Individuals development of the metacognitive thinking skills on solving math word problems

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Abstract. Metacognition as knowledge and cognition on cognitive phenomenon and one's own knowledge on his self-cognitive processes and use of this knowledge in order to monitor cognitive processes. Metacognitive skills refer to a person's procedural knowledge for regulating one's learning activities including problem solving. Word problems in mathematics have been vastly included in educational literature mainly due to the fact that the issue is considered to be one of the most difficult in math lessons . This research aimed at investigating the contribution of students' ability to metacognitive thinking to metacognitive thinking skills in the aspects of prediction, planning, monitoring, and evaluation through the provision of mathematical words problems. The data was collected through tests, Metacognitive Awareness Inventory (MAI-Jr-Modified) observation sheets and interviews. The results of the study showed that the score of students metacognitive ability was 75.80 which contributed to the level of students metacognitive thinking skills at 78.98% in the high category based on the four aspects of metacognitive skills namely 78.13%; 81.25%; 84.38% and 71.88%. Learning through the provision of mathematical problems in the form of words problems can develop students metacognitive skills.

1. Introduction

The approach of thinking scientifically in learning involves students to be active, creative, critical, able to think logically and able to think highly in conveying their ideas to solve a problem. The process of thinking in problem solving is carried out systematically through certain stages and empirically based on clear data and facts. Learning is a process of interaction among students and interaction among students, teachers and learning resources in a learning environment. The learning process will be meaningful and gain learning experience if the learning is scientific with logical steps including observing, asking questions, collecting information/trying, reasoning/associating, and communicating. These logical steps are very strategic to regulate students 'thinking processes so that they can be used to empower students' metacognitive abilities.

Defines metacognitive as a person's awareness of how he learns, the ability to assess the difficulties of a problem, the ability to observe the level of his own understanding, the ability to use various information to achieve goals, and the ability to assess the progress of his own learning [10]. Metacognition as the ability to contemplate, understand and control one's learning [18]. Metacognition has been defined as any knowledge or cognitive activity that takes as its object, or regulates, any aspect of any cognitive activity [11]. Recently, the definition of metacognition has been elaborated. And as defined in the past, it has only consisted of "thinking on think", but now it covers of awareness of one's own knowledge, cognitive steps, cognitive and effective situations, intentional and awareness

monitoring ability, and regulating his/herself knowledge. In this line, individuals are also supposed to effectively use the cognitive processes and skills. Metacognition is defined as thinking to think [13].

The concept of metacognitive thinking skills is a common name of skills that not only help current knowledge to be remembered and understood but also help them to be organized and used [5]. Metacognitive thinking skills refer to all skills of critical and creative thinking, decision making and problem solving [14]. Metacognitive skills are very important in terms of several professions. Individuals development of metacognitive thinking skills will provide a better performance in their professions [8]. Metacognitive Skills refer to prediction skills, planning skills, monitoring skills, and evaluation skills [3]. Predictive aspects are fulfilled when students understand the problem, and what is known and asked about the problem which implicate that students can plan the steps to be completed. The planning aspect focuses on students' ability in transforming words problems into mathematical models and determining the right strategy in solving mathematical problems. The monitoring aspect focuses on the application or use of the right formula in solving problems and applying the appropriate concepts. Then, the evaluation aspect is a revised aspect of students which is said to apply metacognitive skills in solving problems. Finally, the evaluation aspect focuses on accuracy in the calculation process and re-checking the answers.

Mathematical problems according to Polya [17] there are two kinds of problems to find which students are expected to determine the solution or answer to the problem and the problem to prove which students are expected to show the truth of a theorem or statement. More deeply develops steps in solving mathematical problems, which include: (1) understanding the problem; (2) devise a plan, (3) carry out a plan, and (4) look back. In understanding the problem, the activities carried out in this step are: what (data) is known, what is unknown (asked), whether the information is sufficient, what conditions must be met, restating the original problem in a more operational form (can be solved). In planning a solution, the activities that can be carried out in this step are: trying to find or remember problems that have been resolved that have similarities to the problems to solve , looking for patterns or rules, and developing settlement procedures (making conjectures). Then, in resolving the problem according the plan, the activities that can be carried out in this step are: carrying out the procedure made in the previous step to get a solution. Finally, in re-examining the procedure and outcome of the solution , the activities that can be carried out in this step are: analyzing and evaluating whether or not the procedures applied and the results obtained are correct, are there other more effective procedures, whether the procedures made can be used to resolve similar problems, or whether the procedure can be generalized.

