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Metacognitive Awareness as a Predictor of Mathematics Problem-Solving Skills Among BSEd Mathematics Students

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Abstract: This study aimed to determine the significant relationship between metacognitive awareness in terms of planning, monitoring, and evaluation, and mathematics problem-solving skills in terms of Polya's four steps in problem-solving: understanding the problem, devising a plan, implementing a plan, and re-evaluation among BSEd Mathematics students in Davao de Oro State College, A.Y. 2022-2023. Utilizing a non-experimental quantitative design with a predictive correlational approach, the researchers surveyed students across all year levels using the Metacognitive Awareness Inventory (MAI) and the Problem-Solving Test Questionnaire (PSTQ) to gather data on their metacognitive awareness and problem-solving skills. Data analysis involved descriptive statistics and Kendall's Tau Correlation, given the ordinal and continuous nature of the variables. Results indicated that students exhibited high metacognitive awareness and very high problem-solving skills. However, the study found no significant relationship between the two, as evidenced by a p-value of 0.566 (greater than 0.05) and a Kendall's Tau correlation coefficient of 0.046. This signifies that the BSEd Mathematics students' level of problem-solving skills is not affected or associated with the extent of their metacognitive awareness. This indicates that the students' problem-solving skills are not influenced by their metacognitive awareness. The unexpected nature of this finding highlights the need for further research to understand the factors contributing to the lack of a significant relationship between these variables.

Keywords: Mathematics, Metacognitive Awareness, Problem-Solving Skills, Word Problem

INTRODUCTION

Problem solving is the focus of the school's mathematics curriculum, and students are expected to gain experience in transferring and applying learned knowledge and skills to solve problems during the learning process (Permata et al., 2018). However, some students received poor grades and were uninterested in learning mathematics (Sipayung & Anzelina, 2019). Despite having a solid understanding of mathematical concepts, students struggle with computation and analysis. They make mistakes because they misread, carry, or write numbers incorrectly, or because they may not write the numbers clearly or in the right column (Siniguian, 2017). In fact, the study of Irsal, et al. (2017) revealed that almost all students have low problem-solving skill because they did not re-examine their answer solutions. As added, it is because students are unable to correctly read the problem, read the concept that exists in question, and determine the correct solution.

Metacognitive awareness is a variable thought to influence problem-solving beliefs. Reviewing the literature, it is clear that this study primarily focuses on metacognitive awareness and problem-solving skills. This part is related to our study on the relationship between the two variables.

In 2018, Setiawan & Supiandi stated that Mathematics courses are thought to have the potential to be used as research material to improve problem-solving and conceptual skills. Mathematics is one of the most important scientific disciplines taught from elementary school to college level due to its importance. Thus, mathematics must be taught to all students for them to be able to think logically, analytically, systematically, critically, creatively, and collaboratively, and to be able to acquire, manage, and apply information in an ever-changing, uncertain, and competitive environment.

Correspondingly, mathematical word problems are among the most difficult types of problems in mathematics, and many reasons have been identified for their difficult nature (Reinhard et al., 2022). It is one of the most difficult aspects in the process of seeking a solution, which requires a few steps. First, the text must be read and comprehended. Following that, a decision must be made about which mathematical operations are necessary to formulate an equation. Finally, to obtain the answer, the learner must solve the mathematical equation (Kusaka & Ndihokubwayo, 2022).

Generally speaking, solving mathematics problems necessitates the analysis of the given problem, the planning of the strategy to be used to solve the problem, the implementation of the planned strategy, and the verification that the steps taken are correct (Izzati & Mahmudi, 2018). When solving problems, teachers encourage their students to read and identify known information, predict results, reflect on problem-solving processes, and consider alternative solutions, which allow students to use metacognition (Kusaka & Ndihokubwayo, 2022). All steps in the problem-solving process are examples of metacognitive abilities. Thus, metacognition is a skill required for problem-solving (Siagian et al., 2019).

