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Student's Metacognitive Activities in Solving Mathematics Problems

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***Abstract*—Metacognitive activities in mathematics problem solving are important in order to obtain the right solution. The implementation of metacognitive in solving problems indicates that the activities are supported by awareness and regulation of knowledge. For education students, the awareness and regulation of knowledge must underlie in all problem-solving process, not only to obtain the right solutions, but also to be the important basis to develop the strong understanding for their future students. The methods used in this research are (a) problem-solving with think-aloud method, (b) interview, and (c) observation during the problem-solving process. To ensure data validity, triangulation is done by combining the methods triangulation and times triangulation. The result of research shows that: (1) metacognitive activity conducted by students in solving contextual mathematical problem shows higher dynamics on implementation especially when compared with the formal mathematical problems, (2) the dynamics are shown in the diversity of metacognition activity types as well as the frequency of implementation of each metacognition activity, (3) one of the contributing factors is in the contextual mathematical problems, the subject must translate the contextual situation of the problem into mathematical model in order to use formal mathematical solving procedures.**

Keywords*—*mathematical problem, metacognitive activities, awareness and regulation

I. Introduction

Education in Indonesia today has realized that metacognition must be one of the important points to be considered. This is related to optimize students' ability to solve problems or optimize learning outcomes that can be achieved [1]. In principle, this efforts to involve metacognition in various learning activities are expected to provide benefits to improve the quality of learning carried out.

The implementation of metacognition activities in problem-solving is one of the interesting factors that many researchers pay attention to. This is due to the benefits that can be obtained when problem-solving is done by involving awareness of thinking process and self-regulate ability because it enables a strong understanding of the problem with logical reasons. The understanding is always emphasized when mathematics learning takes place at all levels of education. Students who know and can control their cognition have a better ability to solve real problems and communicate the reasons [2].

The suitability of learning mathematics with the experienced by students daily conditions is a topic that has been reviewed in recent times in the development and improvement of the education process, such as in learning with a contextual, realistic approach, or by using mathematics teaching aids. Utilization of mathematics teaching aids in learning mathematics provides excellent opportunities for improving understanding of the concept to the students, based on their awareness about why and how a concept built and then can use the awareness to solve problems [3]. The use of context as a starting point in the implementation of learning shows various objects or situations that students have to understand in their daily environment can be utilized and contribute greatly to build an understanding of mathematical facts, concepts, and principles. In this regard, various improvements in mathematics education increasingly emphasize the importance of mathematical reasoning, problem-solving skills, and suitability with real-life situations [4]. Cognition and metacognition are tied to concrete facts of the work situation [5]. Concrete facts in this work situation are related to various things that occur and are understood related to the place, time, or background of knowledge when the problem-solving process is carried out.

From the description above, it can be seen how important metacognition skills are owned by students at all levels of education. Teachers, in this case, can encourage students to have these abilities through learning activities. One that must be done is to encourage students always to be aware and manage their thinking processes through the implementation of metacognition activities in learning and in solving problems.

II. Metacognition

There are several definitions of metacognition that develop in the field of cognitive psychology. Metacognition as the ability to understand and monitor one's own thoughts and assumptions and the implications of one's activities. Meanwhile, Brown defines Metacognition as an awareness of one's own cognitive activity; the methods are employed to regulate one's own cognitive processes; and a command of how one directs, plans, and monitors cognitive activity [6]. From the two definitions above, it can be understood that Flavell emphasizes metacognition as the ability to understand and monitor thinking activities so that the process of metacognition of each person will be different according to their abilities. Brown emphasizes metacognition as an awareness of cognition activities; in this case, metacognition is related to how a person is aware of his thinking process. This awareness will manifest in the way a person regulates and manages the thinking activities.

There are many different perspectives about metacognition, resulting in differing views about the scope of metacognition, including the differences in views between Flavell and Brown. Flavell tends to view metacognition as a metacognitive knowledge, whereas Brown tends to view metacognition as a process of managing cognition.

Flavell suggests that there are three variables that interact with each other and influence a person's metacognitive knowledge, namely assignment, individual, and strategy variables [7]. Brown specifically grouped four components of metacognition: planning, monitoring, evaluating, and revising [6]. The same thing also expressed by Kirsh, metacognition in education, for instance, is associated with the activities and skills related to planning, monitoring, evaluating and repairing performance [5]. In principle, metacognition activities and skills are one of the important factors that will determine success, both related to the learning outcomes achieved, and the formation of a mindset that enables students to be able to do the next learning activities or solve problems.

In another section, Cohors-Fresenborg and Kaune [8] summarize the metacognition components into four metacognition activities conducted on problem-solving in classroom discussion settings, consist of (1) planning, (2) monitoring, (3) reflection, and (4) discursivity. Although many metacognition groupings have been stated, in general, the grouping has a strong relationship. The grouping by Brown and Kirsh related to the learning activities or educational processes, while grouping by Cohors-Fresenborg and Kaune more specifically addresses to problem-solving activities.

