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Effects of Teaching through Problem-Solving (TtPS) on Students' Metacognition and Academic Performance

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Abstract

This research investigated the effects of teaching through problem-solving on students' metacognitive processes, metacognitive awareness and academic performance in mathematics through one group pretest-posttest pre-experimental design. The subjects consisted of an entire class composed of 17 Grade 11 students in one public school in Albay, Philippines. Data were gathered through a test, metacognitive awareness inventory, interview, journal entries and observation. These were analyzed with the aid of descriptive statistics, t-test, and effect size. Results revealed that the metacognitive processes employed by the students were those classified under the knowledge of cognition and regulation of cognition. Students who utilized metacognitive processes in their tasks often had expected answers than those who did not. Further, teaching through problem-solving affected both students' metacognitive awareness and academic performance significantly. These findings showed that the more often students reflect on a task, the more often they have the opportunity to modify and refine their efforts. Hence, it is imperative that educators design experiences that could help students optimize their learning by reflecting on their activities, enhancing their metacognition.

Keywords: *effect size, learning, metacognition, problem-solving, teaching*

Introduction

Flavell (1979) coined the term metacognition to describe both metacognitive knowledge and metacognitive experiences or regulation. Metacognitive knowledge or knowledge of cognition includes awareness of oneself as a learner, and the factors that might impact learners' performance, knowledge about strategies and knowledge about when and why to use strategies. Regulation of cognition includes monitoring one's cognition and includes planning activities, awareness of comprehension and task performances, and evaluation of monitoring processes and strategies (Lai, 2011). The term metacognition refers to thinking about thinking or learning how to learn, which involves active awareness and control over the cognitive processes engaged in learning. Schraw and Dennison (1994) defined this term as the capability of a person to reflect upon, understand, and control one's learning, which allows him to plan, sequence, monitor and improve his performance.

In order to improve students' learning, students themselves must understand their thinking and reasoning by helping them reflect on their learning. This supports one of the United Nations Educational, Scientific and Cultural Organization's (UNESCO) sustainable development goals, which focuses on inclusive and equitable quality education to ensure lifelong learning opportunities for all. Lifelong learning encompasses all aspects of education, and metacognition is key to the development of lifelong learning yet is rarely directly addressed in education (Zohar & Barzilai, 2013).

In support of the development of lifelong learning, emphasizing problem-solving at the heart of teaching and learning mathematics entails the development of students' metacognition. This involves teaching them how to learn independently, have a deeper awareness of how they process information, evaluate their thinking, and think of ways to make their learning process more effective. However, knowing how to incorporate problem-solving meaningfully into the mathematics classroom remains a challenging task to mathematics educators nowadays (Matlala, 2015; Siswono *et al.*, 2016). In the Philippines, these factors contributed to students' low performance

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in national and international competitions and surveys, including Trends in International Maths and Science Survey (TIMSS).

In the study conducted on high school students in 2008, the TIMSS-Advanced showed that among the 10 countries that participated, the Philippines ranked 10th, the lowest, with an average scale score of 355 (Ogena *et al.*, 2010). The TIMSS revealed that more schools in higher-achieving countries have policies and practices that foster higher collaboration and cooperation and mathematics learning embedded in a framework that supports students in developing thinking processes and attitudes and metacognition necessary for problem-solving. This is evident in the outstanding performances of Singapore students in 1995, 1999, and 2003 (Kaur, 2009).

The low achievement of Filipino students in mathematics prompted transformations in mathematics education in the country, placing critical thinking and problem-solving as the twin goals of the K to 12 Mathematics Education. This also addresses UNESCO's call for developing complex problem-solving and critical thinking among learners to prepare them for the world of work.

It is for this reason why teaching through problem-solving gained attention in mathematics education. Donaldson (2011) highlighted that if problem-solving is what mathematics is all about, teachers should help students develop this ability through this strategy which is a way for students to learn new mathematical concepts.

