International Journal of Scientific Engineering and Science
Volume 8, Issue 9, pp. 88-91, 2024. ISSN (Online): 2456-7361

Enhancing Students' Metacognitive Skills Through Problem-Solving Strategy in Teaching Mathematics

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Abstract— *Metacognitive skills are essential to be developed by the students to help improve their academic performance. This study was conducted with the aim of determining whether the use of problem-solving strategies can increase students' metacognitive skills. Students of the Mathematics in the World course offered at a local college in the Philippines were selected to participate in this study. Using an independent sample t-test, results revealed that students who were the recipients of problem-solving strategies scored statistically higher in formal examinations compared to those students who were taught using conventional strategies. The researchers concluded that students who were taught using the problem-solving strategy enhanced their metacognitive skills based on their scores in the test of metacognitive skills during the post-test. The researchers suggested that teachers should incorporate problem-solving strategies into their lessons since this research demonstrates this to be an effective strategy for enhancing students' metacognitive skills essential to their learning.*

Keywords— *Academic Performance, Metacognitive Skills, Problem-Solving Strategy.*

I. INTRODUCTION

The 21st century has brought enormous changes to the world today. These changes are evident in every individual's activity. These might be in education, business, or industry; apparent changes are indeed everywhere. As people embrace these global changes, they must acquire the skills necessary for their adaptation and adjustment. As for students in the 21st century, they must develop the 21st-century skills needed for their survival such as metacognitive skills. Erlin & Fitriani (2019) defined metacognitive skills as self-cognitive awareness, an understanding of the cognitive processes and how to manage them. This implies that with metacognitive skills, students can effectively make use of their critical and creative thinking skills which solve problems in Mathematics or even in other learning areas. Indeed, metacognitive skills are significant skills that must be acquired by the students since these can help them acquire learning and improve their academic performance.

Penneguin et. al (2010) attested that metacognitive training is beneficial among learners since it enables them to make progress and complete problem-solving tasks. This is supported by Mohamad & Mahamod (2014) who affirmed that metacognitive skills are significant in enhancing students' motivation and boosting their interest in a course which eventually plays a crucial role in improving their academic performance. Java (2014) claimed that a specific problem-solving strategy in teaching mathematics (GEAR strategy) does have a significant effect in improving learners' metacognitive skills and creates satisfactory improvement in their academic performance. This emphasizes that for the students to acquire metacognitive skills, teachers should implement problem-solving strategies in their teaching. Hodgson (1998) earlier claimed that teachers must build problems adapted to the various modes of thinking they want the students to acquire through administering problem-solving tasks to strengthen their metacognitive skills.

However, students' inability to solve mathematical problems is due to their lack of metacognitive skills or low metacognitive skills. Grizzle & Martin (2014) supported the claim that students struggled in mathematics and problem-solving tasks because they are ignoring an extensive series of cognitive or metacognitive processes. Erlin & Fitriani (2019) attested that the lack of metacognitive skills causes students to be less able to use appropriate learning strategies which will affect their cognitive abilities. Furthermore, Embodo & Baraquia (2019) later revealed that a group of students in a local college in a city of Misamis Occidental, Philippines, which happens to be the researcher's workstation, were found to have low metacognitive skills.

With such findings, this study aims to determine if the implementation of problem-solving strategies in mathematics courses improves students' metacognitive skills. The results of this study would afford insights into the whole educational community, especially in enhancing students' overall performance. Explicitly, this study would provide an opportunity for teachers to contemplate how they should effectively innovate in the teaching of mathematics both in basic education and tertiary education through face-to-face learning modality to enhance the students' metacognitive skills that are essential for their adaptation, adjustment, and survival in the real world.

II. METHOD

Participants

The participants of this study were 44 students from the two sections of 1st year Bachelor of Science in Business Administration (BSBA – MM 1) enrolled in the General Education Mathematics in the Modern World (GE ModMath) course offered during the second semester of the academic year 2020-2021 at Gov. Alfonso D. Tan College. Using the purposive sampling techniques, these participants were selected by the researchers based on the information provided by the instructor of this course. The information shows that the students in these two sections exhibited low achievement in

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their problem-solving activities. To ensure their voluntary participation, they were given an informed consent form wherein they affixed their signature confirming their willing participation. The participants are made up of two groups: those in the experimental group were taught using a problem-solving strategy while those in the control group were taught using conventional teaching techniques.

Instruments

Three sets of researcher-accomplished detailed lesson plans following the problem-solving strategy were utilized as instruments of this study. These lesson plans were handed to the instructor, and this was utilized by the instructor as they discussed the selected lessons among the students in the experimental group. The adopted questionnaire for metacognitive skills from the study of Embodo & Baraquia (2019) was also utilized to assess the impact of these techniques.

