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Fluctuations in Students' Higher Order Mathematical Thinking Ability Solving HOT Problems With Metacognitive Strategies

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Abstract

This study wanted to examine the development and barriers of students' Higher-Order-Thinking skills through metacognitive strategies. The purpose of this study was to determine the tendency of the development of students' higher-order thinking skills and the difficulties encountered during learning. The research instruments were student on task activity sheets, student activity observation sheets, formative tests and learning outcomes tests. The sample subjects were 66 students of class X SMAN 3 and SMAN 5 Banda Aceh. The results showed that the tendency of the development of higher order thinking skills (HOTS) of students in formative exercises (T1 and T2) moved up and the Learning Outcome Test was in good category, an average of 72%.. The difficulties faced by students are dominant in the indicators of creation and evaluation. The implication of this study is that learning mathematics with higher order thinking with metacognitive strategies has been able to improve the HOT ability of class X high school students.

Volume 1, No.3, November 2021, Pages : 1-18

Volume 1, No.3, November 2021, Pages: 1-18
ISSN 2775-4928 (Print) ISSN 2775-8893 (Online)
http://internationaljournal.unigha.ac.id/

Introduction

To support the Industrial Era 4.0 paradigm, there are several competencies that must be possessed in facing the 21st century, namely the ability to think critically and solve problems, communicate and work together, creative abilities and innovation.(Mursidik, Samsiyah, & Rudyanto, 2015). Based on the demands of the industrial world and the preparation of human resources in the 21st century above, students need to be equipped with higher order thinking skills (HOTS), becauseHigher order thinking skills are the ability to solve problems, think critically and creatively, argue, make decisions, where this ability is one of the important competencies in the modern world so that it is mandatory for every student.

Higher order thinking skills are thinking activities that involve higher hierarchical cognitive levels from Blom's Taxonomy, namely analysis, evaluation, and creation. This is in line with the thought(Usmaedi, 2017)that the domains of cognitive processes that are included in higher order thinking skills are the domains of analysis (analyze), evaluation (evaluate), and create (create). On the other hand,(Luthfiana, 2013) states that higher order thinking skills include thinkingcritical, logical, reflective, metacognitive, and creative. This ability is activated when the individual faces an unusual problem, uncertainty, question, or dilemma. Therefore,(Yanti, 2015)said that students should be active in learning. If a student is active in learning, then he is able to analyze, evaluate, and create, and if students in learning tend to be passive then he is a recipient of information.

This shows that learning using higher order thinking skills is very urgent because it is more concerned with the process, so that the class is more lively, students are more active and achievement will increase. One of the easiest ways to encourage higher order thinking is to engage students through metacognitive questions, becauseHigher order thinking questions (HOT) are used to measure the ability to: (1) transfer one concept to another, (2) process and apply information, (3) find connections from different kinds of information, (4) use information to solve problems. problems, and (5) critically examine ideas and information (Usmaedi, 2017).

Regarding HOT and the learning process, as described above, teachers are required to improve their teaching skills because teachers are the main key in the success of education

Volume 1, No.3, November 2021, Pages: 1-18
ISSN 2775-4928 (Print) ISSN 2775-8893 (Online)
http://internationaljournal.unigha.ac.id/

reform.Paradigm change in the Industrial Age 4.0will not have a positive impact on the progress of mathematics education if the hard skills and teaching methods used by teachers have not changed. Therefore, teachers need to have several competencies, including academic competence (hard skills), namely the ability to master the material and learning methods.

This study wants to know the fluctuations in students' abilities in solving HOT questions using metacognitive strategies assisted by the improve method. The IMPROVE method is believed to be able to develop students' higher order thinking skills through metacognitive questions and interactions with peers. IMPROVE method according to(Li, 2013), an acronym for Introducting new concept, Metacognitive question, Practicing, Reviewing and reducing difficulties, Obtaining mastery, Verification, and Enrichment. This means that there are seven interrelated components, namely recognizing new concepts, metacognitive questions, exercises, reviewing and reducing difficulties, obtaining mastery, verification and enrichment. In short, there are only three interrelated components, namely strategies and cognitive processes, interaction with peer teams and systematic activities of feedback-improvement-enrichment.