The main objective of the study was to determine the significant relationship between metacognitive awareness and problem-solving skills among BSEd Mathematics students in Davao de Oro State College. Specifically, the study sought answers to the following objectives:

1. To determine the extent of metacognitive awareness among BSEd Mathematics students in Davao de Oro State College in terms of:
   a. planning;
   b. monitoring; and
   c. evaluation.
2. To determine the level of mathematics problem-solving skills among BSEd Mathematics students in Davao de Oro State College in terms of:
   a. understanding the problem;
   b. devising a plan;
   c. implementing a plan; and
   d. re-evaluation.
3. To determine the significant relationship between metacognitive awareness and mathematics problem-solving skills among BSEd Mathematics students in Davao de Oro State College; and
4. To determine what domain in metacognitive awareness significantly predicts the mathematics problem-solving skill among BSEd Mathematics students in Davao de Oro State College.

A low concentration of metacognitive and problem-solving skills can have a significant impact on society. The study's findings can be used to improve appropriate courses that concentrate on the content, methodology, and pedagogy of how mathematics subjects are learned and taught. If metacognitive and problem-solving skills in math students predict mathematical achievement, this can be used as a starting point for future research. The findings of this study, in particular, may assist tertiary education institutions in determining the effectiveness of their mathematics courses.

Furthermore, administrators and educators can use the study's findings as a starting point for recognizing the occurrence of metacognition in mathematics learning and teaching, specifically how to deal with the problem of a more efficient learning approach using the relationship between metacognitive awareness and problem-solving skills. This could also help Davao de Oro State College Bachelor of Secondary Education major in Mathematics students hone their teaching and learning skills, especially their problem-solving skills as future mathematics educators. It provides them with the knowledge they need to become better teachers in the future. As a result, the researchers hope to draw attention to certain factors contributing to students' continued underachievement in mathematics one of the most important subjects in the curriculum. Because students are the primary users of the educational system, the study's findings may one day benefit them. Hence, if a significant relationship is determined, metacognitive awareness should be applied more frequently in mathematics to enhance the students' mathematical achievement and problem-solving skills, which benefits future math educators and problem solvers in society. Therefore, this study helps reduce the number of students who struggle with mathematics.

METHOD

Research Design

The study is non-experimental quantitative research with a predictive correlational design to predict the association or value of one variable based on the values obtained for another variable or variables. Correlational studies do not establish cause and effect, but seek to establish the existence and degree of relationship between two or more variables, involving independent and dependent variables. In predictive correlational design, the variable to be predicted is classified as the dependent or outcome variable, and the other variable is the independent or predictor variable which is used by the researchers to estimate the value of the dependent variable (Panda, et al., 2022). In this study, the dependent variable is the problem-solving skills of students and the independent variable is the metacognitive awareness. This study also uses post-test-only design as it aimed to determine the relationship between the metacognitive awareness and problem-solving skills, without manipulating either variable, at a single point in time and not on measuring change over time.

This quantitative study used Kendall's Tau correlation, a non-parametric measure of correlation between two variables which seeks to measure the degree of association between the two variables, where the variables are ordinal or ranked and continuous (Khamis, 2008).

Research Locale

This study was conducted at Davao de Oro State College (DDOSC) – Main Campus at Purok 10, Poblacion, Compostela, Davao de Oro. Due to COVID 19 pandemic, the College was implementing limited face-to-face delivery of instruction.

The Davao de Oro is located in Region XI with geographical coordinates of 7.5125°North and 126.1763°East, situated in the Davao Region inhabiting the Southeastern section of Mindanao. It is bordered, clockwise from the north, by Agusan Del Sur, Davao Oriental, Davao Gulf and Davao del Norte. According to the 2015 census, the population in Davao de Oro was 736, 107. This embodies 15.04 % of the whole population in Davao Region, 3.05% of the total population in Mindanao and 0.73% in the entire population of the Philippines. Davao de Oro is divided into two districts, comprising eleven municipalities: Compostela, Maragusan, Monkayo, Montevista, and New Bataan in District 1, and Laak, Mabini, Maco, Mawab, Nabunturan, and Pantukan in District 2 (see Figure 1).