Teaching problem-solving is different from teaching through problem-solving. The former focuses on teaching strategies to find solutions to given problems, while the latter's goal is for students to learn new mathematics concepts. Takahashi (2021) detailed teaching through problem-solving as beginning a lesson with the teacher setting up the context, and introducing the problem. Students are then given time to work on the problem while the teacher observes their approaches, followed by a whole-class discussion.

At this time, the teacher calls on students to share their ideas and strategies, then asks them to compare and contrast those ideas and strategies, noting which are easier, correct, similar to each other, more efficient, and more. Through this, students learn new mathematical ideas or procedures.

It is then necessary that students understand their thinking and reasoning by helping them reflect on their learning, and in a way, helping them develop their metacognition. Thus, this study explored teaching through problem-solving (TtPS) and analyzed its effects on the students' metacognitive processes, metacognitive awareness and academic performance while they were subjected to the strategy.

Materials and Methods

Research Method

This study used a pre-experimental design utilizing both qualitative and quantitative methods. The qualitative method of research was mainly used to determine the students' metacognitive processes. The quantitative method was utilized in the analysis of the effects of teaching through problem-solving on the students' metacognitive awareness and academic performance.

Participants of the Study

The research was done in Libon Agro-Industrial High School, Albay, for School Year 2017 – 2018. One Grade 11 heterogeneous class composed of 17 students, whose ages ranged from 16 to 18, was selected using purposive sampling. The class was taught for the first time using teaching through problem-solving. The strategy was piloted in five schools in Albay, including Libon Agro-Industrial High School, in 2015-2016 through lesson study, a professional development strategy. Grade 7 students were involved during the pilot implementation. In 2017, the strategy was introduced to all grade levels in the junior high school by continuing the lesson study.

Due to limited teachers handling mathematics, the lesson study was not implemented in the senior high school, thus piloting teaching through problem-solving to Grade 11 students through this study.

Research Instruments

The teacher-made parallel pretest and posttest contained multiple-choice and open-ended problem-solving items good for 30 points. Ten items covering the competencies in the study were included, three multiple-choice and seven open-ended questions, since some questions required students' solutions to the problems and were only allotted for one hour. These tests were validated, evaluated and critiqued by five content and TtPS strategy experts, three Master Teacher II and two Teacher III, all from different schools. Pilot testing was done after revision to a class different from the identified subjects consisting of 24 students. Using Kuder-Richardson, the reliability index of the test was 0.729, which shows that the test has high reliability. An item analysis was made to determine the difficulty and discrimination indices of each item. Initially, the pretest and posttest consisted of 13 items, five multiple-choice and eight open-ended problem-solving. After item analysis, six items were accepted, four were revised, and three were discarded. The following are sample items taken from the test:

(MC) In the cooperative canteen of LAIHS, one banana cue costs ₱7.00, what is the function C, that represents the cost of buying x banana cues? (1 point)

a. $C(x) = 7 + x$

b. $C(x) = 7 - x$

c. $C(x) = 7x$

d. $C(x) = 7/x$

(PS)A company has a budget of ₱120,000.00, which is to be divided evenly among its various offices. The marketing office of the company receives twice the amount of money than the other offices.

a. Given x as the number of offices in the company, construct a function f(x) which would give the amount of money each of the non-marketing offices would receive. (1 point)

b. If the company had five offices, how much would the marketing office receive? How much would each of the non-marketing offices receive? (2 points)

A rubric was used in scoring items with 2 or 3 points (Table 1).

Table 1. Rubric for scoring items.

Point/s	Indicators
3, 2	Correct solution and correct answer
2, 1	Correct solution and partially correct answer
1, 1	Correct solution but wrong answer or correct answer without solution
0, 0	No attempt to solve/ no answer

Metacognitive Awareness Inventory (MAI)

The Metacognitive Awareness Inventory designed by Schraw and Dennison (1994) was utilized in the study. This was a 52-item inventory that measures adolescents and adults' metacognitive skills and contains items that examine each of the eight components subsumed under two broader categories, knowledge of cognition and regulation of cognition. Factors were reliable at α=0.90 and intercorrelated at r = 0.54. This was utilized as a pretest and posttest instrument. In the inventory, the two categories of metacognition were distributed across the different items.