Procedure

To conduct this study, the researchers sent a letter to the presidential research registry and asked for permission to conduct this study. The participants were purposively selected from the two sections of 1st year Bachelor of Science in Business Administration (BSBA – MM 1) enrolled in the General Education Mathematics in the Modern World (GE ModMath) course. Assessments were conducted on both the experimental and control groups after every class discussion using the problem-solving strategy. The scores of students were collected, treated, and analyzed using the mean, standard deviation, and independent sample t-test. The mean and standard deviation were used to describe the level of students' achievement in the metacognitive test while the independent sample t-test was used to determine the significant difference between the students' achievement in the metacognitive test from the control and experimental groups.

The pre- and post-test was conducted before and after the implementation of the problem-solving strategy in the control and experimental groups. An independent t-test was utilized to determine if a significant difference in students' performance existed between the two groups at the pretest phase. Furthermore, this statistical technique was again employed to determine if any significant difference resulted in the performance of the students in these two groups during the post-test phase. Lastly, this technique was also implemented to determine if there was a significant difference between the pre-and post-test performance of the control group as well as that of the experimental group.

III. Results

The mean and standard deviation of the level of metacognitive skills of the students obtained in the pre- and post-test. The differences between the control and experimental groups' pre-test and posttest were also obtained through t-test.

Table 1 shows the students' level of metacognitive skills in the Pretest based on their scores in a 30-item problem-solving test. Students in the experimental group had a mean starting score of 9.68 and a standard deviation of 2.26 while students from the control group had a mean score of 8.77 and a standard deviation of 2.60.

TABLE 1. Level of Metacognitive Skills (Pretest)

Group	N	Mean	SD	Total Score	Maximum Score	Minimum Score
Experimental	22	9.68	2.26	30	15	7
Control	22	8.77	2.60		13	5

TABLE 2. Independent Samples Test (Pretest)

Pretest	T	Df	Sig. (2-tailed)
Control X Experimental	1.238	42	0.22

As shown in Table 2, an independent-sample t-test was conducted to compare the students' level of Metacognitive skills based on their scores in the problem-solving pretest. It can be seen in the table that there is no significant difference in students' metacognitive skills at the pre-test phase between the experimental (M=9.68, SD= 2.26) and control group (M= 8.77, SD= 2.60); t (42) = 1.239, p= 0.22.

TABLE 3. Level of Metacognitive Skill (Post-test)

Group	N	Mean	SD	Total Score	Maximum Score	Minimum Score
Experimental	22	15.27	4.18	30	28	10
Control	22	9.55	3.23		18	5

Table 3. shows the students' level of metacognitive skills in the post-test based on their scores in a 30-item problem-solving test. Students in the experimental group had a mean score of 15.27 and a standard deviation of 4.18, while students from the control group had a mean score of 9.55 and a standard deviation of 3.23.

TABLE 4. Independent Samples T-Test (Post-test)

Post Test	T	Df	Sig. (2 tailed)
Control X Experimental	5.096	42	0.000

Table 4 shows the results of an independent-sample t-test employed to determine the comparison of students' level of academic performance following the implementation of a problem-solving strategy in their Mathematics in the Modern World course. There is a significant difference in students' performance between the experimental (M=15.27, SD= 4.18) and control group (M= 9.55, SD= 3.23); t (42) = 5.096, p= 0.000 following the strategy implementation.

TABLE 5. Student's Level of Metacognitive Skills Pre-Test and Post (Controlled Group)

Control Group	Mean	SD	t	df	Sig. (2-tailed)
Pretest	8.77	2.60	-1.03	21	0.316
Post Test	9.55	2.23			

Table 5 shows the comparison of student's level of metacognitive skills based on their scores on the problem-solving test. It can be observed that the students from the control group have increased their performance over the study,

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as indicated by the pre-and post-test mean scores of (M = 8.77) and (M = 9.55), respectively.

TABLE 6. Student's Level of Metacognitive Skills Pre-Test and Post (Experimental Group)

Experimental Group	Mean	SD	t	df	Sig. (2-tailed)
Pretest	9.68	2.26	-5.6	21	0.00
Post-test	15.27	4.18			

It can be observed from Table 6 that the students in the experimental group have shown a statistically significant increase in performance from pre- to post-test, with means scores of (M = 9.68) and (M = 15.27), respectively.

IV. DISCUSSION

The findings from Table 1 indicate that, before any intervention, both the experimental and control groups had relatively low metacognitive skills, as reflected in their problem-solving test scores. The experimental group had a slightly higher mean score (9.68) compared to the control group (8.77), suggesting that, on average, students in the experimental group started with slightly better problem-solving abilities. However, the small difference between these two means indicates that the groups were very similar at the beginning of the study.

