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Metacognition and Mathematical Problem-Solving Performance of Pre-Service Teachers

Allan T. Tabuyo

Cagayan State University – Lal-lo Campus, Sta. Maria, Lal-lo, Cagayan, Philippines

Abstract

To prepare future educators in the field of teaching, they need to be equipped with the necessary competencies and skills. Metacognition and mathematical problem-solving skills are two of these crucial skills that they need to acquire. Hence, this study determined the role of metacognition in the problem-solving performance of pre-service teachers.

It utilized the descriptive-correlational design to describe the metacognitive awareness, use of metacognition, and problem-solving performance of the 103 pre-service teachers. Further, the use and awareness of metacognition and mathematical problem-solving performance are correlated. The instruments used in gathering data are the MAI questionnaire and a mathematical problem-solving task.

Findings revealed that the pre-service teachers are mindful of their metacognition and acknowledge declarative and procedural knowledge as key cognitive components in recalling significant mathematical concepts. Moreover, they plan and evaluate their strategies and procedures to complete more problem-solving tasks. They recognize the role of self-evaluation as an essential component of metacognition. This process helps the pre-service teachers to identify areas for improvement and develop more effective problem-solving strategies.

Furthermore, satisfactory performance in mathematical problem-solving is attributed to the employment of metacognition. However, applying evaluation and planning requires time to accomplish mathematical problem-solving tasks.

These significant components of metacognition identified in the current study are proposed to be considered in the Mathematics curriculum for their essential role in improving the problem-solving performance of pre-service teachers.

Keywords: metacognition, Mathematics, problem-solving, metacognitive awareness, use of metacognition

Introduction

Education prepares learners for their chosen profession and equips them with the skills to become active, responsible, and engaged citizens (Organisation for Economic Co-operation and Development, 2018). Hence, one of its significant aims is to teach students how to learn independently (Anderson, 2018). They must take responsibility and deal with novelty, change, diversity, and ambiguity to think for themselves and work with others (OECD, 2018). They should gain knowledge and skills in problem-solving to deal with challenges brought by the ever-changing society (Malik, 2018).

Therefore, the school and the teachers must provide students with an education allowing the learners to develop the required competencies (Cebrián & Junyent, 2015). To achieve this, future teachers should be prepared to become qualified teachers by improving their competencies and skills in teaching and learning (Pit-ten Cate et al., 2018). Hence, pre-service teachers must acquire skills to learn, not just to cope with schooling but to prepare them for their chosen profession. Pre-service teachers should equip themselves with pedagogical competencies for professional careers (Instefjord & Munthe, 2017). These competencies, including problem-solving, are key objectives of education systems in preparing them to contribute to society (Wrahatnolo, 2018).

Two valuable skills pre-service teachers need to develop are metacognition and mathematical problem-solving skills. These areas are tightly interconnected (Fiteriani et al., 2021). Effective metacognition results in deep and achieving learning and performance (Jiang et al., 2016). It has become increasingly recognized as necessary for learning (Millis, 2016) and plays a vital role in many facets of strategies for tertiary education (Railean et al., 2017).

Rhodes (2019) remarked that metacognition refers to a collection of mechanisms a person uses to control continuous cognition to regulate one's actions effectively. It requires a

Corresponding Author e-mail: allantabuyo1238@csu.edu.ph

https://orcid.org/0000-0002-8136-6420

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deeper understanding of processing knowledge (Keestra, 2017). It is the ability to measure one's knowledge and has been targeted as a vital learning mechanism in mathematics (Vo et al., 2014).

The metacognitive approach allows students to develop thought skills and track and regulate their engagement and actions during the learning experience (De Ocampo-Acero et al., 2015). It offers an opportunity for creative thinking (Puryear, 2016) whereby students can harness potential at their best, push their limits, and adapt to new situations as they focus on the task intensely (De Ocampo-Acero et al., 2015).

On the other hand, problem-solving skill plays a critical role in solving real-life problems (Regidor, 2014). Educational institutions and theorists emphasize this capacity, especially in Science and Mathematics (Meyer et al., 2017).

Since 1980, the National Council of Teachers of Mathematics (cited in Schoenfeld, 1992) started its *Agenda for Action* by stating that problem-solving must be the focus of school Mathematics since the goal of mathematics education should be for students to become competent problem-solvers (Schoenfeld, 1992).

When metacognition is fully incorporated into the education system, schools are better prepared to build more effective and competitive higher education strategies for students (Railean et al., 2017), and methods such as deep learning facilitate comprehension and long-term retention of concepts that are used to solve problems in unconventional contexts (De Ocampo-Acero et al., 2015).