Respondents

The respondents of this study were all students taking up Bachelor of Secondary Education major in Mathematics in Davao de Oro State College – Main Campus for the Academic Year 2022-2023. Some courses offered by the College were not included since they did not fit as respondents of this research. Stratified random sampling was used as a sampling method in selecting the respondents. Stratified random sampling is a method that divides a population into smaller subgroups known as strata (Hayes-Larson, 2022), which are the BSEd Mathematics First Year, Second Year, Third Year, and Fourth Year students to ensure representation from each year level within the population of BSEd Mathematics students at Davao de Oro State College - Main Campus. This approach was chosen to mitigate potential biases associated with variations across year levels.

The researchers had their printed questionnaire disseminated to their respondents personally on the DDOSC Main Campus. The given printed questionnaire was distributed and retrieved personally at the school. The participant's participation in this study was completely voluntary. Before disseminating the questionnaire, the respondents were provided with printed informed consent/assent. An assent form was provided to minor respondents (below 18 years old) and had signed by the student's parents and a consent form signed by the respondents themselves (if they were 18 or older) before they participated in the study. Participants was required to sign a document acknowledging their full participation in the study. They were advised and given the option to participate and answer the question on a discretionary basis. They were also oriented that they were not required to participate in the study and that declining to do so would not have any negative effects. During the dissemination of the questionnaire, the researchers were open to any questions or concerns from the respondents. Before answering, the respondents were instructed to ensure their answers were honest, clear, and complete. The respondents were given an hour to answer the questions.

In this study, the researchers ensured that the respondents' test results will be kept confidential and that their identities will be never revealed.

Figure 1. Map of Davao de Oro in the Philippines, highlighting the Municipality of Compostela, in which the school is Located

Research Instruments

This study used the Metacognitive Awareness Inventory (MAI) to collect quantitative data on respondents' current level of metacognitive awareness, specifically their planning, monitoring, and evaluation strategies. The MAI was developed by Schraw & Dennison (1994) and adapted by Aljaberi & Gheith (2015) in their study "University Students' Level of Metacognitive Thinking and their Ability to Solve Problems." The MAI consisted of two main components and eight subcomponents of metacognition, but five subcomponents from the original version of the MAI were removed because they did not conform to the purpose and indicators of the study.

The MAI is a 5-point Likert-scale self-reporting questionnaire consisting of 20 items: 7 items for planning, 7 items for monitoring, and 6 items for evaluation. Students, according to their mental processing in solving a word problem, respond by putting a check in the boxes. The responses ranged from: 1=Strongly Disagree, 2=Disagree, 3=Undecided, 4=Agree, to 5=Strongly Agree. Also, the composite score of metacognitive awareness was computed and used to assess how metacognition predicts problem-solving skills.

In the study of Aljaberi & Gheith (2015), the reliability coefficient value (Cronbach's alpha) for the MAI scale as a whole was 0.952, which was calculated using a sample group of 50 students. Likewise, the MAI had been identified as the only currently available and reliable psychometric measure for metacognitive awareness, with $\alpha=0.90$ (Schraw & Dennison, 1994; Hughes, 2019). Additionally, each subcomponent had its own reliability coefficient values. The reliability values for the three indicators for metacognitive awareness were 0.83 for planning, 0.88 for monitoring, and 0.81 for evaluation (Aljaberi & Gheith, 2015). On the other hand, to measure the level of problem-solving skills of BSEd mathematics students, the Problem-Solving Test Questionnaire (PSTQ) was modified by researchers from Siniguian (2017).

