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Metacognitive-Based Mathematics Learning for 21st-Century Students' Higher Order Thinking Skills

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ABSTRACT

In order to face the challenges of 21st century life, mathematics learning must be directed to the development of students' Higher Order Thinking Skills (HOTS) because only these skills can lead students to be able to compete globally. HOTS ability can also improve critical and creative thinking skills. Therefore, learning must be directed at innovative and creative learning. One of the innovative learning offered in this study is metacognitive-based mathematics learning. This study aimed to improve students' Higher Order Thinking Skills. This experimental research was conducted by taking a sample in one of the Senior High Schools in Parepare City, namely class XI of Social Sciences at Senior High School 1 Parepare. This study was designed using a pre-test and post-test design with a metacognitive-based mathematics learning treatment. The results of the study were analyzed by normalized gain T-test. The results showed that there was an increase in students' Higher Order Thinking Skills through metacognitive-based mathematics learning at a significance level of $\alpha = 5\%$. In addition, it was found that the HOTS ability related to the students' Analyzing (C4) ability was in the very good category, while Evaluating (C5) ability and Creating (C6) ability were included in the good category, respectively. Therefore, the researchers hope that metacognitive knowledge become one of the alternatives that need to be developed to improve students' thinking skills.

I. Introduction

The challenge of learning in the 21st century is how to equip students to have competence, such as good reasoning, applying mathematical concepts in everyday life, creative and innovative, critical thinking and mastering information and communication technology literacy [1], [2]. [3] One of the alternatives to overcome these challenges is to improve students' Higher Order Thinking Skills (HOTS). Mathematics is one of the subjects that has a significant role in improving students' HOTS ability through skill material whose contents are to train students' problem solving abilities, and mastering and utilizing technology in the future requires strong mastery of mathematics. [4], [5]

Realizing the importance of mastering mathematics, Law of the Republic of Indonesia No. 20 of 2003 concerning the National Education System in Article 37 states that mathematics is one of the compulsory subjects for students at the primary and secondary education levels. Therefore, one of the important components in learning mathematics that must be mastered and continuously improved is problem-solving skills oriented to HOTS ability.

Higher Order Thinking Skills (HOTS) are thought processes that require more cognitive processing to face 21st century life. Thus, development in learning is needed such as 4C skills (communication, collaboration, creativity and critical); [6], [7], [8]. However, in practice, one of the problems in mathematics education and learning faced by Indonesian teachers and students is the low ability and Higher Order Thinking Skills of students. This is shown by the 2015 Trends in International Mathematics and Sciences Study (TIMSS) test results in mathematics, Indonesia ranked 44th out of 49 countries, and the 2018 Program for International Student Assessment (PISA) test results were ranked 72th out of 78 countries [9], [10]. These data, especially in the reasoning domain, clearly indicate that the HOTS ability of students in Indonesia is still low.

The low mathematical HOTS ability of Indonesian students is partly due to the learning process in schools that have not been accustomed to working on questions using the HOTS type. The characteristics of mathematics learning are still familiar with Lower Order Thinking Skills questions. [11], [12] This phenomenon is triggered by the lack of implementation of learning models and methods oriented towards improving HOTS abilities. To respond to these problems, teachers should strengthen high-level reasoning teaching patterns or High Order Thinking Skills in learning mathematics.

In Bloom's Taxonomy learning rules and principles, skills that involve analysis, evaluation, and knowledge creation are considered to have a higher order so that they require different learning and teaching models and methods from learning facts, concepts and procedures.

The test results on 25 Senior High School students in Parepare showed that: (1) 11 (44%) students had completed their study, 14 (56%) students did not complete the Minimum Completeness Criteria (MCC) standard, which was 75%; (2) If 54% of students did not complete, then classically it wasstated incomplete. This is because the classical standard of completion is if there are 85% of students who complete their studies according to the Minimum Completeness Criteria (MCC) standard. Thus, this data proves that the HOTS ability of Senior High School mathematics students in Parepare is still relatively low. Another fact obtained through interviews showed that most of the mathematics teachers in Parepare still carried out the process of learning mathematics without implementing learning oriented towards improving students' HOTS abilities. Therefore, students were not familiar with HOTS questions.

