RELATIONSHIP BETWEEN MATHEMATICS ANXIETY AND MATHEMATICS PROBLEM-SOLVING PROFICIENCY OF PRE-SERVICE MATHEMATICS TEACHERS: A MIXED-METHOD STUDY

Art Walden A. Dejoras
University of Science and Technology of Southern Philippines, Cagayan de Oro City, Philippines
Contact: art.dejoras@ustp.edu.ph.

ABSTRACT. *This study investigates the relationship between mathematics anxiety and mathematics problem-solving proficiency among pre-service secondary mathematics teachers (PSMTs) in a Philippine university. The mixed-method sequential explanatory research design was utilized to understand math anxiety's role in their problem-solving proficiency. Complete enumeration-based survey data were obtained from Fennema-Sherman Math Anxiety Scale (MAS) and author-developed non-routine math problem-solving proficiency test (MPSPT) questionnaires. Results showed the prevalence of low to average levels of math anxiety levels, and novice to practitioner levels of problem-solving proficiency among PSMTs. Correlation analysis, however, revealed a statistically significant weak linear relationship between the two variables. Simple linear regression analysis revealed MAS rating significantly has a weak ability to predict MPSPT score. Interviews were employed for in-depth understanding of the phenomenon. Findings suggest the prevalence of weak math anxiety in pre-service math teachers should still be taken seriously when crafting classroom activities. Other factors must be explored to determine a more accurate model for predicting MPSPT scores.*

Keywords: Mathematics Non-routine Problem Solving, Problem-Solving Proficiency, Mathematics Anxiety, Pre-service Mathematics Teachers

1. INTRODUCTION

Developing problem-solving proficiency is considered at the heart of mathematics teaching and learning [1, 2, 3]. George Polya (1887-1985) described problem solving as an activity wherein "a student is confronted by an unfamiliar situation for which no immediate path to the answer is apparent" [1]. This formulation of problem solving however seems to speaks more of non-routine problem solving which is a problem-solving type where there is no predictable, well-rehearsed approach or pathway or a worked-out example for solving [2]. The other kind of problem-solving refers to routine problem solving wherein rules and algorithms required to solve them are previously known or practiced [2]. A number of studies in the literature have argued that non-routine problem solving is non-negotiable in the development of students' problem-solving proficiency and reasoning skills [2,3].

During the past decades, math problem-solving proficiency has been associated with math anxiety. The latter has been generally described as a state of discomfort associated with performing math tasks [3, 4, 5, 6, 7]. The association between the two variables has been the focus of vast research undertakings as more and more students continually developed high math anxiety especially those with poor math problem-solving proficiency [3-5]. A number of studies have revealed a negative association between these two variables among early elementary school [8], primary school [9], secondary school students [3, 10, 11], and pre-service teachers [12]. Results were linked to lack of basic math skills [13], less exposure to math problem-solving strategies, less time allotment given in performing problem-solving tasks [12], teachers' too much emphasis on memorizing formulas, learning math problem-solving through drill and practice [6], and teacher insisting on single correct way to solve mathematics problems [7]. Students with higher math anxiety levels were described to experience higher levels of worry and emotion [14, 15]. Studies explained that these levels of worry and emotion can overload their working memory [16, 17] which may disturb their processing of math problems [14, 15], resulting to answering math problems less accurately than those with lower mathematics anxiety [4]. Working memory overload is the tendency of anxious people to have intrusive thoughts about how badly they are doing, which may distract attention from the task or problem at hand and overload working memory resources [12, 16]. Greater efficiency in problem-solving tasks occurs when individuals have more capacity and dedicated cognitive resources targeted toward task demands which can be maximized when there are no intrusive thoughts and distractions [12].

