The Effect of the Metacognitive Strategies in The Problem Solving Skills of College Algebra Students

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***Abstract*— This study aims to determine the effect of metacognitive processes in the problem solving skills of the students. It employed the quasi-experimental matching-only pre-test and post-test research design and utilized the two intact sections with 19 matched- paired first year students coming from the two sections of Bachelor of Science in Office Administration and Bachelor of Science in Entrepreneurship students enrolled at Carlos Hilado Memorial State College–Fortune Town Campus during the second semester of school year 2016-2017. One section was exposed to metacognitive strategies as the experimental group and the other section as the control group exposed to the traditional method of teaching. Results of the study showed that problem solving skill of both the control group and experimental group is "novice" before their exposure in the concepts and problem solving in Algebra. After the experimental group were exposed to the concepts and problem solving using the metacognitive strategies, their posttest scores increased to "developing" problem solver. However, the control group after they were exposed to the concepts and problem solving only is still novice problem solver. There was no significant difference in the pretest problem solving skills of the control and experimental group of students; there was a significant difference in the pretest and posttest problem solving skills of traditional group of students; there was a significant difference in the pretest and posttest problem solving skills of the metacognitive group of students; there was a significant difference in the problem solving skills of the control and metacognitive group of students after exposure to the concepts and problem solving in Algebra; there was a significant relationship between problem–solving skills and metacognition skills of the students. Students who utilized metacognitive strategies during the course of problem solving enhanced their problem–solving skills since they could regulate their thinking processes, thus, making them aware of what they were going to do to solve the problem. The results of this study were taken as bases for developing a Learning Model on Metacognition.**

***Index Terms*— Metacognitive, Performance, Strategies**

I. INTRODUCTION

Problem solving is a skill that is required by life in general. In Mathematics particularly, problem solving has been advocated by the National Council of Teachers of Mathematics to be the focus of mathematics teaching.

According to Culaste (2011) problem solving is an important component of mathematics education because of its practical role to the individual and society. Moreover, the NCTM (2000) avers that "by learning problem solving in Mathematics, students should acquire the ways of thinking, habits of persistence and curiosity, and confidence in unfamiliar situations that will serve them well outside the mathematics classroom."

According to Biryucov (2004), a primary source of difficulties in problem solving has been suggested as a student's inability to actively monitor and regulate their own cognitive processes. It has been found by some researchers that metacognitive is a key factor in a successful problem solving, Schoenfield (1987). Metacognition in problem solving is the basis for the use of appropriate knowledge and strategies. Metacognitive regulation is the monitoring of one's cognition and includes planning activities, awareness of comprehension and task performance, and evaluation of the efficacy of monitoring processes and strategies. (Lai, 2011).

The K to 12 Curriculum Guide in Mathematics (2012) emphasized that teachers' teaching must be directed to the honing of students' skills on critical thinking and problem solving. Difficulties that students express in word problem solving can be overcome through employing of the different strategies and activities. Student need to be exposed to problem solving using the metacognitive strategies especially in solving non- routine problems to help them develop their problem solving skills and enhance their potentials as good problem solvers. To answer this claims, the researcher developed a learning model and used this in the six-week intervention method to check whether metacognitive strategies really affects the problem solving skills of the students.

A. Statement of the Problem

This study aimed at determining the effects of metacognitive processes on the mathematics problem–solving skills of students.

Specifically, this study sought answers to the following questions:

1. What is the mathematics problem–solving skills of the students before and after their exposure to traditional approach and metacognitive approach?
2. Is there a significant difference in the pretest results of problem–solving skills of the students exposed to traditional and metacognitive approaches?
3. Is there a significant difference in the pretest and posttest results of problem–solving skills of students exposed to traditional approach?

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4. Is there a significant difference in the pretest and posttest results of problem- solving skills of students exposed to metacognitive approach?

5. Is there a significant difference in the posttest results of problem–solving skills of the students exposed to traditional and metacognitive approaches?

6. Is there a significant relationship between mathematics problem–solving skills and metacognition skills of the students in the experimental group?