Thinking skills in problem solving are needed by students to solve mathematical problems. The ability to solve mathematical problems is the ability or potential of students in solving words problems, solving problems that are not routine, applying mathematics in everyday life or other circumstances, and proving, creating or testing conjectures. Problem solving in mathematics will build a logic of reasoning skills that can be applied in various situations in daily life, today and in the future [12]. Stated the purpose of teaching problem solving in learning mathematics is to: (1) develop students' thinking skills, (2) develop the ability to select and use problem solving strategies, (3) develop attitudes and beliefs in completing problems, (4) develop students' ability to use interconnected knowledge, (5) develop students' ability to monitor and evaluate their own thoughts and work results during problem solving, (6) develop students' ability to solve problems in a cooperative learning environment, and (7) develop students' ability to find the right answers to various problems [1]. Nevertheless, only problem in this kind of teaching is the low ability of students in solving problems that are characterized by (1) the low ability of students in analyzing problems, (2) the low ability of students in designing problem solving plans, and (3) the low ability of students in carrying out calculations, especially relating to the material apperception which supports the problem solving process.

Words problems are real-life, practical problems in which the correlation between the known and unknown quantities are provided in the form of text, and their solutions need some kind of mathematical model [20]. A subset of word problems are story problems, which are situated in "real-

world" contexts that reference concrete people, places, and objects [21]. Solving word problems involves a number of complex cognitive abilities in which students must accurately decode, comprehend, interpret, and apply a strategy to solve a mathematical word problem [15]. Solving word problems can be a challenge for any student who has difficulty in mathematics [4].

To develop an efficient problem-solving skills, it is recommended to use more new words problems to which students have to find the algorithm steps leading to the solution. The teacher should introduce students to solving words problems using correct interpretations, understanding, observing steps in problem solving, possible representations, and interpreting results in terms of real life situations because words problems play an important role in developing understanding.

Based on the above description, this study aims to describe how to develop metacognitive thinking skills and know the ability of students' mathematical thinking skills in solving mathematical words problems in terms of aspects of prediction, planning, monitoring, and evaluation. Students who have high metacognitive skills will be able to complete their learning tasks well because they are able to plan learning, organize themselves, and evaluate their learning.

2. Methods

This type of research is descriptive qualitative research. The subject of the research was the teacher and 32 students of class XII IPA 3 SMA N 1 Jatibarang, Brebes, Central Java, Indonesia. Data collection techniques in this study are: documentation of student work results, observation, and interviews conducted to trace the process of students 'metacognitive skills and students' understanding in solving math words problem. The validity of the data uses the method of triangulation method by comparing the results of observation, interviews, and documentation. This study uses data analysis with the following stages: (1) data reduction, (2) data presentation, and (3) conclusion drawing. Data reduction in the form of test results and interviews, then the data is presented in the form of narrative text after which conclusions are drawn regarding the process of students' metacognitive skills.

Students' metacognitive awareness is measured using a Metacognitive Awareness Inventory (MAI-Jr-Modified) instrument modified from the Metaconitive Awareness Inventory (MAI) compiled by Schraw & Dennison. Modification of this instrument relates to language, simplification of terms, colaboration of several aspects and adjustments to some mathematical scientific disciplines. This level of metacognitive ability is based on the criteria and classification adapted from Schraw & Dennison, namely: poor (score ≤ 50), lack ($51 <$ Score < 69), sufficient ($70 <$ Score < 79), and good ($80 <$ Score ≤ 100). The interpretation criteria for the category level of students' metacognitive thinking skills in mathematical problem solving are based on the test score range: Very High ($80.00 <$Test Score ≤ 100.00); Height ($60.00 <$Test Score ≤ 80.00); Enough ($40.00 <$Test Score ≤ 60.00), Low ($20.00 <$Test Score ≤ 40.00), and Very Low (Test Score ≤ 20.00).