Knowledge of cognition is divided into three components: declarative knowledge (8 items), procedural knowledge (4 items), and conditional knowledge (5 items). Sample items under this category are: (5) I understand my intellectual strengths and weaknesses (DK); (3) I try to use strategies that have worked in the past (PK); and (15) I learn best when I know something about the topic (CK).

On the other hand, regulation of cognition is divided into five components: planning (7 items), information management (10 items), monitoring (7 items), debugging (5 items) and evaluation (6 items). Sample items in the instrument under this category are: (4) I pace myself while learning in order to have enough time (P); (9) I slow down when I encounter important information (IM); (1)I ask myself periodically if I am meeting my goals (M); (25) I ask others for help when I do not understand something (D); and, (7) I know how well I did once I finish a test (E).

In the original version of the MAI (Schraw & Dennison, 1994), students were asked to rate each statement as True (score of 1) or False (score of 0). This study adopted the variations done in several studies using the 5-point Likert scale in rating each statement: Always False (score of 1), Sometimes False (score of 2), Neutral (score of 3), Sometimes True (score of 4) or Always True (score of 5) (Bogdanović *et al.*, 2015; Tosun & Senocak, 2013). The mean scores for the different subcomponents were obtained and were used in determining the students' level of metacognitive awareness using the following interpretations: 1.0 – 1.5 (Low Metacognitive Awareness); 1.6 – 2.5 (Moderately Low Metacognitive Awareness) 2.6 – 3.5 (Average Metacognitive Awareness) 3.6 – 4.5 (Moderately High Metacognitive Awareness) 4.6 – 5.0 (High Metacognitive Awareness).

Students' Journals

The students were asked to write their reflections on their journals every lesson utilizing teaching through problem-solving. Guide questions were focused on how the students understood the problem, the difficulties

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they encountered and the strategies they employed while subjected to teaching through problem-solving to facilitate ease in documenting their metacognitive processes. These questions were validated by the same content experts who validated the mathematics pretest and posttest. The students were able to prepare six journals for the duration of the intervention.

Unstructured Interviews

Unstructured interviews were conducted with random students after every lesson depending on their availability and willingness. However, at the end of the intervention, all students were interviewed. The researcher used similar questions used in the journal to avoid wasting time and irrelevant conversations. This was done to triangulate what they have written in their journals. Sample guide questions include: (1) How complex is the problem to you? Why? (2) How did you solve the problems during the activity? (3) What helped you understand the problem? (4) What difficulties or challenges did you encounter while subjected to teaching through problem-solving?

Implementation Procedure

Before conducting the study, proper protocol and consideration of research ethics were considered. Permission from the division office and school was sought and approval from the parents of the involved students in the study. The students were also informed of the intent of the study. Before the students were subjected to teaching through problem-solving, the metacognitive awareness inventory and pretest were administered on two consecutive days. The inventory lasted for 30 minutes to one hour, while the mathematics pretest lasted from 45 minutes to one hour. Six teaching through problem-solving lessons on functions validated by five content experts were implemented for six topics in General Mathematics.

In developing the lessons utilizing teaching through problem-solving in this study, the researcher looked into the competencies of the curriculum guide for General Mathematics intended for the Grade 11 students of the senior high school. Along with the content, the performance standard was considered in the choice of the competencies, which can be developed through problem-solving.

The developed lessons consisted merely of topics in Algebra focusing on functions. Lee and Fong (2009) underscored the importance of understanding Algebra in learning mathematics as students and many adults find this difficult.

All students must be given the opportunity to learn algebra that allows them to see its relevance to the world they live in. Hence, this study opted to focus on the topics in General Mathematics under Algebra which were deemed important for the succeeding topics in senior high school mathematics.

