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Do Military Students' Mathematical Self-Efficacy and Metacognitive Awareness Matter on Their Problem Solving Performance?

Joseph B. Ajan Jr*, Charita A. Luna, Dennis B. Roble

University of Science and Technology of Southern Philippines, Lapasan Highway, Cagayan de Oro City, Philippines
*Corresponding author: jbajan47@gmail.com

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Abstract The military of every country is viewed as a problem-solving and decision-making branch of government for safety concerns. To enrich the military students' problem-solving skills and decision-making ability, they must be trained to become excellent problem solvers. This study focused on determining the military students' personal attributes like their self-concept in mathematics, mathematical beliefs, and metacognitive awareness in relation to their problem-solving performance. The study was conducted in a military school in the Philippines for second-year cadets during the first term of the academic year 2019-2020. This study used a descriptive correlational research design. The instruments used in this study are the mathematics self-concept, mathematical beliefs, and Metacognitive Awareness Inventory (MAI). A validated teacher-made test with a reliability coefficient of 0.73 was used with a rubric scale to measure students' problem-solving performance. The correlation and regression analysis was used to analyze the data collected. Results of the analysis revealed that students' self-concept in mathematics and metacognitive awareness, self-concept and problem-solving performance, and metacognitive awareness and problem-solving performance has a strong positive correlation while students' mathematical beliefs and metacognitive awareness, as well as the students' self-concept in mathematics and metacognitive awareness, showed a low positive association. Further analysis also showed that students' self-concept in mathematics and metacognitive awareness is found to predict military students' problem-solving performance. Hence, it is recommended that military school professors need to develop students' self-concept in mathematics and use metacognitive teaching strategies in teaching mathematics to enhance students' problems solving skills. Further research can be explored for other factors that may affect military students' problem-solving skills.

Keywords: *self-concept in mathematics, mathematical beliefs, metacognitive awareness, mathematics problem solving performance, military school*

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1. Introduction

The military personnel of every country needs to solve complex problems on the battlefield. They need to possess strong problem-solving skills to effectively execute their course of action in the battlefield situations [1]. The military school demands this vital skill to be effectively developed among their students' and the curriculum plays an important role in the successful development. Mathematics is a fundamental part of the school curriculum and it is considered a core skill for life and a key for critical thinking flexibility need for economic prosperity as well as in crisis. However, many students, including those in the military school, regarded mathematics as one of the difficult subjects, and others viewed it as a roadblock for their success in school [2]. This is evident in the consistently poor performance of Filipino students in mathematical problem-solving at the national and international comparison assessments.

Students' poor performance in problem-solving in mathematics could be attributed to a number of factors which include students' lack of specific domain knowledge and skills and the shortcomings in the heuristic, metacognitive and affective aspects of mathematical competence. Metacognition refers to the ability of students to understand one's learning and reflecting on the process of thinking [3]. Metacognition is essential to successful learning because it enables individuals to better manage their cognitive skills and to determine weaknesses that can be corrected by constructing new cognitive skills. Almost anyone who can perform a skill is capable of metacognition, that is, thinking about how they perform that skill. Recent research indicates that metacognitively aware learners are more strategic in solving problems and perform better than unaware learners. Metacognitive awareness allows individuals to plan, sequence, and monitor their learning in a way that directly improves performance. In mathematics classrooms, it is important that students can develop independent learning and can regulate their own learning which metacognitive abilities can be highlighted and taught [4]. According to Schraw and Dennison who created the Metacognitive Awareness Inventory (MAI), this situation enables a student to plan, sequence, and monitor his or her learning so that the improvements can be seen directly in their performances [5]. Therefore, it is important for researchers and practitioners to assess students' metacognition [6]. One of the domains in which metacognition is a key variable predicting learning performance is the domain of the mathematical problem solving [7] which is necessary for military students because they are the future leaders of the military force of the country.

Meanwhile, students' beliefs about mathematics and outlook about mathematics learning can have a substantial impact on their interest, enjoyment, and motivation in mathematics classes [8]. There has been increasing research on the essential role of beliefs of students in the learning of mathematics. This motivated the researcher to include this variable which might also affect their level of metacognitive skills in mathematics because when students' had negative beliefs in the subject then it may greatly affect their performance in mathematics. Likewise, the mathematics self-concept may also affect the performance of the students. There is a positive relationship between self-concept in Mathematics as stated in Programme for International Student Assessment (PISA) [9].