Previous studies investigating the relationship between math anxiety and math problem-solving proficiency emphasize ways in which math anxiety weakens problem-solving proficiency [3, 8, 9, 10, 11, 12]. These studies, however, have used only quantitative methods of investigation which may be insufficient in providing a comprehensive understanding of the role of math anxiety in math problem-solving proficiency. More insights could be revealed if individuals under investigation were given opportunities to help validate quantitative results, to provide explanations, and to express personal thoughts and reflections. Moreover, most of the previous studies in the literature on the relationship between the said variables among pre-service teachers involves non-math majors as subjects of investigation [12]. Little attention is given to PSMTs. This may be due to the common perception influenced by the traditional culture that if you are a math major then you do not have serious trouble dealing with the subject. But this perception may not always be true since there are some math majors who struggle in math [18]. Thus, the present study was conducted and aimed to determine both quantitatively and qualitatively significant associations between math anxiety levels and math problem-solving proficiency among PSMTs. Specifically, the study aims to address the following research questions: (RQ#1) What is PSMTs' level in terms of their math anxiety ratings and of their math problem-solving proficiency scores? (RQ#2) Is there a significant association between their math anxiety ratings and math problem-solving proficiency scores? (RQ#3) Can PSMT math anxiety rating predict PSMT problem-solving proficiency score? If it does, then up to what extent?
Results of the study would provide valuable insights in determining necessary interventions to improve PSMTs' math problem-solving proficiency.

2. MATERIALS AND METHODS

2.1 Research Design

This study utilized a mixed-method sequential explanatory research design which is characterized by the collection and analysis of quantitative data followed by a collection and analysis of qualitative data to assist in explaining and interpreting the results of the quantitative study [19]. The 12-item Fennema-Sherman Mathematics Anxiety Scale (MAS) and the 10-item Math Problem-Solving Proficiency Test (MPSPT) were used to gather quantitative data. Interviews were carried out to gather qualitative data. PSMTs were asked questions to provide explanations, clarifications, verification of information, and further understanding of the results of quantitative data analyses. Field notes were taken to secure valuable responses from PSMTs.

2.2 Instruments

In the present study, the adopted 12-item Fennema-Sherman MAS was used to determine PSMTs' math anxiety rating. It was originally designed for high school students [20]. It was employed with college students in the present study due to its briefness and suitability. In the present study, its reliability value using Cronbach's alpha is 0.80 (acceptable). It uses a 5-point Likert scale (1 = strongly disagree to 5 = strongly agree). The score of each student on the scale was obtained by dividing the tallied score of the 12 items by the total number of items which was 12. The highest possible score is 5 and the lowest possible score is 1. High scores are interpreted as a high mathematics anxiety rating. Table 1 provides the MAS rating and corresponding level/description.

Table 1. MAS Ratings and Descriptions

Rating	Level/Description
1.00 – 1.49	Level 1: Very Low
1.50 – 2.49	Level 2: Low
2.50 – 3.49	Level 3: Average
3.50 – 4.49	Level 4: High
4.50 – 5.00	Level 5: Very High

The researcher-made 10-item MPSPT composed of open-ended non-routine mathematics word problems that are applications of the basic mathematics concepts at the Philippine K-12 secondary level which can be solved by at least two strategies. The problems were reviewed by a panel of three mathematics educators who determined their appropriateness. The original test consisted of 27 items which were narrowed down to 10 based on the result of item analysis. Table 2 shows the test composing of items that are 10% easy and 90% average difficulty. The item difficulty levels varied from 0.43 to 0.71 with an average of 0.59 (average difficulty) and the discrimination index varied from 0.35 to 0.65 with an average of 0.51 (very good).

Table 2. . Item Difficulty Level (IDL) and Discrimination Index (DI) for Problem-Solving Proficiency Test

1	0.55 (Average)	0.40 (Very Good)
2	0.76 (Easy)	0.42 (Very Good)
3	0.71 (Average)	0.38 (Good)
4	0.50 (Average)	0.50 (Very Good)
5	0.43 (Average)	0.35 (Good)
6	0.58 (Average)	0.65 (Very Good)
7	0.53 (Average)	0.55 (Very Good)
8	0.59 (Average)	0.65 (Very Good)
9	0.67 (Average)	0.57 (Very Good)
10	0.59 (Average)	0.62 (Very Good)

The test's reliability value using Cronbach's alpha is 0.79 (acceptable). Sample of the validated MPSPT problems are shown in table 3.

Table 3. Sample Validated MPSPT Problems

#	Sample Non-Routine Math Problems
1	A frog is in a well 15 feet deep. Each day it climbs up 3 feet and each night it slips back 2 feet. How many days will it take the frog to get out of the well?
2	Leo's salary and Mark's salary are in the ratio of 4:5. If Leo's salary is increased by 30%, by what percent must Mark's salary be increased or decreased so that they will have the same salary?

