, normalized gain and a very large effect size. Pretest scores were a significant predictor of the posttest performance while academic background or specializations did not significantly affect the outcomes. These results affirm the potential of the structured writing strategies as an instructional strategy which supports students in deepening their conceptual understanding and enhancing their mathematics performance, specifically problem-solving.

However, the participants experienced several challenges related to articulating their thoughts to writing, limited content knowledge, understanding and analyzing problems, applying problem-solving strategies and emotional factors such as low self-efficacy and confidence. These

challenges indicate a need for continuous scaffolding and opportunities to develop both mathematical content knowledge, and higher-order thinking such as problem-solving. Based on these findings, integration of writing in mathematics instruction is recommended may it be in the development of the concept or assessment, in the form of reflective writing prompts, logs, or metacognitive writing strategies. Future research could explore refinement of the writing interventions, its long-term effects and applicability to other areas in mathematics education.

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