Based on these problems above, teachers must innovate, both in terms of strategy, media and evaluation in learning mathematics. HOTS cannot be achieved through a direct learning process, but student-centered learning is needed such as project-based learning discovery, problem-based learning and metacognitive skills-based mathematics learning [13], [14], [15], [16]. Furthermore, Mas'ud stated that a learning model that optimizes metacognitive skills can improve problem solving skills. Problem solving skills help students to develop their Higher Order Thinking Skills. [17]

Higher Order Thinking Skills are thinking at a higher level such as remembering facts or retelling something heard to others [18]. HOTS has some characteristics, including (a) non-algorithmic, which means that the action steps cannot be fully determined in advance; (b) complex, which means that the steps cannot be seen/guessed directly from a certain point of view; (c) generating multiple solutions; (d) involving differences of opinion and interpretation; (e) involving the application of multiple criteria; (f) involving uncertainty; (g) demanding independence in the thought process; (h) involving impressive meaning; and (i) requiring hard work (effortfull) [19].

When associated with thinking skills, Higher Order Thinking Skills are the ability to think critically, creatively, analytically in solving problems[20]. When associated with cognitive processes in Bloom's taxonomy, the term Higher Order Thinking Skills are often contrasted with the term LOTS (Lower Order Thinking Skills) [21][12]. Critical thinking can be interpreted as an effort to process and assess information on a situation or problem based on strong and logical evidence. While the ability to think creatively is characterized by the ability to create. The following are the indicators used to measure students' HOTS.

Table 1. Description of HOTS Indicators

Aspect	Indicator	Sub-Indicator
Critical thinking	Analyzing (C4)	Differentiating Organizing Attributing
	Evaluating (C5)	Checking Critiquing
Creative Thinking	Creating (C6)	Formulating Planning Producing

From the knowledge dimension point of view, HOTS questions generally do not only measure the factual, conceptual, or procedural dimensions, but also measure the metacognitive dimensions. The metacognitive dimension describes the ability to connect several different concepts, interpret, problem-solving, choose problem-solving strategies, discovery new methods, reasoning, and make the right decisions, as well as the highest level of the knowledge dimension, namely metacognitive knowledge [17], [22] Metacognitive is the ability of students to monitor (supervise), plan and evaluate a learning process.

Metacognitive is a unique thinking ability carried out independently, differs between individuals and has an important role in the thought process of each individual [23]. Furthermore, metacognitive skills refer to prediction skills, planning skills, monitoring skills, and evaluation skills. In conclusion, metacognitive skills are students' thinking skills to realize their own thinking processes related to prediction, planning, monitoring, and evaluation skills in learning.

Metacognitive is closely related to the development of HOTS abilities. If every learning activity is carried out with reference to metacognitive, then the optimal HOTS ability of students is undoubtedly easy to achieve. Someone who can succeed in solving-problems is also influenced by his metacognitive activity. Itgo and Mas'ud mentioned that the metacognitive approach in the learning process is able to improve students' High Order Thinking Skills. [24], [17] This is possible because in the process of solving mathematical problems, there is an interaction between cognitive and metacognitive activities. Cognitive activity is limited to "how information is processed to achieve goals", while metacognitive activity emphasizes "a person's awareness of what he/she is doing". This illustrates that the role of metacognitive is very important in learning to achieve the expected learning objectives, namely the development of students' mathematical HOTS abilities.

The HOTS classification for each dimension in the revised Bloom's Taxonomy can be seen in Table 2.

Table 2. Metacognitive, HOTS and Revised Bloom's Taxonomy

		Dimensions of Cognitive Process					
		Remembering	***Understanding***	***Applying***	***Analysing***	***Evaluating***	***Creating***
Knowledge Dimension	Factual						
	Conceptual						
	Procedural				Higher Order Thinking Skills		
	Metacognitive						

II. Methods

This study was quantitative research with an experimental approach. The research design used was a one group pre-test and post-test design with the following pattern.

O_1	**X**	**O_2**

[25]

Fig. 1. Research Design

Description:
O1 : Initial test of Higher Order Thinking Skills
X : Metacognitive-based mathematics learning
O2 : Final test of Higher Order Thinking Skills

The population of this study was all students of class XI of Social Sciences at Senior High School 1 Parepare in the odd semester of the 2021/2022 academic year, consisting of 139 students from four classes. The sample was one class with 30 students obtained by using a probability sampling technique, namely Cluster Random Sampling. The data was obtained by using test and interview techniques. The data collection instrument used was in the form of a HOTS test sheet before the learning process (pre-test) and after the learning process (post-test). The test used to obtain data on students' Higher Order Thinking Skills was in the form of essay questions containing HOTS indicators, namely: analysing (C4), evaluating (C5) and creating (C6). The test in this study was conducted twice, namely the initial test and the final test. The initial test was conducted to find out how the students' Higher Order Thinking Skills were before applying metacognitive-based mathematics learning. While the final test was conducted to find out how the students' Higher Order Thinking Skills were after applying metacognitive-based mathematics learning. The analysis was carried out on the scores obtained by students from the HOTS mathematics ability test given at the beginning and at the end of the lesson using the rubric as shown in Table 3.