The six lessons developed in this study were: representation of functions, operations on functions, rational functions, rational equations, inverse functions and exponential functions. Unlike the lessons using traditional means where the teacher instructs students in a concept or skill, the lessons developed utilizing teaching through problem-solving consisted of three phases: before, during and after, adapted from Van de Walle and Lovin (2004). In the before phase, problems were posed to the class to provide a springboard for developing the new mathematics concepts or skills. One example of a problem in solving rational equations is: In an inter-barangay basketball league, the team from Barangay Bonbon has won 12 out of 25 games, a winning percentage of 48%. How many games should they win in a row to improve their win percentage to 60%? This problem required higher-level thinking so the solution or strategy was not made evident to the students.

It also required students' knowledge in translating the problem into mathematical form, which is crucial for developing their skill in solving a rational equation. In as much as this problem required further analysis, it also encouraged students' engagement and discourse.

To build the concept of an inverse function, the problem used was: You and your friend are playing a number guessing game. You ask your friend to think of a positive number, multiply the result by 2, subtract five and then divide the result by 3. If your friend's first answer was 59, what was the original number chosen? The given problem attempted to pique students' curiosity and mathematics skills in representation and computations using a problem that appeared to be a puzzle or trick.

It also encouraged students' engagement and discourse as it required higher-order thinking and problem-solving skills. It also allowed different solutions or strategies and has embedded mathematics concepts in it. The concept of an inverse may surface on their analysis of the problem situation and their strategy in solving the problem.

In the lesson on exponential function, the problem was: A high school student plans to save his daily allowance to buy something for his mother's birthday. Which option is better? Why? (A): Save ₱2.00 on the first week and increase his weekly savings by ₱3.00 every week. (B) Save ₱2.00 on the first week and double the previous weekly savings after that. In this lesson, a real-life problem was employed in the activity, which involved a decision-making task. It also provided opportunities for students to explore multiple representations using different strategies leading to the development of an exponential function. In this case, the students have to decide and justify their actions by reasoning mathematically or by illustrating their decision through different means like the table and graph.

In the during phase, students were allowed to solve the problems collaboratively in small groups consisting of two or three members. At the same time, the teacher observed, listened, and took note of students' works. The group members assumed different roles, either as a leader, a recorder or a presenter. The after phase of the lessons highlighted the importance of organizing classroom discourse. In this phase, students presented their works to the whole class either individually or as a team. Students were then asked to note the strategies presented then questions were provided to build connections with the mathematics concept being developed. It also consisted of extending the problem and firming up the new math concepts or skills. Also included in the lessons were short formative assessments in the evaluation part to check students' understanding of the competencies.

After every lesson, the students were asked to record their experiences in their journals and were also interviewed randomly. After completing the teaching through problem-solving episodes, posttests, metacognitive awareness inventory and final interview were conducted.

Results and Discussion

Metacognitive Processes Employed by the Students

From the analysis of the students' written works, observations, journals and transcribed responses during the interview, metacognitive processes in developing knowledge of cognition surfaced (Table 2).

At the start of the lesson, the problem was embedded with important and valuable mathematics, which the students approached in multiple ways using different strategies. Various solutions were allowed, which encouraged students' engagement and classroom discourse. In the process, it required higher-level thinking and problem-solving, which contributed to students' conceptual development. The students' use of varied strategies in solving the problems was dominant and evident in their written works across the different lessons. This process created an opportunity for the teacher to assess her students' learning and where they were experiencing difficulty.

Interestingly, most of the students' strategies arrived at an expected answer though some were not considered the most effective. An example of this metacognitive process using different strategies or heuristics to solve problems is illustrated through the students' written works and written reflections in solving this opening problem in the first lesson: One summer vacation, you and your family plan to go to Trinity Island in Maramba. Your father is looking for a parking area for the car you rented. Two parking areas are near your location, but your father has difficulty deciding where to park due to the parking fee. Which parking area will your father choose if he needs to park for 7 hours? 10 hours? For less than or equal to 3 hours? Help him decide. Area A: It charges ₱75.00 per hour for the first 3 hours of parking and an additional ₱25.00 for every hour after that. Area B: It charges ₱35.00 per hour for every hour of parking.