Abdullah, Abidin, & Ali, (2015)defining higher order thinking skills (HOTS) is divided into three categories, (1) transfer, which requires students to understand and be able to use what they have learned, (2) critical thinking and (3) problem solving. Furthermore, Widana (2017) suggests higher-order thinking skills including problem solving skills, critical and creative thinking skills, argumentative abilities and decision-making abilities. Accordingly, the last three aspects in Bloom's revised Taxonomy, namely (1) analysis, (2) evaluation, and (3) creation, are high-level thinking that has many characteristics that distinguish one another. Analyzing, for example, is associated with the cognitive processes of linking, organizing, integrating and validating. Evaluating includes examining, critiquing, hypothesize and experiment. Creation includes produce, design and manufacture.

Based on the description above, in this study to measure the ability of HOTS,aspresented in table 1 below.

Table 1. Cognitive Aspects and indicators of higher order thinking skills

Volume 1, No.3, November 2021, Pages: 1-18
ISSN 2775-4928 (Print) ISSN 2775-8893 (Online)
http://internationaljournal.unigha.ac.id/

Cognitive Aspect	Indicator
Analysis (C4)	Analyze: Identify the problem Structuring the problem into smaller parts Recognizing patterns or relationships of complex problems Formulating questions and manipulating algebraic forms
Synthesis (C5)	Evaluate: Gather some guesswork solutions to the problem Provide an assessment of the proposed solution using suitable criteria Accept or reject a proposed solution Assess problem information or statements provided
Evaluation (6)	Create/create: Understanding pictures for information on a solution Making connections between problem information and previous concepts of completion and solutions Designing a way to solve the problem Elaborating a solution and performing calculations

Source: (Luthfiana, 2013)

Taking into account the criteria for higher order thinking skills (HOTS) above, the student's ability to completeHOT questions are expected to equip students to have a number of competencies needed in the 21st century (21st century skills). according toSeman, Yusoff, & Embong (2017) some of them are (1) critical thinking and problem solving skills, (2) communication and collaboration skills, (3) creation and innovation skills, and (4) information skills and media literacy.

Volume 1, No.3, November 2021, Pages: 1-18
ISSN 2775-4928 (Print) ISSN 2775-8893 (Online)
http://internationaljournal.unigha.ac.id/

Pratama & Retnawati (2018) also stated that, if students are equipped with higher-order thinking skills, there will be some changes in their way of thinking, namely: (1) organize learned knowledge into long-term memory. This organization increases the retention of information that is quite long compared to if it is stored in short-term memory which is a characteristic of lower-order thinking. For example, students who learn by rote tend to forget quickly than students who learn by problem-solving processes will push this knowledge into long-term memory, making it easy to access and use in various situations that tend to change, (2) develop attitudes and creative ways of thinking to get out. of life's increasingly complex problems.

Fleming & Lau (2014)suggested that to improve students' thinking skills, they could solve problems through group study given metacognitive questions. Metacognition questions are the main key that the teacher must present in this method. This question aims to improve the ability to understand, analyze, and self-regulate the application of problem solving, and to make connections between prior knowledge and new knowledge.

Theystates, "The metacognitive questions were constructed and arranged to follow the 4-stage model of the problem-solving process: orientation and problem identification, organization, execution, and evaluation". That is, metacognition questions are built based on 4 stages of the problem solving process, namely orientation and problem identification, organization, implementation and evaluation. Through this metacognitive question, it is hoped that it will help students in solving mathematical problems. In this connection,Rhodes (2019) states "metacognition is our knowledge, awareness, and control of our cognitive process".