Over the last 15 years, educators and policymakers have considered metacognition crucial and vital (Avargil et al., 2018). It has been an area of interest to educational researchers for many years. As Ellis et al. (2014) mentioned, a large body of literature exists about metacognition. They recognized the importance of metacognition in developing students' problem-solving skills (Hargrove & Nietfeld, 2015; Safari & Meskini, 2016; Medina et al., 2017; Herawaty et al., 2018; Kozikoglu, 2019). Metacognition is considered a significant predictor of Mathematics performance (Schneider & Artelt, 2010; Kuzle, 2018; Ohtani & Hisasaka, 2018; Desoete & Craene, 2019).

In the Philippines, the core skills expected to develop by the learners in the K-12 Basic Education Curriculum are critical thinking and problem-solving (Department of Education, 2016). Many studies on metacognition and problem-solving were conducted, either focusing on each area or determining their relationship. Regidor (2014) determined the influence of metacognitive and motivational dimensions of problem-solving skills on students' progress in problem-solving transfer. He used the MAI (Schraw & Dennison, 1994) to measure awareness in metacognitive skills such as knowledge and regulation. Gurat & Medula (2016) focused on using metacognitive strategy knowledge through mathematical problem-solving among pre-service teachers. Alma Jose et al. (2011) examined the correlation between elementary pupils' metacognitive skills and mathematical problem-solving.

However, few studies in the Philippine context present specific metacognitive components that should be emphasized in Mathematics instruction. Hence, there is a dearth of evidence showing how the dimensions of metacognition could improve the problem-solving performance of pre-service teachers. Also, not many learners have been taught and encouraged to apply metacognition, and international assessment of problem-solving skills reveals an apparent failure to implement this in classrooms (Oliveros, 2014).

In light of this, the current research proposed to determine the role of metacognition in the mathematical problem-solving performance of pre-service teachers. It aims to investigate the association between metacognition and problem-solving skills. Implications would be salient in the Mathematics curriculum, especially the components of metacognition that should be integrated.

Objectives of the Study

The study aimed to determine the role of metacognition in the mathematical problem-solving performance of pre-service teachers. Specifically, it sought answers to the succeeding questions:

1. What is the mathematical problem-solving performance of the participants, along performance task accomplishment, time spent in answering the task, and score?
2. Is there a significant relationship between the participants' mathematical problem-solving performance and their metacognitive awareness and use of metacognition?

Method

Research Design

In this study, the descriptive-correlational design was employed to determine the relationship of metacognition to the mathematical problem-solving performance of pre-service teachers. The research design used was appropriate for its aim of investigating the current situation (Kraska-Miller, 2013) of metacognition and mathematical problem-solving performance. Described were the metacognitive awareness, use of metacognition, and problem-solving performance of the participants. Moreover, the correlational method was used to determine the correlation between the participants' use and awareness of metacognition and their problem-solving performance.

Participants

All 103 senior students at the College of Teacher Education of Cagayan State University at Lal-lo were the participants of the study. Thus, total enumeration was employed. According to Calderon and Gonzales (2014), this sampling consideration yields a more generalizing result as it covers every data that could be gathered from among the population members.

The students were enrolled in their field study subject (practice teaching) at the time of the study. As presented in table 1, there were 87 (84.5%) female and 16 (15.5%) male participants. Their mean age was 20.12, with a standard deviation of 2.38. Most (97 or 94.2%) were single, and the rest (6 or 5.8%) were married. These indicate that the pre-service teachers were female-dominated, post-adolescent, and single.

Research Instruments

The instruments used in gathering data were a questionnaire and a mathematical problem-solving task. The questionnaire was adopted from the study of Schraw and Dennison (1994) to determine the metacognitive awareness and use of metacognition of the participants. The questionnaire utilized to measure the metacognitive awareness and use of metacognition of the participants was the MAI (Schraw & Dennison, 1994). It consists of 52 statements modified to become a 4-point Likert-scale instead of the original point system wherein the participants rate it as yes or no. It is subdivided into two components of metacognition-metacognitive knowledge and metacognitive regulation.

The inventory consists of 17 statements related to metacognitive awareness and 35 statements related to their use of metacognition. The average of their rating was computed to determine their corresponding metacognitive awareness and the use of metacognition value (Young & Fry, 2008; Sperling et al., 2004). The inventory is available online so that it can be accessibly completed.