One strategy was using arithmetic or computing or simplifying. Computing or simplifying includes straightforward application of arithmetic rules, order of operations, and other procedures (Krulik and Rudnick, 1996). When a student was asked about the arithmetic strategy he employed, his response was: "*I computed to answer the problem. For Area A, I multiplied 75 by the number of hours of parking for the first 3 hours, and after that, I multiplied the excess by 25 and add. For example, for 3 hours, for option A, 75 x 3 = 225. For Option B, multiply the number of hours by 35. So for 3 hours, 35 x 3 = 105. So for 3 hours, it is better to choose Option B since 105 is less than 225.*"

Another solution that emerged was the use of algebra. This strategy was found to be extensively used in all the lessons included in this study. A student who employed an algebraic solution explained, "*I tried using x in my solution because I remembered the lessons in junior high school. It was easy for me because I can easily find the value even for longer hours. I do not need to multiply again and again and add many numbers because I can get the answer easily like, for example, in 24 hours.*" Moreover, this student who employed algebraic strategy was also observed to employ other strategies like arithmetic and graph in solving the same problem. When asked why, she explained that she used several strategies in solving the

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Table 2. Metacognitive processes in developing knowledge of cognition.

Metacognitive Processes	Frequency	Percentage (%)	Rank
1. Declarative Knowledge			
a. assessing intellectual strengths and weaknesses	27	26.47	4
b. analyzing task requirements in terms of existing knowledge and beliefs	30	29.41	3
c. activating prior knowledge	38	37.25	2
2. Procedural Knowledge			
a. using different strategies or heuristics to solve problems	82	80.39	1
3. Conditional Knowledge			
a. justifying the use of strategies	24	23.53	5

*n=102 (17 students x 6 lessons), Percentage = f/n*100*

problem so that she can check if she was getting the same answers for the different strategies. Further, she can also determine whether she was getting correct answers by using different strategies to check her answers.

From the written outputs of the students, they were noted to employ more than one strategy in approaching the problem. As illustrated in their works, the students' use of varied strategies in solving the problems were indicative of the metacognitive process in developing procedural knowledge. Metacognition is the awareness of one's thinking and the strategies one is using. It enables students to be more mindful of what they are doing, why, and how their learning skills might be used differently in different situations. Metacognition starts when students think about the strategies they use to perform a task. They choose the most effective strategies and how these skills can be used in different situations (Jaleel, 2016). However, the least, as shown, was the metacognitive process under conditional knowledge. This further shows that even though students knew how to use strategies in solving problems, they seldom rationalized their choice of a particular strategy. Across the six lessons, when students were asked to defend their strategies while solving the problem during processing, only 24 occurrences accounted for this metacognitive process.

For example, in answering the first problem using the graph, the student explained: "*The graph is an excellent visual tool to see the trend of y as the value of x increases*."

In using the table, the students could easily compare the amount of parking fee with the same number of hours. The use of straightforward computation, according to them, was easier since they need to compute without thinking of any variable. A student who resorted to algebra reasoned that it was the strategy that can be used to solve for more extended hours, which was difficult both for graph and table since it needed longer computations. The use of algebra, according to her, was a "shortcut" for providing answers and justification to the problem.

The justifications presented were evidence of students' reflective thinking while using the strategies they preferred in solving the problem. In problem-solving, such a level of thinking is critical as it contributes to developing critical and analytical thinking skills, improvement of metacognitive skills of the students, and developing the intended competencies in the lessons.

Moreover, in developing regulation of cognition, the metacognitive processes were classified under the control aspect of learning, such as planning, information management, monitoring, debugging and evaluating (Table 3).

Planning requires the choice of suitable strategies in solving a problem or performing a task. Setting goals, identifying and selecting appropriate strategies are essentially linked. Therefore, it is sensible to combine these two processes to accurately represent how these two surfaced in the students' works. Across the six lessons, these two processes accounted for the majority of the frequency of occurrences under planning. Students' writing provided information about the plans they developed to solve the problems, although some were not the most effective approach. In solving the problem in lesson 5 which states: "You and your friend are playing a number guessing game. You ask your friend to think of a positive number, multiply the result by 2, subtract 5 and then divide the result by 3. If your friend's first answer was 59, what was the original number chosen?", one student developed a cumbersome yet practical approach as stated in her journal: "*I started with 20, multiplied it by 2*

Table 3. Metacognitive processes in developing regulation of cognition.