Table 3. Assessment Rubric of HOTS Ability

Indicator	Score	Assessment Aspect
Analyzing Level	3	Students can determine the description of the problem and connect it to the required quadratic function formula
	2	Students can determine the required quadratic function formula but do not include a description of the problem in the question
	1	Students can determine the description of the problem in the question but cannot connect it to the required quadratic function formula
	0	Students cannot determine the description of the problem in the question and cannot connect it to the required quadratic function formula
Evaluating Level	3	Students can carefully select all stages of problem-solving correctly
	2	Students can carefully select all stages of problem-solving but with inaccurate answers
	1	Students select most of the stages of problem-solving
	0	Students are not able to select all stages of problem-solving
Creating Level	3	Students are able to find the results of solving problems and perfecting them by including the final solution correctly
	2	Students are able to find the results of solving problems and perfecting them by including the final solution but with an incorrect answers
	1	Students are able to find the results of solving problems but not perfecting them by including the last solution correctly
	0	Students are not able to find the results of solving problems and do not perfect them by including the final solution correctly

$$\text{Final Score} = \frac{\text{Gain Score}}{\text{Total Score}} \times \text{Ideal score } (100)$$

After scoring the students' HOTS ability, then the categorization was used to determine the level of HOTS ability. The categories used to determine students' HOTS abilities were made on a scale (very high, high, medium, low, and very low) according to Riduwanas follows.[26]

Table 4. The categorization of HOTS by Riduan

Score Interval	Category
81-100	Very High
61-80	High
41-60	Medium
21-40	Low
0-20	Very Low

The HOTS ability test score data was analyzed using descriptive and inferential analysis. Descriptive analysis was used to describe students' Higher Order Thinking Skills in the form of pre-test and post-test results. Meanwhile, inferential analysis was used to test the researcher's hypothesis regarding a significant increase in students' HOTS abilities before and after metacognitive-based mathematics learning using the normalized gain t-test at a significance level of a = 5%. For the purposes of testing the hypothesis, the formulation of the hypothesis is written as follows:

$$H_o : \mu_B = 0 \text{ versus } H_1 : \mu_B > 0$$

Description $\mu_B = \mu_2 - \mu_1$
μ_2 = Average post-test results
μ_1 = Average pre-test results.

III. Result and Discussion

The results of questionnaire from 34 Senior High School teachers in Parepare City showed that 64.70% stated that the learning model used did not support students' Higher Order Thinking Skills. Meanwhile, 35.30% stated that the learning model used had supported students' Higher Order Thinking Skills. However, when viewed from the teacher's difficulty in teaching materials that could improve students' HOTS abilities, the researcher found that there were 50% of teachers experiencing difficulties, and 50% not experiencing difficulties.

The results of the HOTS ability data analysis before treatment were 12 of 30 (40%) students who achieved the completeness of learning with an average gain of 37 and a standard deviation of 18.27 from the ideal score of 100. If confirmed by categorization according to Riduan, the average ability (Table 4) was in the low category [26]. Furthermore, the results of the HOTS ability data analysis after treatment were 26 out of 30 (86.67%) students who achieved the completeness of learning. The criteria for student learning completeness individually if they reached a Minimum Completeness Criteria (MCC) score equal to 75. Meanwhile, it was said to be classically complete if there were at least 85% of students who have completed their study. Therefore, based on the results of the analysis, the results of the study (post-test results) have reached classical completeness. The average post-test result of the students' mathematical HOTS ability was 74.83, with a standard deviation of 19.84. If the average HOTS ability was consulted to Table 4, the HOTS ability was in the high category.

The following is an overview of learning completeness and the average learning outcomes before and after metacognitive-based learning carried out.