MenmassageFrith (2012), metacognition as thinking about one's own thinking is an interaction between three important aspects, namely: knowledge of one's own thinking process, self-control or self-regulation, and belief and intuition. This interaction is very important because with the knowledge possessed about cognitive processes, it can help to organize things around and select strategies to improve further cognitive abilities. For example, when we realize that we often forget or do not understand a mathematical concept and we realize that the concept is difficult compared to other concepts, so we need to choose a certain

Volume 1, No.3, November 2021, Pages: 1-18
ISSN 2775-4928 (Print) ISSN 2775-8893 (Online)
http://internationaljournal.unigha.ac.id/

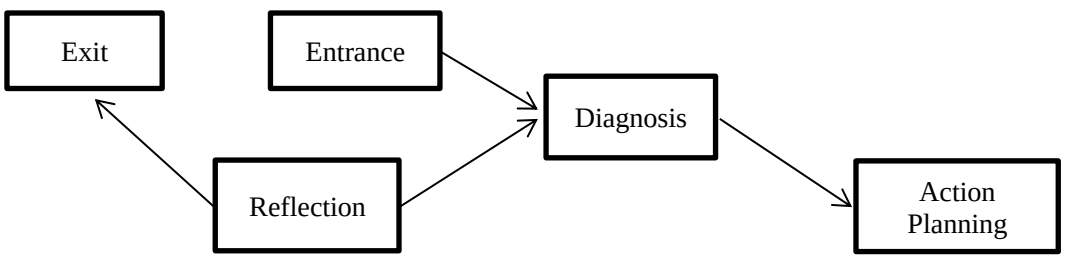
way, for example by underlining the meaning and concept that can help us understand and remember which we forgot earlier.

Jiang, Ma, & Gao (2016)mentions metacognitive questions include, (1) comprehension questions encourage students to read questions, describe a concept in their own words, and try to understand the meaning of a concept. Examples of understanding questions, namely: What is this whole problem about? (2) connection questions can encourage students to see the similarities and differences of a concept/problem. As for examples of connection questions, namely: What are the similarities and differences between the current problem and the problems that have been solved previously? (3) firstStrategy questions encourage students to consider suitable strategies in solving a given problem and include reasons for choosing the strategy. As for examples of strategy questions, namely: What strategies, tactics or principles are suitable to solve the problem? (4) reflection questions are questions that encourage students to ask themselves about the completion process. Examples of reflection questions include: "what am I doing?"

Method

This study was designed qualitatively, with the aim of revealing developmental fluctuations and difficulties experienced by students in solving HOT questions with metacognitive strategies. The selection of sample subjects for the model trial was carried out by purposive sampling, namely the students of class X at SMAN 3 and SMAN 5 Banda Aceh totaled 63 people.

This study uses a qualitative design in the form of a cycle, according toFletcher (2015) as follows:



Volume 1, No.3, November 2021, Pages: 1-18
ISSN 2775-4928 (Print) ISSN 2775-8893 (Online)
http://internationaljournal.unigha.ac.id/

Figure 1. Qualitative research design

*Entrance*In this study, students' HOTS were low, while the diagnosis was problem identification through an analysis of teacher needs, school curriculum and student characteristics. Problem identification was assessed through a questionnaire to high school teachers. After knowing the symptoms and the causative factors, the researcher then developed an action plan to overcome the low HOTS. The next stage is to design a HOTS-based learning model and the evaluation tool is followed by validation by experts. The valid learning design is then applied in the classroom using a metacognitive strategy (Intervention/action taking). After the learning was carried out, the researcher then conducted an evaluation. Evaluation is carried out thoroughly, not only giving THB about HOTS questions, besides that, they also make observations on learning while applying the method. After the evaluation is complete, then do a reflection by looking at the advantages and disadvantages of metacognitive strategies in overcoming the low HOTS of students. If the results of the reflection show that the student's ability is still low, then the treatment is continued again following the previous steps. The cycle ends if the results of the last reflection show that the student's HOTS has been resolved (Exit).

The procedure for carrying out the research is to carry out treatment in class using metacognitive strategies for three meetings with the material "System of Linear Equations with Three Variables". During the treatment, the students worked on the Discussion Worksheets, completed the practice questions and worked on the Assignment Worksheets at home for those who scored $x > 75$. At the end of the meeting students were given a final test (THB). Fluctuations in students' cognitive development in solving HOTS questions are seen based on the tendency of increasing formative test scores for three meetings and THB, while students' difficulties are seen based on HOTS indicators. Data collection tools use tests and non-tests, such as formative tests (practice questions) and final tests, while to collect qualitative data using questionnaires and observation sheets.