Metacognitive Processes	Frequency	Percentage (%)	Rank
1. Planning			
a. setting goals	72	70.58	1
b. asking questions about the material	19	18.63	9
c. reading instructions carefully before doing the task	43	42.16	3
d. identifying and selecting appropriate strategies	36	35.29	6
2. Information Management			
a. focusing attention on important information	35	34.31	7
b. drawing picture or diagram to understand the problem	3	2.94	13
c. elaborating	22	21.57	8
3. Monitoring			
a. assessing strategy used	11	10.78	12
b. assessing understanding of what he is doing	15	14.71	10
4. Debugging			
a. asking others for help	39	38.24	5
b. rereading when confused	42	41.18	4
5. Evaluation			
a. checking and verifying	46	45.10	2
b. evaluating decisions or solutions	12	11.76	11

*n=102 (17 students x 6 lessons), Percentage = f/n*100*

which resulted to 40, subtracted 5, giving 35, and then I divided the result by 3. I ended up with a decimal number, a tinier compared to 59. I repeated the process with a higher number, 50, I still did not get 59. Next, I tried 100, but I got more than 59. So the answer might be lower than 100. So I tried 90, the answer was closer to 59. After more than 10 numbers (it is easy because I used a calculator), I finally arrived at 91, resulting in 59."

A response such as this indicated the thinking a student had that guided the development and implementation of his plan. The student thought that by trying any positive number, he would arrive at an expected answer as the problem stated. Though the student could arrive at the expected answer, the strategy in solving the problem required more time by trying different numbers before arriving at the answer. However, his strategy can still be considered appropriate for that particular type of problem. Moreover, the two metacognitive processes of setting goals and selecting appropriate strategies were still evident in his solution and explanation.

In the metacognitive processes which facilitated good planning to solve problems, some of the students' responses were: *"Binabasa ko po muna yung problem, pag hindi ko naintindhan, binabasa ko po ulit nang maayos, tapos iniisiip ko po kung paano isosolve."* [*I read the problem first; if I don't understand, I read again carefully, then think about solving it.*] "If I still don't understand, especially some words in the problem, I ask from my classmates." The students' writing and responses provided insights into the thinking that supports the planning and implementation of the plan.

In some lessons, setting goals and identifying and selecting appropriate strategies were not explicitly stated but implied in their works. For instance, in lesson 3, one student, while answering the problem at the start of the lesson, drew a diagram to illustrate and understand the problem. This aspect of metacognition falls under information management. In developing information management, students employed the metacognitive processes of drawing pictures or diagrams to understand the problem, focusing on important information and elaborating. Consider her work illustrated as follows:

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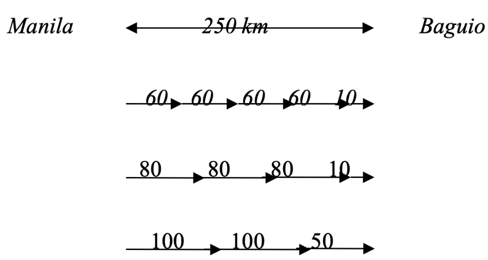

When asked to explain her thinking, her response was: *"I used drawing to visualize the distance from Manila to Baguio, which is 250 km. I then think of a car running 60 km per hour, and I saw that it would take more than 4 hours since I came up with four 60s and 10. I did the same for 80 km per hour and 100 km per hour, and I observed that when the rate was 100 km per hour, it only took more than 2 hours."*

This student's explanation shows that she had devised a plan in which visualizing the rate of the car and the required distance would help her provide evidence for her answer to the problem. However, it was noted that the student was not able to come up with the expected answer due to incorrect computation and interpretation of the remaining 10 and 50, which she interpreted as minutes, thereby arriving at 4 hours and 10 min, 3 hours and 10 min and 2 hours and 50 min. Though the student did not arrive at the expected answer, through her diagram, the thinking that guided her computation was evident.