In this study, the metacognition activity that is of concern is accomplished in problem-solving activities. Thus, the metacognition process that is considered includes activities whose scope is limited to three components, namely planning, monitoring, and reflection. These three components are a series and interrelated in metacognition activity. This grouping is as stated by Cohors-Fresenborg and Kaune, who were chosen because of their suitability with this research, namely the process of metacognition when problem-solving takes place.

In general, all groupings stated above are attempts to elaborate on the two dimensions of metacognition itself. As already defined, metacognition has two interdependent dimensions, namely (1) awareness about cognition and, (2) control or regulation of cognition processes.

Flavell views these two metacognition dimensions as an inseparable part of cognitive activities, and suggests that monitoring of wide variations of cognitive activities occurs in all actions and interactions between the four types of phenomena, namely: (1) metacognitive knowledge, (2) metacognitive experiences, (3) goals or tasks, and (4) action or strategies [7]. The ability of a person to control the extent of variation of cognitive activities depends on how it works and the interaction between the four components.

Brown divides metacognition into two distinct categories: (1) knowledge of cognition, as an activity that includes conscious reflection on one's cognitive abilities and activities, and (2) regulation of cognition, as an activity that pays attention to the mechanism of self-regulation during the effort to learn or solve problems. These two forms of cognition have a very close relationship, each of which replenishes each other, although both can be distinguished [1].

III. Mathematical Problem Solving

Problem-solving is the embodiment of a mental activity consisting of various cognitive skills and actions [9] which are intended to get the right solution to the problem. Each problem contains three important characteristics, namely: (1) givens, are all elements, relations, and requirements form the formulation of the state of the problem, (2) goals, is the completion or desired outcome of the problem, and (3) obstacles are characteristics from problems and people who solve problems that make the problem difficult for the person to transform the formulation of the problem into the desired form [1].

In learning mathematics at schools, teachers usually make problem-solving activities as an important part that must be carried out. This is intended in addition to knowing the level of student mastery of the subject matter, as well as to train students to be able to apply their knowledge to different situations and problems. Gagne [10] suggests that problem-solving is the highest form of learning. Thus it can be said that all activities are studying the rules, techniques, and content of the lesson so that they can understand mathematics, are intended to enable students to solve mathematical problems.

In solving mathematical problems, one of the most referred was Polya's phasing, which revealed four important steps that needed to be carried out:

- Understanding the problem includes understanding various things that exist in the problem such as what is not known, what data is available, what are the conditions, and so on.
- Devising a plan encompasses various attempts to find the relationship of a problem with other problems or the relationship between data with unknown things, and so on.
- Carrying out the plan including checking every step of the solution, whether the steps taken are correct or can it be proven that the step is correct.
- Looking back includes testing the resulting solution [11].

The problem-solving stages put forward by Polya contains details of the steps that students should take and implement, so that problem solving can be carried out efficiently and the right solution is obtained. The recommended problem-solving steps lead students always to be able to realize their potential abilities and can manage these abilities to be used in problem-solving.

IV. Metacognition in Mathematical Problem Solving

This study is intended to see metacognition activities in solving mathematical problems. The focus chosen is on the process of metacognition conducted by students when doing mathematical problem-solving. Thus, the discussion of metacognition is done in relation to the problem-solving process.

Base on Polya's idea [11] of problem-solving steps, it can be said that all the steps put forward lead to awareness and regulation of students towards the process carried out to obtain the right solution. Polya himself mentions his thinking as "thinking about the process" in relation to successful problem-solving.

Cohors-Fresenborg & Kaune [8] classify metacognition activities in solving mathematical problems consisting of (1) planning (planning), (2) monitoring (monitoring), (3) reflection (reflection), and (4) discursivity. For the purposes of this study, discursivity is not implemented because it is suitable in the context of problem-solving that is carried out in classroom discussions, whereas in this study, problem-solving is carried out by each subject independently,

The metacognition process in this study was applied to mathematical problem solving, which refers to Polya's phasing, and metacognition activities by Cohors-Fresenborg and Kaune. Thus a table of relationships between problem-solving stages and metacognition activities can be arranged in solving mathematical problems.