II. METHODOLOGY

A. Research Design

This study utilized the quasi-experimental research design, specifically a pre-test, post-test design. According to White and Sabarwal (2014) quasi-experimental is a design in which it lacks random assignment because participants in the control group were intentionally matched to the participants in the experimental group in an individual level resulting in a one-to-one match pairing. There were two intact groups considered as participants in the conduct of the study. Mathematics grades in the first semester of School Year 2016-2017 and their pretest scores were used as the bases of match-pairing.

B. Data Collection Procedure

The data gathering procedure was done in three stages: the pre-intervention stage, the intervention stage, and the post-intervention stage.

Pre-intervention stage. The researcher secured the letter asking permission from the head of the school to conduct the study for six weeks utilizing the two sections of freshmen students enrolled in college algebra course.

The metacognition skill instrument and problem solving questionnaires together with the table of specification, lesson plan and rubrics has been subjected for validation by the three validators who are experts in the field of research and mathematics and has been pilot tested to the college students who were also taking the college algebra course at another State University during the second semester of school year 2016-2017.

The participants belonged to the two intact classes coming from the Bachelor of Science in Office Administration and Bachelor of Science in Entrepreneurship who are enrolled in the M COl ALG - College Algebra course during the second semester of school year 2016-2017 at Carlos Hilado Memorial State College. All of the members of the two intact classes were given a pretest. However, the data of 19 students coming from each class who were matched paired on the basis of the pretest result and Mathematics grades in the previous semester were the ones utilized for data analysis.

Intervention stage. Two teaching strategies were used: the Metacognitive strategies that utilized problem solving using metacognitive process for the experimental group and the traditional lecture method for the control group. The participants was taught using the same topics and has differed solely the strategy used by the teacher. The same type and amount of homework and problems was given to both groups. Students has been taught for three hours per week equivalent to 18 hours period for the entire duration of the experiment.

Post-intervention stage. After the intervention the participants were given post-test. The results in the post-test had served as end-line data. The pretest and posttest data were compared and analyzed.

III. RESULTS AND DISCUSSIONS

Table 1 shows the problem solving skill of students before and after the exposure in the traditional and metacognitive approach in Algebra. During the pretest the traditional group manifested a “novice” skill in problem solving (M = 7.37, SD = .68) meaning the students have low level of problem solving skill. The same was observed in the posttest result (M = 13.53, SD = 4.0). On the other hand, the metacognitive group manifested a “novice” problem solving skill in the pretest M = 7.42, SD = .69) which means that they have a low level of problem solving skill. However, in the posttest result the students manifested a “developing“ problem solving skill (M = 22.68, SD = 4.15) which indicates that the students have a moderate level of problem solving skills. The low pretest scores of the students indicate that the students were not introduced yet to the lesson and the concepts in Algebra and of course it was difficult for them to understand the subject. According to Muijs and Reynolds (2005), the connection of prior knowledge and new concepts should take place during the lesson and not only when a new concept is introduced. This integration of prior knowledge and new concepts enables the learner to understand the unified and interconnected nature of knowledge, while also facilitating profound understanding of subject matter (Ornstein & Hunkins, 1998). On the other hand, when the lesson has been introduced both groups had increased their problem solving skills, however, the traditional group has a slight increase in their posttest while the metacognitive group has a remarkable increase in their posttest. The results show that metacognitive strategies is indeed a better approach and can enhance the problem solving skills of the students compared to the traditional approach.

Table 1

Problem Solving Skill of the Student's Before and After Exposure to the Intervention

	Before Exposure				After Exposure			
	N	*SD*	*M*	Interpretation	*N*	*SD*	*M*	Interpretation
Metacognitive	19	.69	7.42	Novice	19	4.15	22.68	Developing
Traditional	19	.68	7.37	Novice	19	4.0	13.53	Novice

Note: Skillful (32.01-50.00); Developing (16.01-32.00); Novice (0.00- 16.00)

Table 2 below reveals a no significant difference in the pretest problem solving skills of the students in the control and experimental group with t (18)= .236, and p = .815. This implies that the problem solving skills of the students in the traditional and metacognitive group in the pretest are not significantly different, implying that the groups are

comparable at the onset of the study. This findings is in consonance to the result of the study of Grant (2014), which reveals that there is no statistically significant difference between the problem solving performance of the control and experimental group of students during the pretest, which means that the students' mathematics performance is comparable before the intervention was introduced.