Other metacognitive processes in developing information management inferred by the researcher from the students' works were elaborating and focusing on important information. Consider this journal entry of one student in lesson 4: *"To solve the problem, let x represent the number of games that they need to win to raise their percentage to 60% [setting goal]. The team has already won 12 out of their 25 games. If they win x games in a row to increase their winning percentage to 60, then they would have played 12 + x games out of their 25 + x games. So I need to add the same number to their winning games and the total games, then by division check if I get 60% [elaborating]. Winning x games in a row mean winning consecutive games [focusing on important information]."*

The journal entry illustrated clearly shows evidence of the metacognitive processes the student employed in understanding and solving the problem.

The student constructed additional ideas using words to aid her in understanding the problem. Elaboration occurs when learners enrich new information by adding new information into their schema. Overall, across the six lessons, planning accounted for the most significant percentage of the metacognitive processes used by the students in developing regulation of cognition while monitoring was the least. This result aligns with Schraw (1998), who mentioned that monitoring ability develops slowly and is relatively poor in children and even adults but will improve with training and practice.

Effects of Teaching through Problem-solving in terms of Metacognitive Awareness

The pretest and posttest results of the students in the metacognitive awareness inventory were categorized according to the knowledge of cognition and regulation of cognition. The students' mean self-ratings on the 52 statements in the inventory were classified into levels of awareness (Figure 1).

The figure shows the differences between the number of statements in the knowledge of cognition and regulation of cognition, where the students' mean self-ratings were classified under average and moderately high awareness, although very little was noted on the moderately low awareness. The deviations from average to moderately high awareness on 17 statements under the knowledge of cognition and 35 statements under the regulation of cognition imply a positive impact of utilizing teaching through problem-solving on the metacognitive knowledge and regulation of the students. It was noted that no students rated themselves with low awareness before and after the intervention. Moreover, though it was apparent that there is a difference between how they rated themselves from pretest to posttest, no rating of high awareness was noted even after the intervention.

This finding clearly shows that although the students were exposed to teaching through problem-solving and reflecting on their thinking during the study, an abrupt improvement in their metacognition cannot be instantaneously expected. As with any skill, the development of metacognition requires time, practice and strategies (Jaleel, 2016). This implies that teachers should provide activities, strategies and learning environments to students to develop this skill.

Table 4 revealed that there is a significant difference on the pretest and posttest scores of the students on the six subcomponents of metacognition except on conditional knowledge and monitoring. Further analysis of the magnitude of the effect of the six subcomponents, which showed significant differences, revealed large effect sizes.

Moreover, the effect was larger in the knowledge of cognition than in the regulation of cognition. This

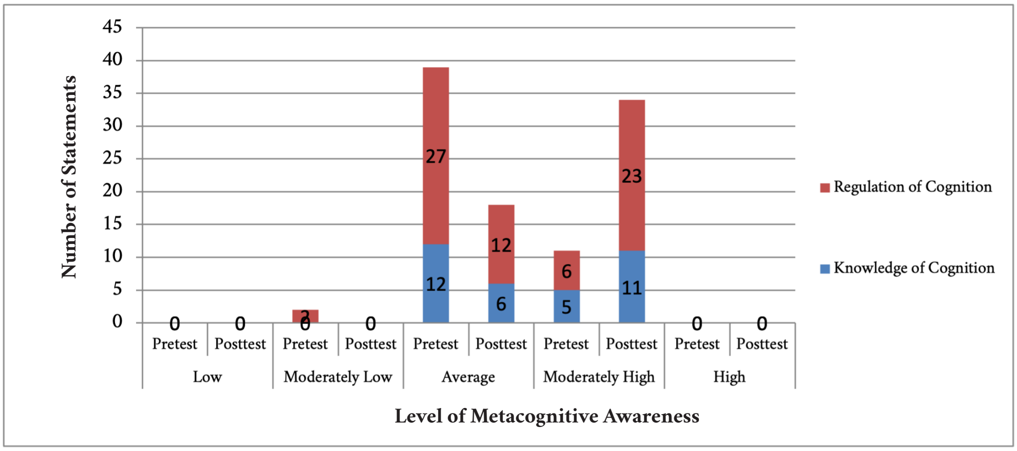

Figure 1. Students' Metacognitive Awareness Level.