TABLE I. METACOGNITION ACTIVITIES IN PROBLEM SOLVING

No	Planning		Monitoring		Reflection	
1	P1	Set goals	M1	Control terminology / notation	R1	Reflection on concepts
2	P2	Establish a solution strategy	M2	Control errors (when counting or rewriting)	R2	Awareness of the application/use of strategies
3.	P3	Establish intermediate results that can be achieved	M3	Control the accuracy of calculations	R3	Analysis of the structure of a mathematical expression/symbol
4.	P4	Plan a representation (formulas, graphics, text, etc.) to support understanding	M4	Control argumentation	R4	Analysis of decision making structures
5.			M5	express a lack of understanding	R5	Intentional choice of representation (formulas, graphs, terms, texts, etc.)
6.			M6	express a lack of planning	R6	Recognizing the interaction between representation and wrong ideas as a control theme
7.			M7	Monitor conformity between facts and objectives		
Source: Cohors-Fresenborg & Kaune (2007) with modifications						

Problem-solving is done by subject independently and avoiding all kinds of interventions (by researchers, friends or other subjects). in the implementation of the research, metacognition activity table developed by Cohors-Fresenborg and Kaune [8] was used by making a few modifications according to the research situation.

V. METHOD

This type of research is exploratory research with a qualitative approach. The subjects of this study were students of the Mathematics Education Study Program at Halu Oleo University Kendari; this option was intended to obtain information about the metacognition abilities possessed, so that a prospective teacher learning system could be designed that was able to optimize the involvement of metacognition processes, especially in problem-solving.

The main instrument in this study is the researcher himself. As a supporter of the smooth implementation of the research function as the main instrument, several supporting instruments were used, namely: (1) formal math problem assignments, (2) contextual math problem assignments, (3) interview guidelines based on problems solved, and (4) basic math test — other instruments as supporting equipment in the form of recording devices and cameras.

Metacognition activities conducted by research subjects when solving problems were identified based on 2 data sources, namely: (1) results of problem-solving (written and think aloud), (2) interview results. To express the process of metacognition, think aloud method is used.

Triangulation is carried out through a problem-solving process carried out at different times. The problem solved in the triangulation process is a similar problem and is equivalent to a problem that has been solved before.

VI. RESULT AND DISCUSSION

The metacognition activities that were carried out on problem-solving by research subjects from different ability groups found a significant difference. These differences occur both in solving formal mathematical problems and in solving contextual mathematical problems. In solving formal mathematical problems, subject 01 (from high ability group) and subject 02 (from low ability group) perform metacognition activities as shown in Figure 1.

Based on the picture in figure 1, it appears that the metacognition activities carried out by both subjects showed significant differences. Subjects 01 from the high ability group carried out various types of metacognition activities at all stages of problem-solving. Different things were done by subject 02 from the low ability group,that is not all stages of problem-solving involved metacognition activities, one of which was not doing reflection activities.

The results show that subjects from the high ability group carry out formal mathematical problem solving with the support of awareness and more dynamic thinking arrangements when compared to subjects from low ability groups. This comparison is shown by the lines of metacognition activity at each stage of problem-solving.In solving a contextual mathematics problem, both subjects perform metacognition activities as presented in figure 2.

In contextual mathematical problem solving, subjects from high ability groups carry out a very dynamic metacognition process at all stages of problem-solving. This dynamic shows the involvement of awareness and good thinking arrangements carried out by the subject. At all stages of problem-solving, a variety of different metacognition activities are carried out that support their efforts in solving problems.

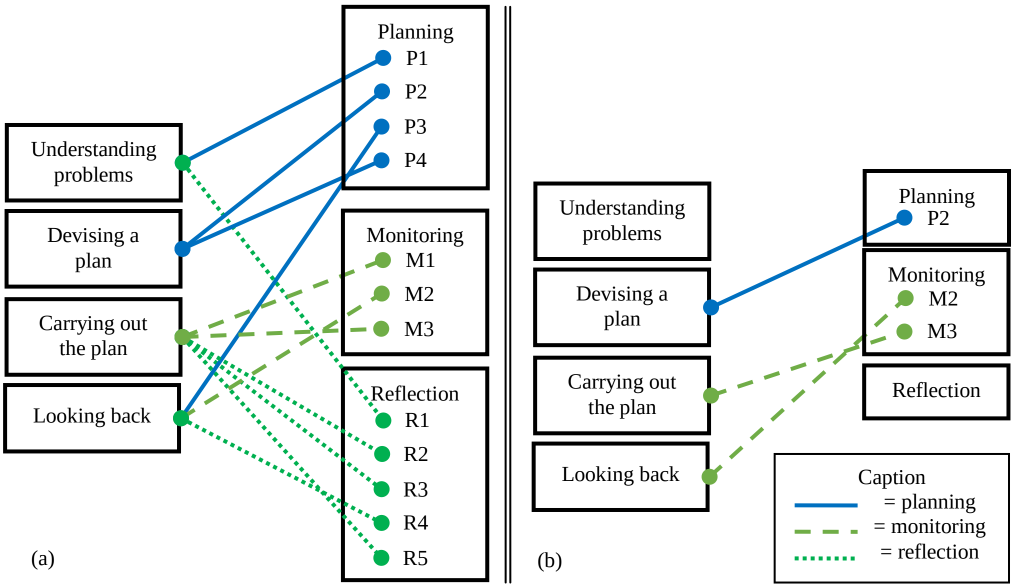

Fig. 1. Comparison of metacognition activities in formal mathematical problem-solving. (a) subject 01, (b) subject 02