The National Council of Teachers of Mathematics (NCTM) as well as the Philippine Council of Mathematics Teacher Educators (MATHED) promoted and advocated problem-solving to be given emphasis in instructions because that it plays a critical role in mathematics. In fact, problem-solving is considered as the most significant cognitive skill in everyday life and in professional environments [10]. The Principles and Standards for School Mathematics suggests that by learning problem-solving in mathematics, students can acquire critical thinking skills, persistence, curiosity, and confidence in facing unfamiliar situations that will help them well in the real-life especially in their future workplace. Good problem solvers can lead to great advantages [11]. Thus, one of the major goals of mathematics education is the acquisition of this skill of learning how to solve problems [12]. Learning how to help students at every level to become successful problem solvers has emerged as one of the most important contemporary research issues in mathematics education [13].

2. Literature Review

Studies and researches that support the current study are considered as regards to metacognition, self-concept, mathematical beliefs, and problem-solving performance in mathematics of students.

Chiu & Klassen examined the effects of mathematics self-concept and mathematics calibration on mathematics achievement through multilevel analyses of the mathematics tests and questionnaire. There were 88, 590 respondents among 15-year old who participated. Students with higher mathematics self-concept had higher mathematics scores. Mathematics self-concept was more strongly linked to mathematics achievement for boys. Students who were overestimating their mathematics competence had low mathematics scores [14].

Tan examined the relationship of academic self-concept and problem-solving achievement in mathematics. He used a descriptive correlational design with 249 randomly chosen students as respondents. A parametric correlational test was used to analyze the association of academic self-concept and problem-solving performance. The result suggests that higher self-concept in academics and extent of utilization of learning strategies in solving mathematical problems result in a high-problem solving achievement [15].

Suthar, Tarmizi, Midi & Adam did a study on students' beliefs on mathematics and achievement of university students using logistic regression analysis. The study involves a sample of university undergraduate mathematics students. Those who completed the self-reported questionnaire on how mathematical beliefs on relationship to beliefs about mathematics, beliefs about the importance of mathematics, and beliefs about one's ability in mathematics. They also analyzed students' mathematical beliefs based on the logistic regression model estimation technique, appropriate for a survey design study. The results revealed a significant relationship between students' beliefs about the importance of mathematics and beliefs about one's ability in mathematics with mathematics ability. In addition, the overall model explained further that 74.6% of the sample was classified correctly. Their study is related to the present study because the variable belief is also used [16].

Tarmizi, Tarmizi & Mokhtar also investigated the extent of humanizing mathematics among secondary mathematics teachers based on student's perception of their teachers' practices in the classroom, specifically their beliefs about the classroom context such as the role and functioning of the mathematics teacher in the classroom. The mean scores for students' beliefs in their teachers' role and functioning in the mathematics classroom was positive with high ratings on showing step-by-step procedures in solving mathematical problems. Students also showed positive beliefs on teachers' role in making mathematics learning enjoyable, interesting, and making learning mathematics understandable, meaningful, and a friendly atmosphere [17].

Du Toit & Kotze investigated the use of metacognitive strategies using Grade 11 mathematics learners with their teachers. In their study, two objectives were to investigate which metacognitive strategies Grade 11 mathematics learners are using and how mathematics teachers can enhance metacognition among learners, and to investigate the extent to which Grade 11 mathematics learners are using metacognitive strategies. Questionnaires were used to obtain quantitative data about the use of metacognitive strategies by learners and teachers. Their findings revealed that planning strategy, evaluating their way of thinking and doing were used mostly by teachers and learners. Journal-writing and thinking loud were used least by teachers and learners [18].

Schneider & Artelt analyzed the role of metacognition in mathematics education based on theoretical and empirical work from the last four decades. Their study emphasizes the importance of metacognition in mathematics education, summarizing empirical evidence on the relationships between various aspects of metacognition and mathematics performance. The main result of correlational studies, revealed the impact of declarative metacognition on mathematics performance is substantial [19].

Abdullah, Rahman & Hamzah, studied students' metacognitive skills and the impact of such skills on non-routine mathematical problem-solving. Using a total of 304 students from Johor Bahru district of Malaysia were asked to respond to a Self-Monitoring Questionnaire (SMQ) and a mathematical test for data collection and was analyzed. Results showed that the level of the students' performance in solving non-routine mathematical problems was very low. There was also a significant difference in the metacognitive skills among students with different performance levels in solving non-routine mathematical problems, and they concluded that these metacognitive skills should be emphasized in the learning process [20].