RESULT AND DISCUSSION

The Extent of Metacognitive Awareness among BSEd Mathematics Students

Table 1. The Extent of Metacognitive Awareness among BSEd Mathematics Students in Terms of Planning, Monitoring, and Evaluation

Indicators	Mode	Descriptive Equivalent
Planning	4	High
Monitoring	4	High
Evaluation	4	High
Overall	**4**	**High**

Table 1 summarizes the extent of metacognitive awareness in terms of planning, monitoring, and evaluation. As presented in Table 1, BSEd Mathematics students demonstrated a high level of metacognitive awareness, with a mode of 4, across planning, monitoring, and evaluation. This high level is consistent across all three components.

The high level in planning reflects the students' ability to choose right strategy and allocate resources that affect their performance. The high level in monitoring indicates their awareness of their understanding and task performance. Finally, the high level in evaluation points to their skill assessing their work and regulating their learning. Using the data of the abovementioned indicators, the average extent of metacognitive awareness among BSEd Mathematics students is 4, and described as high. This means that the extent of metacognitive awareness among BSEd Mathematics students in terms of planning, monitoring, and evaluation is much exhibited. This overall high metacognitive awareness aligns with the findings from Aurah et al. (2011), which also showed a majority of the students scoring high on the MAI scale. A high level of metacognitive awareness is advantageous for student's learning and has the potential to significantly improve the awareness of their learning in the classroom. As per Siagian et al. (2019), there is a need for awareness that students must have at every step of their thinking in order to improve their metacognitive ability, which primarily involves planning, monitoring, and evaluation.

The Level of Problem-solving Skills among BSEd Mathematics Students

Table 2. The Level of Problem-solving Skills among BSEd Mathematics Students in Terms of Understanding the Problem, Devising a Plan, Implementing a Plan, and Re-evaluation

Indicators	Mean	Standard Deviation	Descriptive
Understanding the Problem	2.69	0.4300	Very High
Devising a Plan	2.74	0.4181	Very High
Implementing a Plan	2.65	0.4300	Very High
Re-evaluation	2.45	0.4763	Very High
Overall	**2.63**	**0.4515**	**Very High**

Table 2 summarizes the level of problem-solving skills among BSEd Mathematics students across Polya's four steps: understanding the problem, devising a plan, implementing a plan, and re-evaluation. Across all four steps, students exhibited a very high problem-solving skills, with an overall mean of 2.63. Understanding the problem, with a mean of 2.69, and devising a plan, with a mean of 2.74, show particularly very high scores, indicating strong abilities in these initial problem-solving stages. This implies that students were able to understand and recognize all concepts that are needed for solving the problem, and were able to clarify the relations between parts of the problem, combine previously learned knowledge to develop thoughts for solving a problem, and develop a plan, respectively. While implementing a plan, with a mean of 2.65, and re-evaluation, with a mean of 2.45, also show very high scores, the lower mean for re-evaluation suggests a potential area for improvement in this process.

While each step showed a very high mean, the mean score for "devising a plan" (2.74) was the highest, and this step also exhibited the lowest standard deviation (0.4181), suggesting more consistent performance in this area compared to other steps. Conversely, "re-evaluation" had the lowest mean (2.45) and the highest standard deviation (0.4763), indicating greater variability in student performance on this aspect of problem-solving. Since the four indicators have closer standard deviation values, the coefficients of variation are presented in Table 3 to compare their relative variability.

Based on the table below, the coefficient of variation for understanding the problem is 15.99%; devising a plan is 15.26%; implementing a plan is 16.23%; and re-evaluation is 19.44%.

Table 3. Coefficient of Variation for Problem-solving Skills in Terms of Understanding the Problem, Devising a Plan, Implementing a Plan, and Re-evaluation

Indicators	Mean	Standard Deviation	Coefficient of Variation (%)
Understanding the Problem	2.69	0.4300	15.99
Devising a Plan	2.74	0.4181	15.26
Implementing a Plan	2.65	0.4300	16.23
Re-evaluation	2.45	0.4763	19.44

Since the coefficient of variation for re-evaluation is larger than that of understanding the problem, devising a plan, and implementing a plan, the re-evaluation in problem-solving skills is more dispersed, which means that the problem-solving skills of BSEd Mathematics students in terms of the re-evaluation are less consistent than the other indicators, followed by the skill in implementing a plan.