The results of the independent-sample t-test in Table 2 show that there was no significant difference in the students' metacognitive skills between the experimental group (M = 9.68, SD = 2.26) and the control group (M = 8.77, SD = 2.60) at the pre-test stage. The t-value (t(42) = 1.239) and p-value (p = 0.22) indicate that the observed difference in mean scores is not statistically significant. This suggests that, before the intervention, both groups had similar levels of metacognitive skills, and any differences in their problem-solving abilities were likely due to chance rather than meaningful variation.

The findings in Table 3 reveal that after the intervention, students in the experimental group showed a significant improvement in their metacognitive skills, with a higher mean score of 15.27 (SD = 4.18) on the post-test compared to the control group, which had a mean score of 9.55 (SD = 3.23). This suggests that the experimental group, which likely received a targeted intervention or training, developed stronger problem-solving abilities and metacognitive skills, while the control group showed much less improvement. The larger difference in scores highlights the impact of the intervention on enhancing the experimental group's performance.

The results in Table 4 indicate a significant difference in academic performance between the experimental and control groups after implementing the problem-solving strategy in their Mathematics in the Modern World course. The experimental group had a notably higher mean score (M = 15.27, SD = 4.18) compared to the control group (M = 9.55, SD = 3.23), with the t-test yielding a statistically significant result (t(42) = 5.096, p = 0.000). This suggests that the problem-solving strategy had a positive impact on the experimental group's academic performance, leading to a meaningful improvement in their outcomes compared to those who did not receive the same intervention. This further implies that the use of problem-solving strategies in the experimental group generated a significantly higher performance compared to that of the control group which received a conventional teaching strategy. This is consistent with the study of Idawati et. al (2020) who found that there is a significant difference observed between the metacognitive skills scores of the students where problem-solving methods were applied in the discussion. They further suggested that problem-solving methods can be used to improve and develop students' metacognitive skills.

The findings in Table 5 show that the control group made a modest improvement in their metacognitive skills over the course of the study, with their mean score increasing slightly from 8.77 in the pre-test to 9.55 in the post-test. Although this indicates some growth in their problem-solving abilities, the increase is minimal. This suggests that while the control group experienced some natural development in their metacognitive skills, the lack of a targeted intervention likely limited the extent of their improvement.

The results in Table 6 show that the students in the experimental group performed significantly better and their average scores increased from 9.68 in the pre-test to 15.27 in the next test. This marked increase suggests that whatever intervention or strategy was applied during the study had a strong positive effect, helping students enhance their skills and understanding considerably. This implies that the use of problem-solving strategies in teaching mathematics has helped students increase their performance in the metacognitive test. In addition, Jagals & Walt (2016) emphasized that metacognitive reflection fosters metacognitive awareness which assembles metacognitive skills necessary for Mathematics problem-solving. Mayer (1998) suggested that successful problem-solving depends on three components – skill, meta-skill, and will – and that each of these components can be influenced by instruction.

Desoete, A., Roeyers, H., & De Clercq, A. (2003), found in their study that children who received metacognitive training performed much better compared to the other groups of students who had not received such training. They emphasized that metacognitive instruction had a sustained effect on cognitive problem-solving after the training. The same goes for the findings of Hargrove & Nietfeld (2014), that the students from the treatment group, those who received metacognitive instruction, have scored significantly higher on fluency and originality measures compared to their matched peers. Furthermore, students in the treatment group obtained higher scores on a summative domain-specific task graded by outside design experts. The treatment group's Metacognitive Awareness Inventory ratings improved with time, whereas the comparison groups remained unchanged. Safari & Meskini (2016) also found that in their study, the performance of those students who were given with metacognitive instruction was significantly higher than those students who were not. Thus, they concluded that metacognitive teaching improves students' problem-solving abilities and is essential to improve academic accomplishment.

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Lastly, Gok, T. (2010), reported that problem-solving strategies (in general; analyze, solve, and check) used by students are very effective and can enhance their performance. However, merely teaching these problem-solving skills to the learners isn't enough to help them build actual expertise; they also require lengthy training. Instructors should also incorporate any of these problem-solving methods into their classes since these can help students increase their test performances and eventually learn better.

V. Conclusion And Recommendations

Students' entry level of metacognitive skills did not vary significantly during the pre-test at the beginning of this study. However, based on the post test result, students from the experimental group who were the recipients of a problem-solving strategy during the teaching of their mathematics course scored higher compared to students who received traditional teaching. Thus, problem-solving strategies in teaching mathematics have helped the students increase their scores on the test of metacognitive skills. Based on these findings, the researchers suggest that teachers should regularly adopt problem-solving strategies in their teaching lessons. This should be applied not just in mathematics courses but also to other courses or subjects since this has proven to be an effective method in enhancing the metacognitive skills of students. Students must engage themselves in solving problem-solving activities to help improve their critical thinking and metacognitive skills.

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