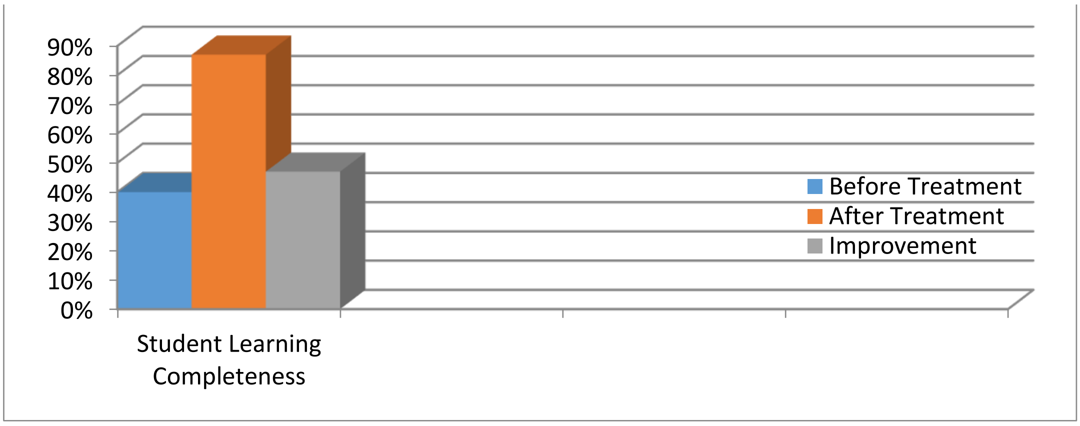

Fig. 2. Improvement of students' learning completeness before and after metacognitive-based learning

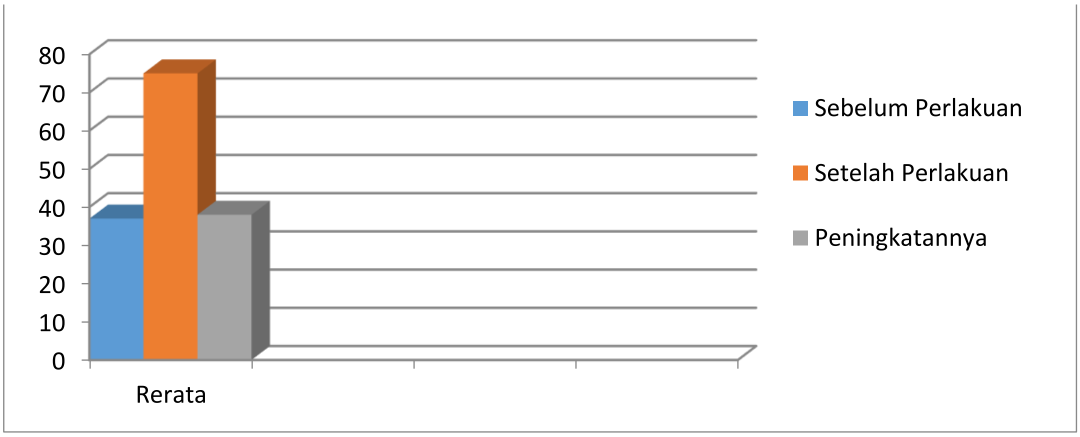

Fig. 3. Improvement of HOTS ability before and after metacognitive-based learning

If the HOTS ability score of the post-test results is categorized based on Table 4, the results are summarized in Table 5.

Table 5. The categorization of HOTS ability score post-test results

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Score Interval	f	(%)	Category
81-100	17	56.67	Very high
61-80	4	13.33	High
41-60	5	16.67	Medium
21-40	4	13.33	Low
0-20	-	-	Very low
Total	30	100	

The data on the percentage of achievement of each HOTS ability indicators in students is presented in Table 6.

Table 6. The percentage of achievement of HOTS ability indicators

Indicator	(%)	Category
Analyzing (C4)	86.1	Very Good
Evaluating (C5)	74.4	Good
Creating (C6)	63.8	Good
Average	74.7	Good

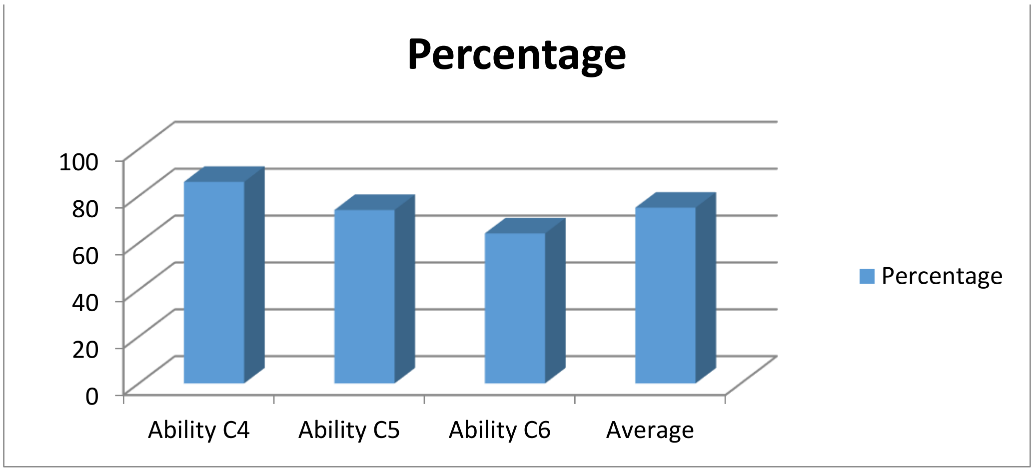


Fig. 4. The percentage of achievement of HOTS ability indicators after meta-cognitive-based learning