3. Results And Discussion

3.1 Student Metacognitive Ability

The results of the study showed that the mean score of aspects of students' metacognitive abilities is 75.80 which is categorized sufficient. The results of the full mean score of each aspect of metacognitive ability are presented in Table 1. below.

From Table 1. shows that students tend to have metacognitive knowledge in enough categories with a mean of 75.94 as part of the self-regulation process, the ability to control the process of self-thinking in each problem solving stage of the contribution of declarative knowledge aspects of 79 , 67; the mean of procedural knowledge is 71.23; and the conditional knowledge is 76.92. This shows that students have knowledge and beliefs elaborated through experiences and stored in their long-term memory. While the ability of metacognitive, in which, regulation of students at enough category, the mean is 75.47 from the contribution mean at the planning aspect of 79.18; Information Management is 69.87; Comprehension Monitoring is 74.59; Debugging Strategies is 78.41; and Evaluation is 76.28.

Tabel 1. Scores of Students' Metacognitive Ability

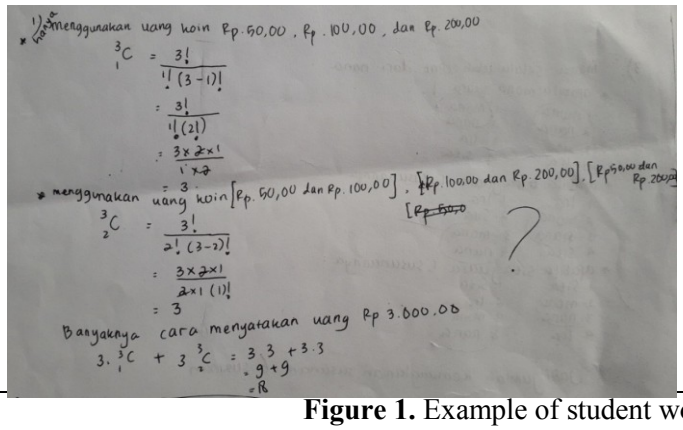
Aspects of metacognitive ability	Mean all students
Declarative Knowledge	79,67
Procedural Knowledge	71,23
Conditional Knowledge	76,92
Metacognitive Knowledge	75,94
Planning	79,18
Information Management	69,87
Comprehension Monitoring	74,59
Debugging Strategies	78,41
Evaluation	76,28
Metacognitive Regulation	75,47
Metacognitive Mean	75,80

3.2 Students Metacognitive thinking skills through words problems

The following is an example of students 'work results in working on words problems and descriptions of students' metacognitive thinking skills in solving mathematical problems.

Problem 1.

Using a Rp.50.00 coin; Rp. 100.00 and Rp. 200.00. How many ways do we declare money in the amount of Rp. 3000.00?



Use coins Rp. 50.00, Rp. 100.00, and Rp. 200.00

Use coins [Rp.50.00 and Rp. 100.00], [Rp. 100.00 and Rp. 200.00[, [Rp. 50.00 and Rp. 200.00]

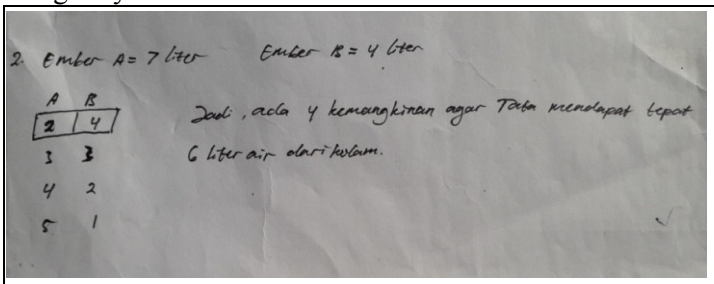
Total ways to express the money Rp. 3.000.00

Figure 1. Example of student work on problem 1

From Figure 1 shows that students have prediction skills and planning skills by understanding the problem and are able to determine the right strategy in solving mathematical problems but in monitoring skills and evaluation skills students have not been able to apply or use the right formula and accuracy in the calculation process.