Sahin & Kendir studied the effect of using metacognitive strategies for solving geometry problems on students' achievement and attitude. The experimental method was used with a pre-test/post-test control group design. Both groups were subject to a pre-test that comprised "the achievement test", "the metacognitive skills inventory" and "the attitude toward mathematics scale". Next, the experimental group (39 students) was taught geometry for eight weeks by lesson plans and worksheets designed to improve the students' ability to use metacognitive skills for solving problems. In the meantime, the control group (36 students) was taught through traditional methods. In the end, the three data collection instruments were administered to both groups as a post-test. The data were analyzed using t-tests on the post-test gain of the experimental and control groups. Results revealed that the experimental group had significantly higher post-test gain scores compared to the control group. More significant results were obtained when the findings revealed by statistical analyses were accompanied by student essays. It was observed that the students in the experimental group had developed a better attitude toward geometry and mathematics, which might be attributed to the improvement in their self-confidence. Furthermore, these students had developed the ability to perceive the importance of problem-solving, to understand problems, to include planning in solving process, and to control and monitor the problem-solving process. The improvement in their attitude toward geometry and mathematics led to a corresponding increase in their achievement [21]. This study has similarities with the variables being investigated.

Smith did an exploration of metacognition and its effect on mathematical performance in differential equations. In this research, the metacognitive levels for two classes of differential equations students were analyzed. Students completed a survey adapted from the Metacognitive Awareness Inventory (MAI) developed by Shraw & Dennison at the start of the course. The questions chosen from the MAI were aimed at three components concerning the students' knowledge about their cognition: declarative knowledge, procedural knowledge, and conditional knowledge. Analysis used student performance, as measured by the course grade, cannot be predicted by metacognitive awareness levels [22]. This study has a semblance with the present study since MAI questionnaire will also be utilized in this present study.

3. Methods

This study utilized the descriptive correlational research design. Correlation analysis and multiple regression were used to determine the relationship of students' mathematical belief, self-concept, and metacognitive awareness and subsequently their association with problem-solving performance.

The respondents were the second year of a military school in the Philippines taking up Analytic Geometry. A total of 150 cadets participated in the study. These cadets are the only ones present during the administration of the tests. Some cadets were not able to participate since they have duties or they are posted as guards during the administration of the tests.

The adopted self-concept for mathematics questionnaire was utilized in this study. This is a 20-item with a four-scale questionnaire that aimed at assessing what the cadets think, feel act, and value in mathematics. Also, the mathematical beliefs of the cadets were assessed through the 26-item four-point scale adapted mathematical beliefs questionnaire. This questionnaire assessed the cadets' beliefs in nature and learning in mathematics.

Another instrument used in this study was the adapted 52-item Metacognitive Awareness Inventory (MAI) questionnaire was used. This instruments was used to measure the degree of metacognitive awareness of the cadets. It assessed the degree of awareness of the cadets on their planning, monitoring, and evaluation while solving a problem which are the essential components of metacognition. In addition, the four-item teacher-made test on analytic geometry problems was also used to assess the problem-solving performance of the cadets with a reliability coefficient of 0.71. A rubric was used to score the papers of the cadets.

Prior to the administration of the tests, the researcher conducted a course conference to all the instructors handling the analytic geometry to ascertain uniformity of answering the test. During the administration, the teachers administered first the 4-item problem-solving which was considered as their lesson examination for the day, then it was followed by the administration of the three (3) other instruments namely: mathematical beliefs, self-concept in mathematics and metacognitive awareness inventory. The correlation analysis was used to determine the degree of relationship of the mathematical beliefs, self-concept in mathematics, and metacognitive awareness inventory. The multiple regression analysis was used to determine the significant relationship of mathematical beliefs, self-concept in mathematics, and metacognitive awareness inventory with the problem-solving performance of the cadets. Also, the multiple regression analysis was used to determine which aspects of metacognitive awareness has bearing on the problems solving of the cadets. In testing the hypotheses, alpha is set at a 0.05 level of significance.

4. Results and Findings

The results of this study was presented in the following tables:

Table 1. Correlation Matrix of Military Students' Self-Concept in Mathematics, Mathematical Belief, Metacognitive Awareness and Problem Solving Performance

	Self-Concept	Mathematical Belief	Metacognitive Awareness	Problem Solving
Self-Concept	1			
Mathematical Belief	**0.4463**	1		
Metacognitive Awareness	**0.9235**	**0.4639**	1	
Problem Solving	**0.8787**	**0.4401**	**0.9145**	1

Table 1 presents the correlation matrix of the cadets' self-concept, mathematical belief and metacognitive awareness, and problem-solving performance. For cadets' self-concept in mathematics and metacognitive awareness perception, the correlation coefficient r is 0.9235. This indicates that these two variables have a high positive correlation. This means that cadets with positive self-concepts have also positive awareness on their metacognitive questionnaire while cadets with negative self-concepts have also negative metacognitive awareness.