Volume 1, No.3, November 2021, Pages: 1-18
ISSN 2775-4928 (Print) ISSN 2775-8893 (Online)
http://internationaljournal.unigha.ac.id/

The data collected is determined by the average calculation and then analyzed qualitatively based on practical and effective product quality indicators. Abdullah et al., (2015)mention, a quality product. if it fulfills six indicators, namely (1) the average student on task activity (discussion) is at least 90%, (2) the average student activity is at least 90%, (3) the level of conformity of student activity is observed with the expected student activity of at least 80% , (4) there is a tendency to increase formative test scores and THB scores, (5) more than 50% of students give positive responses, (6) teachers give positive responses to the use of this product.

Research result

In this article, the data from the test results in schools analyzed consisted of (1) observation sheets on the implementation of learning devices, (2) observations of student activities, (3) practice questions (formative tests) and THB.

Observation data on the implementation of learning based on the lesson plan was carried out by two observers consisting of a teacher and a colleague. The average observer's assessment of student activities is presented in table 2 below.

Table 2. Analysis of learning implementation observation

Aspect	Criteria	high school 3 5				Average	
		Meeting				Per Criteria	Per Aspect
		I	II	I	II		
1	introduction	4	4	5	5	4.50	4.58
	Core activities	5	4	5	4	4.50	
	Closing	5	5	4	5	4.75	
2	Atmosphere	5	5	5	5	5.00	5.00
Total average							**4.80**

Volume 1, No.3, November 2021, Pages: 1-18
ISSN 2775-4928 (Print) ISSN 2775-8893 (Online)
http://internationaljournal.unigha.ac.id/

Data Observation of student activities, carried out by two observers who assess student activities when learning takes place. Data were assessed using descriptive percentage analysis. The results are presented in table 3 below.

Table 3. Student activity observation analysis

Meeting	Rating Percentage	
	high school 3	5
I	88	86
II	92	94
Average	**90**	**90**

Based on the analysis of observations, the teacher's activities and the atmosphere of learning mathematics in higher order thinking with metacognitive strategies showed good criteria. Overall, the average student activity in the two schools in the two meetings has been going very well.

Analysis of Formative Test scores and THB, namely: this formative test/practice question consists of two questions and is given to students at the end of each meeting to be done by students individually according to the stages of metacognitive questions. The formative test developed consists of practice questions 1 (T1) and practice questions 2 (T2), as well as THB. The purpose of the THB is to see students' higher-order thinking skills about the material that has been studied as a whole and the obstacles they face. The following are the results of the analysis of the T1, T2, and THB tests, presented in table 4 below.

Table 4. The results of the analysis of formative tests and THB

SCORE	SMAN 3 (n = 33)			SMAN 5 (n = 30)		
	T1	T2	THB	T1	T2	THB
Average	74.8	77.3	73.2	72.8	76.3	71.2

Volume 1, No.3, November 2021, Pages: 1-18
ISSN 2775-4928 (Print) ISSN 2775-8893 (Online)
http://internationaljournal.unigha.ac.id/

Standard deviation	9.3	11.2

From the presentation of table 4, it can be seen that there is a tendency to increase the formative score of each practice question (T1 and T2). Next, we will describe students' HOTS abilities on THB based on indicators.Overall from table 4, SMAN 3 shows that the average test score of student learning outcomes reaches 73.2 which is in good classification, and the average student learning completeness reaches 57.6%. The number of students who completed 19 people, the number of students who did not complete there were 14 people with the highest score of 100, and the lowest score of 55.