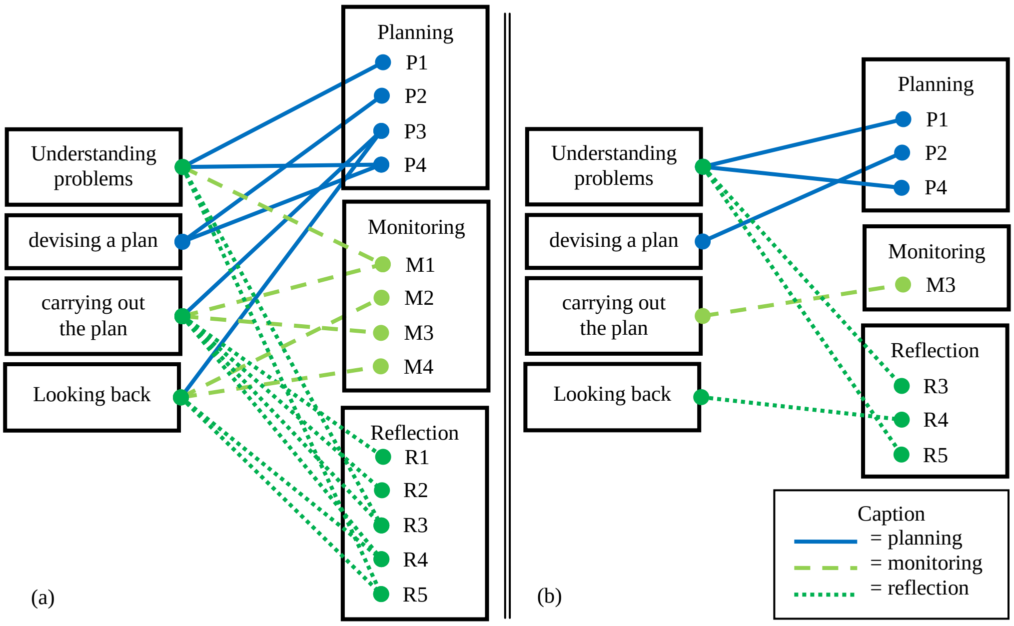

Fig. 2. Comparison of metacognition processes in contextual mathematical problem-solving. (a) subject 01, (b) subject 02

Different activities were done by subjects from low ability groups in solving contextual mathematical problems. The subjects carried out activities that were quite minimal with relatively very low dynamics. When compared to when solving formal mathematical problems, than in solving this contextual mathematical problem the subject only noted an increase in the stage of understanding the problem. This happens as a result of the need to translate contextual situations from problems to be solved into mathematical models so that they can be solved mathematically.

Based on the results of data analysis conducted on the two types of problems that were solved, subject 01 can do a solution with a fairly good metacognition activity, while subject 02 carried out the solution by only carrying out a little metacognition activity.

This situation shows that subject 01 is very aware of his knowledge related to the problem to be solved and can manage that knowledge in the problem-solving process. Subject 02 is quite minimal in terms of realizing his knowledge related to the problem being solved and is less able to demonstrate this ability in the problem-solving process.

In connection with these results, there is one thing that is enough to be the mind of researchers in understanding the thinking process that is carried out by both subjects when solving problems. This is, even though the two subjects carried out different metacognition activities in solving problems with a level of metacognition ability that was also quite different, but both could provide the results of a correct solution.

Through the interviews, subject 01 clearly shows excellent mastery of the knowledge needed and the process of solving that is done, so it is appropriate to produce the right solution. Subject 02 actually did not show sufficient mastery, both in terms of the knowledge needed, and the process of solving that was carried out. However, subject 02 remembers several key steps that need to be done, even though they do not understand the meaning of the step so that the correct end result can be achieved.

VII. CONCLUSION

In solving mathematical contextual problems, subjects perform more metacognition activities than when doing formal mathematical problem-solving. Subjects from the high ability group perform more metacognition activities when compared with subjects from low ability groups both in formal mathematical problem solving and contextual math problems. The deployment of metacognition activities on problem-solving will deliver the subject to obtain the correct results based on his ability to realize the knowledge possessed in relation to the problem being solved, and the ability to manage that knowledge in the problem-solving process. Subjects with good metacognition skills, able to understand all the process of solving that is done and master well the knowledge that is needed to get the right solution. The results of the correct solution of a problem cannot be used as a measure of students' metacognition activities, because true results can be obtained even though they are not supported by adequate metacognition activities, but enough to memorize. Subjects with low metacognitive abilities have the opportunity to produce wrong answers when the context of the problem being solved changes.

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