Each item was scored using a 4-point Likert scale (1 = no response/has the wrong answer and solution/ has correct answer and wrong solution; 2 = has the wrong answer but partly correct solution; 3 = has the correct answer but partly correct solution or no solution/ has the wrong answer but correct solution; 4 = has correct answer and solution). Table 4 provides the MPSPT scores and corresponding level/description. The score of each PSMT in the MPSPT was obtained by dividing the tallied score of the 10 items by the total number of items which was 10. The highest possible score is 4 and the lowest possible score is 1.

Table 4. MPSPT Scores and Level/Description

Score	Level/Description
1.00 – 1.75	Level 1: Novice
1.76 – 2.50	Level 2: Apprentice
2.51 – 3.25	Level 3: Practitioner
3.26 – 4.00	Level 4: Expert

2.3 Participants and Sampling Technique

This study was participated by 104 PSMTs in a Philippine university who were first-year BS Mathematics Education students during the conduct of the study. They were 47 males and 57 females with ages 17 — 44 (mean = 18.7, median = mode = 18). The complete enumeration method [18] was employed since 104 was the total population which was small and all were accessible.

2.4 Data Gathering Procedure

First, the PSMTs answered the 12-item Fennema-Sherman MAS individually. The students were able to answer in less than 15 minutes. One week later, they took the 10-item MPSPT also individually within 90 minutes. Interviews were then carried out two weeks after the conduct of the MPSPT.

2.5 Data Analyses

For quantitative data analysis, the following were obtained: (a) Frequency and percentages at each level of MAS ratings and MPSPT scores, (b) Kolmogorov-Smirnov test to determine the normality of distributions for MAS ratings and for MPSPT scores, (c) Spearman's rank-order correlation (Spearman's rho) to confirm the presence of a significant association between pre-service math teachers' MAS ratings and MPSPT scores, and (d) Simple Linear Regression Analysis (SLRA) to determine the ability of MAS rating to predict PSMT's MPSPT score. For

qualitative data analysis, PSMTs' responses during interviews were gathered and the most common ones were reported.

3. RESULTS AND DISCUSSION

Table 5. MAS Ratings and MPSPT Scores

Variables	Categories	N	%
MAS Rating	Very Low	1	0.96
	Low	13	12.50
	Average	59	56.73
	High Anxiety	28	26.92
	Very High	3	2.88
	Total	104	100
MPSPT Score	Novice	31	29.81
	Apprentice	60	57.69
	Practitioner	11	10.58
	Expert	2	1.92
	Total	104	100

Table 5 shows that 70.19% (or 73 out of 104) of PSMTs have a very low, low, or average level of anxiety. One reason for this, which PSMTs confirmed, is the idea that college students are more matured, and experienced and have developed better coping mechanisms in dealing with math anxiety compared to when they were still high school or lower year students. Moreover, these PSMTs admitted their confidence in mathematics is the main reason why they chose to be math majors in the first place.

The remaining 29.81% (or 31 out of 104) of PSMTs, however, have high or very high anxiety. Their reasons are varied. Many of these students mentioned they generally appreciate mathematics as a discipline and emphasized having a positive attitude towards the subject even if they show high math anxiety. For them, they just worry they might not be able to perform what is expected of them by their peers, parents, teacher, or by themselves. Others stated that it is the anxiety that somehow pushes them to spend more time preparing and practicing before a mathematics test. There are also those who admitted that they have weak mathematics background or lack confidence in their math abilities but chose to attend a math education program to help develop their mathematical abilities.

Table 5 also shows that in terms of MPSPT scores, 87.5% (or 91 out of 104) pre-service math teachers were at the novice or apprentice level. They were the ones who generally scored 1 or 2 out of 4 in most of the problems on the test. They confessed to very limited or no exposure to the type of problems found in MPSPT. Everyone in this group agreed that there is really a hard time answering a problem if the method of solving was not taught in advance. These PSMTs said that they are not familiar with the use of various heuristics in non-routine problem solving as these were not taught to them in the past math classes. They were only exposed to routine problem solving.

Only 12.5% (or 13 out of 104) of PSMTs were at the practitioner or expert level. They usually scored 3 or 4 (out of 4) in the test. These students explained having experienced being mathematics contestants in their respective high schools in the past provided them exposure in non-routine problem-solving.

Kolmogorov-Smirnov test revealed an approximately normal distribution for MAS ratings ($D[104] = 0.071$, $p = 0.2$, $p > 0.05$) but the result for MPSPT scores ($D[104] = 0.108$, $p = 0.005$, $p < 0.05$) indicates a departure from normality. So, a nonparametric procedure, the Spearman's rank-order correlation (Spearman's rho) was performed to confirm the presence of a significant association between PSMTs' MAS ratings and MPSPT scores.