Problem 2.

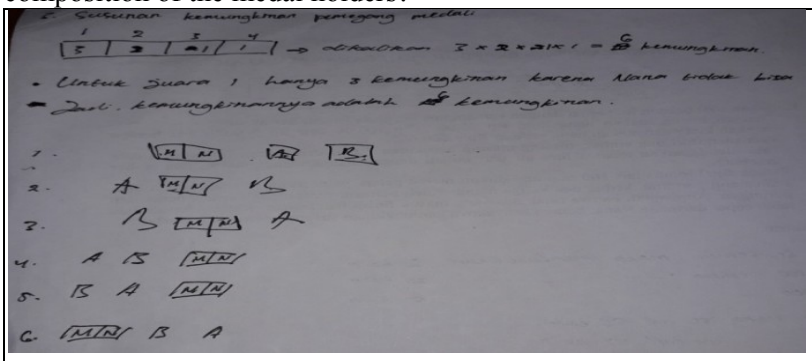
Tata has two buckets, each is 7 liters and 4 liters. How to get exactly 6 liters of water from the pond using only two buckets.



So there are 4 possibilities for Tata to get exactly 6 liters of water from the pond

Figure 2. Example of student work on problem 2

Problem 3.
The final round of the women's 100m running race was followed by 4 runners, namely Mona, Nana, Ira and Sita. The first, second and third winners won, in row, gold, silver and bronze. Suppose that no one entered the finish together. If Mona is always faster than Ana, how many possibilities of composition of the medal holders?



Possible arrangement of medal holders

For the first winner there are only 3 possibilities. So there are 6 possibilities.

Figure 3. Example of student work on problem 3

From Figure 2 and 3 it can be seen that students have prediction skills, planning skills, monitoring skills, and evaluation skills so that they understand the problem and are able to convert problem words into mathematical models, able to apply concepts that are used correctly and accuracy in the calculation process.

Based on the example of the students' work results above, there were still mistakes made by students in solving problems related to words problems. This shows that students still have difficulties in solving problems. Based on field facts, the results of the study show that students' metacognitive thinking skills in solving mathematical problems about words problems as follows:

Table 2. Percentage of Students' Metacognitive Thinking Skills

Aspek dan Indikator	Number (32 students)	Percentage	
		Each Aspect	Total
Prediction skills		78,13	78,98
Understanding the problem	26	81,25	
Understanding what is known and asked about the problem	24	75,00	
Planning skills		81,25	
Ability to transform words problems into mathematical models	27	84,38	
Ability to determine the right strategy in solving mathematical problems	25	78,13	
Monitoring skills		84,38	
Ability to apply or use the right formula in solving problems	28	87,50	
Ability to apply the concepts that are used correctly	26	81,25	
Evaluation skills		71,88	
Accuracy in the calculation process	25	78,13	
Re-check the answer	21	65,63	

From Table 2, it can be seen that from the aspect of prediction, understanding the problem in a words problem if it has been well owned by students it will have an impact on students in which they can understand what is known and asked about the problem. The results of the study show that 81.25% of students tend to understand the problem and 75% know what is asked about the problem so that students have an overview of these elements and can plan the steps to finish the problems. In general, it can be concluded that the prediction skills of students in the high category is 78.13%. To be able to understand what is known and asked by the questions, students must be careful in reading the questions. For students who are not able to understand the problem properly, based on the results of the interview it is because they do not read the questions carefully, so that students cannot determine what is being asked about the problem. As for the effort to minimize the problem-solving mistakes in the form of words problems in which the predictive aspects can be achieved properly, it is necessary to provide problems in term of words problems, careful reading, and underlining what is known and what is being asked.

In the point of view of planning aspect, in general it can be described that students have 81.25% of aspects of planning skills in the very high category through two indicators of student achievement that is able to transform the words problems into a mathematical model as much as 84.38% and able to determine the right strategy in solving math problems as much as 78.13%.