Table 1: Distribution of the pre-service teachers in terms of sex, age, and civil status

Variable	*Frequency (N=103)*	*Percentage*
Sex		
Female	87	84.5
Male	16	15.5
Age		
Below 20	58	56.3
20 to 24	36	35.0
25 and above	9	8.7
Mean = 20.12	SD = 2.38	
Civil Status		
Single	97	94.2
Married	6	5.8

Different studies have supported the satisfactory reliability and validity of the instrument. The internal consistency (reliability) for the entire inventory has been reported to be 0.90 (Schraw & Dennison, 1994; Sperling et al., 2004; Zhang, 2010). The validity of this instrument has been inspected and substantiated by Schraw and Dennison (1994), who performed a two-factor solution on the data. The result supported two factors accounting for 65% of the sample variance. In this study, Cronbach's alpha reliability coefficient of the MAI questionnaire was recalculated and found to be 0.93, which is highly reliable (Can, 2013), while the Knowledge about Cognition (Metacognitive Awareness) and Regulation of Cognition (Use of Metacognition) dimensions were 0.86 and 0.90 respectively.

The second instrument was a mathematical problem-solving test comprising five tasks to test the problem-solving skill of the pre-service teachers. For each task, the participants recorded their time spent in completing the items. A rubric was prepared to score their outputs.

Data Gathering Procedure

Before the questionnaire was administered to the participants, the mechanics were discussed to obtain their full voluntary cooperation. The concepts and role of metacognition in the problem-solving task were also explained.

The participants were personally met and visited in their assigned rooms to clarify any information the researcher wanted to verify. They were requested to give honest answers. They were informed, too, that their responses would be treated in strict confidentiality. The participants kept the questionnaire and the test until they finished the task. The retrieval of the questionnaires was done immediately after the participants answered them.

Analysis of Data

The data gathered from the study were analyzed using the SPSS version 23. Four-point Likert-type scoring intervals were employed to evaluate the pre-service teachers' metacognitive awareness and use of metacognition. For metacognitive awareness, 1.00-1.74 was "Unaware", 1.75-2.49 was "Somewhat Aware", 2.50-3.24 was "Aware", and 3.25-4.00 was "Very Aware"; and for the use of metacognition, 1.00-1.74 was "Never", 1.75-2.49 was "Sometimes", 2.50-3.24 was "Often", and 3.25-4.00 was "Always". The values were correlated to the participants' mathematical problem-solving performance using

Table 2: The descriptive statistics for the various MAI questionnaire dimensions

Dimension	*Mean/ Descriptive Value (N=103)*	*Standard Deviation*	*Skewness Coefficient*
Knowledge of Cognition			
Declarative Knowledge	2.94 (Aware)	0.71	-0.21
Procedural Knowledge	3.09 (Aware)	0.55	0.05
Conditional Knowledge	3.25 (Very Aware)	0.55	-0.11
Regulation of Cognition			
Planning	3.24 (Often)	0.55	0.06
Comprehension Monitoring	3.10 (Often)	0.57	-0.26
Information Management Strategies	3.07 (Often)	0.62	-0.05
Debugging Strategies	3.22 (Often)	0.62	-0.27
Evaluation	3.06 (Often)	0.62	-0.14

Pearson product-moment correlation. This statistical test is used widely to determine the relationship between normally distributed variables (Puth et al., 2014).

The skewness coefficients were examined for the analyses to determine whether the data set was normally distributed. According to Büyüköztürk (2012), the data shows a normal distribution when the skewness coefficient is between -1 and +1. Considering the requirements, the means, standard deviations, and skewness coefficients for the different dimensions of the instrument are provided in Table 2:

Results

Mathematical Problem-Solving Performance

The purpose of conducting the study was communicated to the pre-service teachers, including determining their mathematical problem-solving skills. Hence, they were requested to accomplish the set of mathematical tasks. Their task progress was monitored by asking them about concerns and encouraging them to employ metacognitive strategies.

Thus, evident in table 3 is the mathematical problem-solving performance of the pre-service teachers. It can be gleaned that most (92 or 89.3%) of the participants completed the problem-solving task, while the rest (11 or 10.7%) could not finish all the tasks. Most participants (60 or 58.3%) spent one to two days, while 29 or 28.2 percent needed three to four days to submit their outputs. The average day spent is 2.73, indicating that the students need time to finish mathematical problem-solving tasks. In addition, the table shows that 37 or 35.9 percent performed satisfactorily, and 36 or 35.0 percent performed fairly. The mean score of 12.99 indicates that the participants perform satisfactorily in mathematical problem-solving.