Table 6. Spearman's rank-order correlation between MAS ratings and MPSPT scores

Variable		1	2
1.MAS Rating	r	1	-0.21[a]
	Sig.		0.03
	N	104	104
2. MPSPT Score	r	-0.21[a]	1
	Sig.	0.03	
	N	104	104

[a] : Significant, $p < 0.05$ (2-tailed)

Based on table 6, there was a weak, negative linear correlation between the two variables, which was statistically significant (r_s [104] = -0.21, $p = 0.03$, $p < 0.05$). Thus, a higher MAS rating is slightly associated with a lower MPSPT score (or a lower MAS rating is slightly associated with a higher MPSPT score). This finding is consistent with the finding of previous studies [2, 7, 8, 10, 11].

In the present study, 9.6 % (or 10 out of 104) of the PSMTs have low MAS ratings (those whose MAS rating is 2.49 or below) and at the same time have low MPSPT scores (those whose math proficiency is at the novice or apprentice level). These students admitted they exhibit confidence and positive emotion towards math but just have limited or no exposure to non-routine problem-solving in the past. Others were quite familiar with non-routine problem-solving but they either have difficulty in applying applicable heuristics, fall short of the time allotted for the test, or employed carelessness in answering the problems.

Moreover, 1.8% (or 2 out of 104) of PSMTs in the present study have high MAS ratings (those whose MAS rating is 3.5 or above) and at the same time have high MPSPT scores (those whose math proficiency are at the practitioner or expert level). They affirmed their high problem-solving proficiency was due to good background in math problem-solving but confessed high math anxiety due to high expectations they have set on themselves and feared they might not be able to keep up to their own standard and feared they might fail their teacher's and parents' expectations of them.

Table 7. Simple Linear Regression

	df	SS	MS	F	p
Regression	1	1.22	1.22	5.60	0.02[a]
Residual	102	22.14	0.22		
Total	103	23.36			

*: $p < 0.05$ (significant)

To determine whether MAS rating can predict the MPSPT score of PSMTs, the SLRA was employed. It can be seen in table 7 that since $F(1,102) = 5.60$, $p = 0.02$, $p < 0.05$, we conclude MAS rating does significantly predict MPSPT score among them. This means that the significant portion of the variation in their MPSPT scores can be explained by their MAS ratings.

Table 8. Summary of SLRA for MAS Rating Predicting MPSPT Score

	Coefficient	SE	t	p
Intercept	2.60	0.24	11.05	0.001[a]
MAS Rating	-0.17	0.07	-2.37	0.02[a]

[a] : Significant, $p < 0.05$; $r = -0.21$; $r^2 = 0.05$

Table 8 shows the regression equation: MPSPT Score = 2.60 - 0.17 (MAS Rating). The equation, however, ascertains a significantly weak ability of MAS rating to predict MPSPT score ($F(1,102) = 5.60$, $r = -0.21$, $p = 0.02$, $p < 0.05$).

Moreover, a small coefficient of determination ($r^2 = 0.05$), means that only 5% of the variation in MPSPT scores was due to MAS ratings and approximately 95% were due to other factors. This tells us that the MAS rating indeed provided an impact on pre-service math teachers' MPSPT scores but the extent was too little if taken solely. Other factors need to be explored in terms of the impact they can provide jointly with MAS rating in order to accurately predict pre-service math teachers' MPSPT scores.

4. CONCLUSION

PSMTs in a particular Philippine university generally have little or average math anxiety but still at the novice or apprentice level of math problem-solving proficiency. PSMTs who are low in both MAS rating and math problem-solving proficiency should be given more attention. They are those who lacked confidence in their math ability and displayed weak math background. Pre-service math teachers should be exposed to non-routine problem-solving in their math courses. More exposure to non-routine problem-solving may be necessary to develop their problem-solving proficiency rather than exposure to routine problems solving only. Through practice, this could lessen their worries and anxieties in their future problem-solving encounters. The significantly weak linear relationship between MAS ratings and MPSPT scores gave MAS ratings a significantly weak ability to predict MPSPT scores using a simple linear regression model. It is misleading, therefore, to account for pre-service math teachers' math problem-solving proficiency solely from their math anxiety rating. Other factors may be at play and need to be accounted for.

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