This is in accordance with the study of Siniguian (2017) whose results showed that the students' difficulties in solving mathematical problems are in carrying out the plan, or implementing a plan in this study, and in looking back at the answer, or re-evaluation in this study. In the present study, re-evaluation followed by implementing a plan are two of the most dispersed indicators of problem-solving skills. This could be because some students look back at their answers but have written and checked problem-solving results inconsistently in all situations, which is the same possible instance that goes with the process of implementing a plan.

In addition, according to Aksu (1984) (Sevgi & Caglikose, 2019), some students tend to skip the stage of checking their answers after resolving a problem and coming up with a solution. Siniguian (2017) also stated that students incorrectly translate the problem into mathematical form and use mathematics in answering the problem. However, he emphasized the importance of students mastering mathematical concepts in order to lessen errors in solving mathematical problems and constructing mathematical equations in a well-developed manner in order to get to the correct solution.

Correlation between Metacognitive Awareness and Problem-solving Skills

Table 4. Kendall's Tau Correlation Coefficient between Metacognitive Awareness and Problem-solving Skills

	Kendall's Tau	p-value	Decision	Interpretation
Metacognitive Awareness Problem-solving Skills	0.046	0.566	Fail to Reject H_{0_1}	Not significant

The table above shows that the p-value (0.566) is greater than the level of significance (α=0.05), Fail to Reject H_{0_1}, which reveals that there is no significant relationship between the students' extent of metacognitive awareness and their level of problem-solving skills. This means that there is no sufficient evidence to conclude that there is a significant relationship between the two variables among BSEd Mathematics students in Davao de Oro State College.

As also shown in Table 4, a correlation coefficient of 0.046 indicates no significant relationship between students' metacognitive awareness and problem-solving skills among the BSEd Mathematics students.

These findings are consistent with the study of Aljaberi & Gheith (2015) which revealed that there is no significant correlation between the level of metacognitive thinking and the students' ability to solve mathematical problems. This is supported Coutinho (2006) who stated that metacognitive awareness is not helpful for students who are performing problem-solving tasks, as students with a higher level of metacognitive awareness did not perform any better than those with a lower level of metacognitive awareness.

The findings of this study, on the other hand, are quite unexpected because it is rather expected that the metacognitive awareness of students helps them to better solve mathematical problems (Casaig, 2019) and that if metacognitive of students is high, then their problem-solving skills are also high (Izzati & Mahmudi, 2018). This result is inconsistent with the study of Rahman & Hassan (2017) who assert that there is, in fact, a positive, significant relationship between problem-solving skills and metacognitive awareness. Based on their study, metacognitive awareness plays an important role in ensuring the success of problem-solving process. Problem solving entails understanding and control of more complicated metacognitive processes, such as planning, monitoring, and evaluation, in addition to an attempt to obtain the correct answer (Rahman & Hassan, 2017). This is parallel to the study of Sevgi & Karakaya (2020) which concluded that metacognitive awareness levels in students show a positive and significant relationship with problem solving skills, emphasizing that metacognitive awareness abilities are similar to problem-solving steps, and students use them when defining variables in a problem and determining which technique to use.

This inconsistency of the results sheds light on the need for further studies to better understand the relationship between metacognitive awareness and problem-solving skills, considering the factors that contributed to the two variables having no significant relationship.

Unfortunately, since the result of the correlation analysis found out that there is no significant relationship between the students' metacognitive awareness and their level of problem-solving skills, this indicates that researchers cannot proceed with the regression analysis because it will not meet the assumptions for ordinal-continuous regression.