Table 3: Result of the mathematical problem-solving tasks accomplished by the pre-service teachers

Variable	*Frequency (n=103)*	*Percentage*
Accomplishment		
Completed	92	89.3
Not Completed	11	10.7
Time Spent (in days)		
5 and more	12	11.7
3 to 4	29	28.2
1 to 2	60	58.3
Less than 1	2	1.9
Mean=2.73	SD=1.69	
Score		
24 to 30 (Outstanding)	19	18.4
18 to 23 (Very Satisfactory)	11	10.7
12 to 17 (Satisfactory)	37	35.9
6 to 11 (Fair)	36	35.0
0 to 5 (Poor)	-	-
Mean=12.99 (Satisfactory)	SD=7.03	

Relationship between the Participants' Metacognitive Awareness, Use of Metacognition, and Problem-Solving Performance

Presented in table 4 are the correlation results between the participants' metacognitive awareness, use of metacognition, and problem-solving performance. It can be gleaned that their use of evaluation (r=0.303, p=0.002) had a significant relationship with their accomplishment. Using evaluation (r=0.200, p=0.043) and information management strategies

Table 4: Correlation results between the participants' metacognitive awareness, use of metacognition, and problem-solving performance

	Accomplishment		*Time Spent*		*Score*	
Variables	**r**	*p-value*	*r*	*p-value*	*r*	*p-value*
Metacognitive Awareness						
Conditional Knowledge	0.120	0.226	0.006	0.952	-0.034	0.734
Declarative Knowledge	0.145	0.143	0.001	0.994	0.225*	0.022
Procedural Knowledge	0.188	0.057	-0.028	0.779	0.218*	0.027
Use of Metacognition						
Planning	0.097	0.328	0.113	0.257	0.269**	0.006
Comprehension Monitoring	0.153	0.124	0.020	0.837	-0.088	0.376
Information Management Strategies	0.049	0.622	0.208*	0.035	-0.137	0.168
Debugging Strategies	0.147	0.139	0.167	0.091	-0.095	0.342
Evaluation	0.303**	0.002	0.200*	0.043	0.203*	0.040

*** (Highly Significant) * (Significant)*

(r=0.208, p=0.035) correlated to their time spent completing the tasks. Moreover, the participants' declarative knowledge (r=0.225, p=0.022), procedural knowledge (r=0.218, p=0.027), employing evaluation (r=0.203, p=0.040), and planning (r=0.269, p=0.006) were statistically significantly correlated to their mathematical problem-solving scores.

Participants who evaluate their strategies and procedure can complete more tasks. Applying declarative knowledge, procedural knowledge, evaluation, and planning correlate to better mathematical problem-solving performance. However, employing evaluation and information management strategies relates to more days spent completing the tasks.

These imply that for the pre-service teachers to improve their mathematical problem-solving skills, they need to have declarative and procedural knowledge. In addition, they need to spend time planning and evaluating their thinking and problem-solving processes.

Discussion and Conclusions

This study determined the role of metacognition in the mathematical problem-solving performance of pre-service teachers. This metacognition refers to their ability to reflect on and regulate their thinking and problem-solving processes. It involves their awareness of problem-solving strengths and weaknesses and employing various strategies to enhance learning and performance.

During their performance task, the pre-service teachers were given mathematical problem-solving tasks and were encouraged to employ metacognition. Enough time was provided for the participants to independently employ all problem-solving strategies they had acquired in their schooling.

Findings revealed that the pre-service teachers were mindful of their metacognition. The participants believed to possess the abilities and recognized the importance and usefulness of the different dimensions of metacognitive regulation. They acknowledged declarative and procedural knowledge as key cognitive components in recalling significant mathematical concepts.

Moreover, the pre-service teachers have satisfactory performance in mathematical problem-solving. This is manifested by the significant number of participants who completed the tasks and gained high scores.

It is concluded that pre-service teachers who plan and evaluate their strategies and procedures can finish more problem-solving tasks. Understanding the purpose of the problem-solving tasks can effectively enhance metacognition, allowing the participants to focus their attention and effort on a specific output, hence can accomplish more tasks. Also, self-evaluation is an essential component of metacognition. It allowed the pre-service teachers to reflect on their learning, performance, strengths, and weaknesses. This process helped the participants to identify areas for improvement and develop more effective problem-solving strategies.

Furthermore, satisfactory performance in mathematical problem-solving can be attributed to the employment of declarative knowledge, procedural knowledge, evaluation, and planning. However, applying evaluation and planning requires time to complete mathematical problem-solving tasks.

Hence, for Mathematics learners to perform well in problem-solving, sufficient time should be allotted for planning and evaluating their learning and performance. Students must realize that planning and evaluating are parts of the process and should be emphasized by teachers. In this way, students can employ metacognitive strategies proven to help develop their thinking and learning abilities.

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