The correlation coefficient of self-concept and problem solving is 0.8787. This also indicates a strong positive correlation which means that cadets with positive self-concept have also high problem-solving performance and cadets with negative self-concept have low problem-solving performance. Likewise, there is a high positive correlation between metacognitive awareness perception and problem-solving performance with a correlation coefficient r of 0.9145. This result means that cadets with positive perception on their metacognitive awareness have high problem-solving performance and cadets with negative metacognitive awareness perceptions have low problem-solving performance.

On the other hand, the correlation coefficient r of cadets' self-concept and mathematical belief is 0.4463; this signifies a weak positive correlation. Hence, cadets' self-concept in mathematics and mathematical beliefs are poorly related to each other. Meanwhile, it can be gleaned that the correlation coefficient r of cadets' mathematical beliefs and metacognitive awareness is 0.4639. This also means the weak relationship between mathematical belief and metacognitive awareness. Also, there is a weak correlation of mathematical beliefs and problem-solving performance as evident in the correlation coefficient r which is 0.4401.

Table 2. Regression Analysis of Military Students' Problem Solving Performance as Associated by their Self-Concept in Mathematics, Mathematical Belief and Metacognitive Awareness

Variable	Coefficient	Standard Coefficient	t	p-value
Self-concept	0.6282	0.2869	2.19	0.031*
Mathematical Belief	0.2076	0.5780	0.36	0.743
Metacognitive Awareness	2.5259	0.3864	6.54	0.001*

Table 2 shows the result of the regression analysis of cadets' self-concept in mathematics, mathematical belief, and metacognitive awareness perception with the problem-solving scores. It can be seen that the p-value of cadets' self-concept in mathematics is 0.031 which is less than the level of significance of 0.05. This leads to the rejection of the null hypothesis. This means that there is a statistically significant relationship between cadet's self-concept and problem-solving scores. This implies that cadets' self-concept in mathematics is a predictor of their problem-solving performance.

Meanwhile, the cadets' mathematical belief has a p-value of 0.743, which is greater than the level of significance 0.05. Thus, the null hypothesis is not rejected. This means that there is no significant relationship between cadets' mathematical belief and performance in problem-solving. On metacognitive awareness of the cadets has a p-value of 0.001, which is greater than the level of significance 0.05. This led to the rejection of the null hypothesis. This implies that there is a significant relationship between metacognitive awareness and problem solving scores. This further imply that the metacognitive awareness of the cadets is a predictor of their mathematical problem solving performance.

To further analyze which category of the metacognitive awareness had significant effect of the cadet's problem solving performance, the regression analysis was done.

Table 3. Effect of Metacognitive Awareness Indicators on Military Student's Problem Solving Performance

Variable	Coefficient	Standard Coefficient	t	p-value
1. Planning	1.1579	0.4520	2.56	0.012*
2. Monitoring	0.0589	0.4409	0.13	0.894
3. Evaluation	1.2436	0.5560	2.24	0.028*
4. Information Management Strategies	0.7425	0.4524	1.64	0.104
5. Debugging Strategies	0.6482	0.3793	1.71	0.091
6. Procedural Knowledge	0.2795	0.09385	2.98	0.004*
7. Declarative Knowledge	0.3732	0.4432	0.84	0.402
8. Conditional Knowledge	0.6316	0.4712	1.34	0.184

Table 3 shows the regression analysis of components of metacognitive awareness on the problem-solving scores of the cadets. It can be observed that the p-value of the planning stage is 0.012 which is less than the level of significance. This means that the planning has an association with the problem-solving performance of the cadets. Also, the evaluation component is 0.028 which is less than the level of significance. This indicates that evaluation has also a significant relationship with the problem-solving score of the cadets. Likewise, the p-value of the procedural knowledge component of metacognitive awareness 0.004 is less than the level of significance 0.05; hence, procedural knowledge has a significant relationship with the problem-solving performance of the cadets. Generally, though the metacognitive awareness perception and problem-solving performance of the cadets have a statistically significant relationship only the evaluation and procedural knowledge components were substantially related to their problem-solving performance. This implies that planning and evaluation while solving and a strong foundation on how to solve the problem are important components of metacognition needed in solving any problem which can lead to appropriate decision making. These findings support the study of Du Toit & Kotze [18].

5. Concluding Statements

Based on the analysis and findings of the study the mathematics self-concept and the metacognitive awareness of the students, which are both related to each other are associated with the problem-solving performance of military students. The higher the self-concept and metacognitive awareness the higher is the problem-solving performance. In addition, the planning, evaluation, and procedural knowledge of the students are an important component of metacognition that is associated with their problem-solving performance. Students with high evaluation, planning, and procedural knowledge have high performance. The researchers recommend using metacognitive teaching strategies to enhance students' problem-solving performance.

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