Viewed from the aspect of monitoring based on the on-field facts, the students have been able to apply or use the right formula in solving problems is 87.50%. Students who are able to apply mathematical concepts that are used appropriately is 81.25% so that this gives a positive influence on the ability to solve problems in math words problems. Students' understanding of mathematical concepts makes them easy to remember and determine the right formula. However, most students do not write formulas before solving problems, but students immediately operate with numbers.

The aspect of evaluation as an improvement in metacognitive skills obtained as much as 71.88%. This can be seen from the indicators obtained by metacognitive skills in the accuracy of the calculation process as much as 78.13%. But the students' tendency to re-check the answers was only 65.63%, this was because the students were less able to set the time.

From the results of the study in general it can be concluded that by paying attention to each aspect and indicator, the metacognitive thinking skills students in the high category is 78.98%.

4. Conclusions and Suggestions

The results of the study showed that the score of students 'metacognitive ability was 75.80 which contributed to the level of students' metacognitive thinking skills at 78.98% in the high category based on the four aspects of metacognitive skills namely: 78.13%; 81.25%; 84.38% and 71.88%. Learning through the provision of mathematical problems in the form of words problems can develop students' metacognitive skills.

References

[1] Charles R and O'Daffer P 1997 *How to Evaluate Progress in Problem Solving* (Reston, VA: NCTM)
[2] Daher, W, Anabousy A and Jabarin R 2018 *Int. J. Res. Educ. Sci.* **4** 292
[3] Desoete, Anemi, Herbert R and Ann B 2001 *J. Learn. Dissabilities* **34** 435
[4] Diane M B 2017 *J. Special Educ.* **51** 222
[5] Doğanay A 2007 *Teaching metacognition skills. Doğanay, A. (Ed.), Principles and Methods of Teaching* (Ankara: Pegem A Publishing)
[6] Eda V 2017 *Int. Electron. J. Elem. Educ.* **10** 49
[7] Hegarty M, Mayer R E and Monk C A 1995 *J. Educ. Psychol.* **87** 18
[8] Feyzi K A Y S İ 2003 *Int. J. Learn. Dev.* **3** 70
[9] Flavell J H 1985 *Cognitive Development. (2nd ed.)* (Englewood Cliffs, NJ: Prentice – Hall)
[10] Flavell J H 1976 *Metacognitive Aspect of Problem Solving. In L. B. Resnick (Ed.), The Nature of Intelligence* (Hillsdale, NJ: Erlbaum Association)

[11] Flavell J H, Miller P H and Miller S A 2002 *Cognitive development (4th ed.). Upper Saddle River* (NJ: Prentice Hall)
[12] Mullis I V S, Michael O M, Pierre F and Alka A 2012 *Timss 2011 International Results in Mathematics* (Amsterdam, The Netherlands: International Association for the Evaluation of Educational)
[13] Kartal M 2017 *Univers. J. Educ. Res.* **5** 1
[14] Kaya B 2008 *Assessing social studies preservice teachers' self-efficacy towards teaching thinking skills. Unpublished Phd Thesis* (Gazi University, Institute of Educational Sciences)
[15] Lauren A D 2018 *J. Special Educ. Apprenticesh.* **7** 1
[16] Lewis A B 1989 *J. Educ. Psychol.* **81** 521
[17] Polya G 1973 *How to Solve It. 2nded* (Princeton University Press, ISBN 0-691-08097-6)
[18] Schraw G and Sperling-Dennison R 1994 *Contemp. Educ. Psychol.* **19** 460
[19] Stern E 1993 *J. Educ. Psychol.* **85** 7
[20] T¨OR¨OK T 2013 *Sz¨oveges feladatok ´es tan´ıt´asuk, In K. Herendin´e (Ed.), A matematika tan´ıt´asa az als´o oszt´alyokban* (Budapest: Nemzed´ekek Tud´asa tank¨onyvkiad´o)
[21] Walkington 2017 *Am. Educ. Res. J.* **55** 362