CONCLUSION

In this study, the researchers conducted survey and test questionnaires with BSEd Mathematics students in Davao de Oro State College – Main Campus to determine the significant relationship between metacognitive awareness and problem-solving skills. Based on the findings of this study, the following conclusions were drawn:

The extent of metacognitive awareness among BSEd Mathematics students in terms of planning, monitoring, and evaluation is high. This indicates that the majority of students have a high level of metacognitive awareness. By this means, the researchers concluded that the majority of BSEd Mathematics students in Davao de Oro State College highly exhibited metacognitive awareness. This result points to the Meta-components of Intelligence Theory of Robert Sternberg (1988) which are the complex of processes of selecting one or more approaches, controlling them, and coordinating the various approaches, composed of planning, monitoring, and evaluating courses of thinking and action. This suggests most students possess metacognitive awareness—an understanding of their own cognitive processes—and can effectively apply this knowledge to their learning. With this, empowerment, motivation, and increased relationships of metacognitive awareness can be supported by encouraging good participation in planning, monitoring, and evaluation.

The level of problem-solving skills among BSEd Mathematics students in terms of understanding the problem, devising a plan, implementing a plan, and re-evaluation is very high. This indicates that the majority of students have a very high level of problem-solving skills. By this means, the researchers concluded that the majority of BSEd Mathematics students in Davao de Oro State College very highly exhibited problem-solving skills. However, concerning the coefficients of variation, the study revealed that the re-evaluation in students' problem-solving skills is more dispersed than the understanding the problem, devising a plan, and implementing a plan. This could mean that students write and check their answers inconsistently or that they skip the stage of checking their answer solutions.

With that, it reveals that there is no significant relationship between the extent of metacognitive awareness and the level of problem-solving skills among BSEd Mathematics students in Davao de Oro State College. This result challenges the Meta-components of Intelligence Theory of Sternberg (1988) which states that meta-components are higher-order executive processes used in planning, monitoring, and evaluating one's problem-solving. Additionally, Sternberg (1985) and Mayer (1998) highlight that effective problem-solving requires not only possessing the necessary cognitive skills but also the metacognitive ability to manage and control those skills. This metacognitive knowledge includes knowing when, how, and how often to apply specific problem-solving strategies (Aljaberi & Gheith, 2015). Since metacognitive awareness does not influence problem-solving skills, the result is also inconsistent with Flavell's Metacognition Theory which posits that metacognition is a key factor in the problem-solving process (Gurat & Medula, 2016).

The lack of a significant relationship between metacognitive awareness and problem-solving skills is quite unexpected, given that prior research suggests a positive correlation between high metacognitive awareness and high problem-solving skills (Izzati & Mahmudi, 2018). Several factors may explain this discrepancy. First, the difficulty of the problem-solving test may not have aligned with the students' metacognitive abilities. Second, the weak correlation between motivation to think and critical thinking, and the absence of a direct link between metacognition and critical thinking (Ossa et al., 2023), highlight the importance of considering other variables, such as student motivation. This is significant because critical thinking is known to be related to problem-solving abilities (Snyder & Snyder, 2008). Finally, the study's sample size of the study, encompassing only BSEd Mathematics students at a single institution, may limit the generalizability of the findings. Therefore, the absence of a significant relationship in this study doesn't definitively disprove a link between metacognitive awareness and problem-solving skills; rather, it highlights the need for further research to explore other contributing factors and gain a more complete understanding of their relationship.

RECOMMENDATION

After giving careful consideration to the possible consequences of the results and analysis of the study, the researchers developed some recommendations as follows:

1. Mathematics teachers should integrate metacognitive instruction and provide regular feedback to help students master Polya's all problem-solving steps;
2. School administrators should foster a positive learning environment by prioritizing the development of students' metacognitive awareness in all levels, encouraging collaboration among teachers, parents, and students, and providing necessary resources and support; and
3. Future researchers should explore and examine the possible factors that contributed to the result of this study.

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