Table 2

t-test Result on the Difference in the Mathematics Problem Solving Pretest Results of the Students' in the Traditional and Metacognitive Groups

	Mean	Mean Difference	*Df*	*t*	*P*	95 % confidence interval	
						Lower	Upper
Traditional	7.37	.10	36	.236	.815	-.50550	.40024
Metacognitive	7.42						

As shown in Table 3, significant difference was noted on the pretest and posttest problem solving skills of the students in the control group with t (18) = 7.313, and p = .000. This result showed that the problem solving skills of the students significantly improved before and after their exposure to the traditional approach of teaching. This can be explained by the fact that students were able to learn the concepts and skills essential in the learning of College Algebra. The teacher in the traditional approach shares her knowledge, presents and discusses the step by step process in solving the word problems. Likewise, students during the group activity shares and interact with their classmates. According to Medallion et. al. (2012), "interacting with peers and teachers are both contributing factors to the capability to solve word problem". Hence, students in the traditional group were able to learn the concepts and solve the problems and end up to a significantly better performance in the posttest.

Table 3

t-test Result on the Differences in the Pre-test and Posttest Results of Problem Solving Skills of Students' in the Traditional Approach

Traditional Group	Mean	Mean Difference	*Df*	*t*	*P*	95 % confidence interval	
						Lower	Upper
Pretest	7.37	6.16	18	7.313*	.000	7.927	4.388
Posttest	13.53						

*$p < .001$

Table 4 presents the result of t test for related samples and indicates that a significant difference existed in the pretest and posttest scores of the students exposed to the metacognitive approach with t (18) = 16.58, and

p = .000. This finding explains that the problem solving skills of the students significantly improved before and after their exposure to metacognitive teaching strategies. This implies that metacognitive approach is an effective strategy to enhance the students' problem skills in mathematics. Metacognitive strategies enable the students regulate their thinking process, they were able to integrate math concepts into problem solving skills and they understand deeper the given problem which leads them to arrive to the correct solution.

Table 4

t-test Result on the Difference in the Pretest and Posttest Problem Solving Skills of Students Exposed to Metacognitive Strategy

Metacognitive Strategy	Mean	Mean Difference	*df*	*t*	*P*	95 % confidence interval	
						Lower	Upper
Pretest	7.42	15.26	18	16.584*	.000	17.197	13.329
Posttest	22.68						

*$p < .001$

The result of t test for independent samples in Table 5 indicated that a significant difference existed on the posttest scores of the students exposed to traditional and metacognitive approaches with t (36) = 6.921, and p = .000.

Thus, it suffices to say that although both approaches were observed to be effective in enhancing the students' problem solving skills, yet metacognitive is a more effective approach than the traditional approach.

This finding is similar to the result of the study of Lozada (2012) that students who are exposed in the metacognitive learning strategy perform better than the students who are exposed to traditional methods.

Table 5

t-test Result on the Difference in the Posttest of Problem Solving Skills of Students Exposed to Metacognitive Approach and Traditional Approach

	Mean	Mean Difference	*Df*	*t*	*P*	95 % confidence interval	
						Lower	Upper
Metacognitive	13.53	9.15	36	6.921*	.000	-11.8416	-6.4742
Traditional	22.68						

*$p < .001$

The computed value of r^2 or correlation coefficient value of 0.7465 was converted to percentage (74. 65%) in order to determine the coefficient of determination. This percentage implies that the 74.65 % variation of the students' scores in problem solving was accounted for the students' metacognitive skills. This observation notes that the contribution of the metacognitive skills to the variation on problem solving skills was high.

This implies that the higher the metacognition skills of the students the higher the problem solving skills. This findings conforms to the idea of O'Neil and Abedi (1996), that there is a significant correlation between problem solving skills and metacognition.