Table 4. Metacognitive Awarenesss Inventory Pretest and Posttest Results using Paired t-test and Cohen's Index (*d*).

Components	Pretest	Posttest	p-value	Effect size	Interpretation
A. Knowledge of Cognition					
1. Declarative Knowledge*	3.24±0.41	3.64± 0.35	0.0004	2.2	Large
2. Procedural Knowledge*	3.08±0.24	3.60±0.13	0.0035	4.24	Large
3. Conditional Knowledge ^{ns}	3.39±0.48	3.65±0.29	0.0543	-	-
Mean Score*	3.25±0.40	3.63±0.28	0.0000	1.97	Large
B. Regulation of Cognition					
1. Planning*	3.31±0.28	3.74±0.25	0.0002	3.18	Large
2. Information Management*	3.01±0.34	3.62±0.31	0.0000	2.69	Large
3. Monitoring^{ns}	3.20±0.56	3.47±0.23	0.2751	-	-
4. Debugging*	3.01±0.18	3.54±0.19	0.0039	2.68	Large
5. Evaluation*	3.31±0.31	3.79±0.17	0.0077	1.75	Large
Mean Score*	3.16±0.37	3.63±0.26	0.0000	1.43	Large
Overall Mean Score*	3.19±0.38	3.63±0.26	0.0000	1.51	Large

shows that teaching through problem-solving, in this study, had a more significant impact on metacognitive knowledge than metacognitive regulation. Looking at the overall mean scores of the metacognitive awareness inventory of the students from pretest to posttest, it can be concluded that the use of teaching through problem-solving revealed a favorable effect on their metacognitive awareness. These findings imply that there is hope in improving the students' metacognitive skills through the use of appropriate teaching strategies.

These findings on the positive effect of teaching through problem-solving on the metacognitive awareness of students are in agreement with Karsli (2015), who correlated metacognition level, decision making, problem-solving, and locus of control in a Turkish adolescent population using Metacognitive Awareness Inventory, Problem-solving Inventory and Internal-External Locus of Control Scales. His results indicated that metacognitive developmental level as measured by MAI is a prominent indicator of adolescents' decision-making and problem-solving performances.

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Effects of Teaching through Problem-solving in terms of Academic Performance

Students' academic performance in mathematics lessons included in the study was measured by a 30-point teacher-made parallel pretest and posttest. The mean scores from pretest to posttest show an increase of 10.05, statistically significant at p = 0.05. The Cohen's index (*d*) of 3.113 implies a large effect size. It can be deduced that using teaching through problem-solving produced a positive impact on the students' academic performance in the lessons included in the study. This finding goes alongside Jalili and colleagues' (2018) findings on the relationship between metacognition and academic performance with problem-solving mediation. It proves a significant relationship between metacognition with academic performance, metacognition with problem-solving, and problem-solving with academic performance.

Conclusion

As teaching mathematics through problem-solving had a significant effect on the students' metacognitive awareness and academic performance, teachers should endeavor to use the said strategy in their classrooms. Based on the findings of this study, there is hope that the use of teaching through problem-solving will develop students' higher-order thinking skills such as problem-solving and metacognition. Hence, there is a need for teachers to design classroom tasks geared towards the development of these skills.

Given the relative usefulness of teaching through problem-solving in learning mathematics glimpsed from this study, the following recommendations are made: Teachers need to carefully design lessons suited to the strategy in teaching mathematics. They likewise need to embrace strategies geared towards the development not only of the basic skills but more so of higher-order thinking skills. Reflective journal writing may be employed to elicit, direct and develop students' thinking of their classroom activities.

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