Furthermore, the results of the inferential analysis with the normalized gain T-test showed that 0.000 < 0.005 (p < a). Based on these criteria, H0 is rejected and Ha, or the researcher's hypothesis is accepted. This means that there is a significant increase in mathematical HOTS abilities before and after being given treatment at a significance level of a = 5%. Therefore, it can be concluded that the implementation of metacognitive-based mathematics learning can improve students' mathematical HOTS abilities.

DISCUSSION

A. Achievement of Research Objectives

The research objective of this study is to increase students' Higher Order Thinking Skills through metacognitive-based mathematics learning.

In this study, the students' HOTS abilities are analyzed in terms of their cognitive processes. According to the revised edition of Bloom's Taxonomy, students' HOTS abilities are at the levels of Analysing (C4), Evaluating (C5) and Creating (C6) [12],[27]. Related to this case, the results of the study show that the ability of C5 is included in the very good category and moderate, the ability of C5 is included in the good category, and the ability of C6 is included in the good category. The HOTS ability can be described as shown in Figure 5.

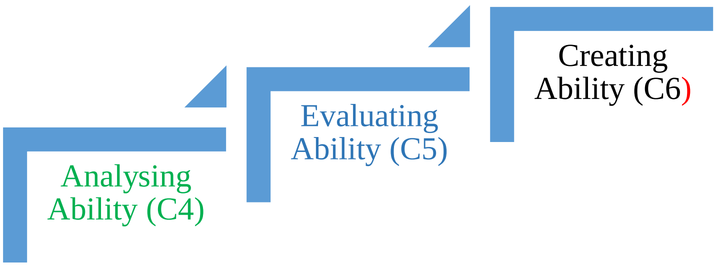
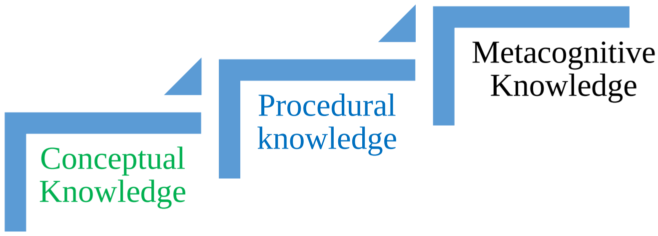


Fig. 5. HOTS Ability Ladder based on Cognitive Process Dimensions

Based on Figure 5, the students learn as if going up a ladder, the lower ladder is reached first and then the higher ladder is reached. Logically, these abilities are hierarchical, which means that these abilities can be obtained if the previous abilities are understood. In addition, the results of the study also follow the rules of cognitive ladder according to Taxonomy Bloom. This is because the ability of C5 and C6 learning outcomes is good because it is supported by the very good ability of C4. The same situation when viewed from the dimension of knowledge.



Metacognitive knowledge-based learning is learning carried out by linking strategies, and knowledge related to tasks and knowledge with self/students. If learning is processed through integration based on cognitive dimensions C4, C5 and C6 with knowledge dimensions, especially metacognitive knowledge, then the cognitive process dimension is seen as a verb that is often formulated in operational verbs whose achievement can be measured. The dimension of knowledge is seen as a noun that functions as an object of the process carried out. By combining or integrating the two dimensions, it is easy to formulate learning achievement indicators, causing the goal of this research to be achieved, namely metacognitive-based mathematics learning can improve students' HOTS thinking skills.

B. *The Obstacles Found in this Study*

The obtacles found in this study are related to the hierarchical dimension of knowledge, in which metacognitive knowledge has the highest level. Thus, metacognitive knowledge is supported by procedural knowledge and conceptual knowledge. In terms of the research object in this case, students still do not fully understand the difference between conceptual knowledge and procedural knowledge. In addition, understanding is still weak about processing knowledge related to oneself.

On the other hand, teachers are still confused about choosing a model that can support metacognitive-based learning. They also lack knowledge in designing learning, such as making teaching materials, students' worksheets and learning instruments.

IV. Conclusion

This study can be concluded that the implementation of metacognitive-based mathematics learning can improve students' mathematical HOTS (Higher Order Thinking Skills) ability at a significant level of a = 5%.

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