Table 6

Relationship Between the Students' Problem-solving Skills and Metacognition Skills

	M	SD	Pearson r	r^2	P
Problem–solving Skills	3.0717	.43391	.864*	.7465	.000
Metacognition Skills	3.3111	.74216			

*p <0.001

IV. CONCLUSIONS

Based on the findings of the study, the following conclusions were drawn:

Both groups of students had initially poor mathematics problem–solving skills. This implies that they had difficulties in solving mathematics problem before their exposure to the concepts and problem–solving tasks in Algebra. One possible reason for this is their poor orientation in problem solving because they were not exposed to problem solving tasks during their high school days or even in their elementary days. However, after exposure to the concepts and problem solving, a marginal improvement occurred in the metacognitive group and is attributed to the metacognitive strategies that was introduced. Students who were utilizing metacognitive strategies during the course of problem solving improved their problem

solving skills since they are able to regulate their thinking process. They are aware of what they are going to do during the course of problem solving, leading them to a complete and correct solution.

It can be inferred that both groups of students in the pretest lacked the ability and skills to solve the problem. One possible reason for this, is that they were not introduced yet to the concepts and problem–solving skills. Another reason is that students were deficient in terms of mathematics problem–solving skills since they were not used to solving problems during their high school days. They encountered difficulties during the problem–solving tasks which made them leave some problems unfinished, thus resulting in the very low scores.

The control group of students, despite their limited learning potential compared to the experimental group, had somehow learned the concepts and problem–solving skills. Even with the traditional strategy used to teach them, they still managed to learn the concepts and problem-solving skills as manifested by the increase in their posttest

scores. This implies that the traditional way of teaching may still be considered as an effective approach in teaching, especially when coupled with other strategies.

It can be inferred that the variation in the problem–solving skills of the metacognitive group of students indicates that the intervention using the metacognitive strategies is a more effective approach in teaching Algebra subject, since it helps them improve their problem–solving skills. Students experienced difficulties in solving word problems before exposure to the concepts and problem–solving tasks, since they lacked the ability to regulate their thinking process. However, this difficulty diminished through the use of metacognitive strategies during the intervention stage. Since the metacognitive group planned, evaluated and monitored their solution while solving the problems, they were able to arrive to correct solutions, thus, resulting in a better test performance after exposure to the intervention.

It can be inferred that the occurrence of variation in the problem–solving skills of the two groups, in favor of the metacognitive group, can be greatly attributed to the metacognitive strategy introduced to the students in the experimental group. They were able to monitor and regulate their own cognitive process in contrast to the control group. Regulating and evaluating their thinking process during the course of problem solving enabled them to successfully solve the problems.

The use of metacognitive strategy lessens the difficulty students encountered during the course of problem solving. They have the ability to reflect on their work results, clarify their thoughts about the concepts, and evaluate their learnings, resulting in the enhancement of their problem–solving skills after their exposure to the concepts and problem solving in Algebra. However, the control group was unable to completely solve the problems because they lacked the ability to self-monitor and self-regulate their thinking process during the course of problem solving, leading them to incorrect solutions. This means that metacognitive strategies are more effective approach in teaching students to solve word problems compared to the traditional strategy of teaching.

The problem–solving skills and metacognition skills of the students were highly correlated; this indicates that metacognitive skills indeed affect the problem–solving skills of the students. The more often students utilize metacognitive strategies in their problem-–solving skills, the more they will be able to successfully solve the problems. Students who utilize metacognitive strategies are given ample opportunities to explore, investigate, and discover for themselves patterns, ideas, and even algorithms. They become more organized and logical in setting up solutions which may lead to correct answers in the problem–solving tasks. Planning, monitoring, and evaluating the solving process help to ensure skillful problem solving. Students with superior metacognitive strategies are better problem solvers.

Students exposed to learning models that focus on metacognitive strategies activate their thinking, leading to their improved performance in problem solving tasks. They think clearly about some inaccuracies when failure occurs during the course of problem solving. They have advantages over others who were not exposed to metacognition strategies as evidenced by the increase in their performance from novice to developing, compared to traditional group which retained their problem-solving skills as novice. They were taught not

only to solve problems but also to reflect on and regulate their thinking process during the course of problem solving..

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