Analysis of the results of THB's answers to high-level thinking based on the indicators. Aspect of Analysis (C4), with analyzing indicators is the ability to analyze valid arguments, recognize mistakes, and make conclusions based on strong evidence. In the THB questions given, questions numbered 1 to 4 are questions of higher order thinking skills with analyzing indicators, question number 1 obtained an average of 33.3%, which means that only 11 students can analyze this question, question number 2 is obtained an average of 100% means that all students are able to analyze the question, for question number 3 an average of 57.6% is obtained, this means 16 students can analyze this question, and for question number 4 an average of 81 is obtained,

Aspects of synthesis (C5) with evaluating indicators, namely evaluating the information collected. In the learning outcomes test (THB) given, questions numbered 1 to 4 are questions of higher order thinking skills (HOTS) with evaluation indicators, the average indicator for evaluating question number 1 is 21.2%, and only 7 students who can evaluate the question, question number 2 obtained an average of 87.9% and there were 29 students able to evaluate the question, question number 3 obtained an average of 48.5% and 16 students were able to evaluate the question, and for question no. 4 obtained an average of 81.8% and there are 27 students who can evaluate the questions.

Volume 1, No.3, November 2021, Pages: 1-18
ISSN 2775-4928 (Print) ISSN 2775-8893 (Online)
http://internationaljournal.unigha.ac.id/

Evaluation aspect (C6) with indicators of creation, namely the ability to find solutions to new problems, create new things. In the learning outcomes test (THB) questions given, questions no. 1 to 4 are questions of higher order thinking skills (HOTS) with indicators of creating, the average indicator of creating question number 1 is 30.3%, and only 10 students who can write down the completion of the answer correctly, question number 2 obtained an average of 69.7% and there were 23 students able to write the completion of the answer correctly, question number 3 obtained an average of 42.4% and only 14 students were able to write the solution answer correctly, and for question number 4 obtained an average of 75.8% and there are 25 students who can write down the completion of the answer correctly.

Analysis of the results of THB's answers to higher order thinking skills based on the indicators can be presented through the following bar chart.

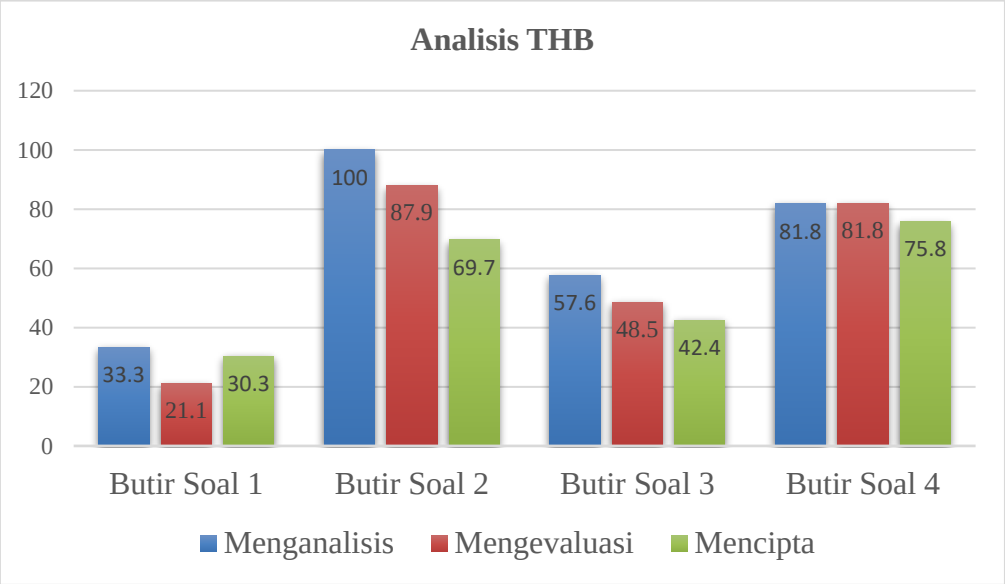


Figure 2. THB answer analysis diagram for SMAN 3 students

Next, we analyze the answers of THB students of SMAN 5, overall from table 4 shows that the average THB score of students reaches 71.2 which is in good classification, and the average student learning completeness reaches 36.7%. The number of students who completed 11 people, the number of students who did not complete there were 19 people with the highest score of 95, and the lowest score of 55.

Volume 1, No.3, November 2021, Pages: 1-18
ISSN 2775-4928 (Print) ISSN 2775-8893 (Online)
http://internationaljournal.unigha.ac.id/

Analysis of the results of THB's answers to high-level thinking based on the indicators. The first is the analysis aspect (C4) with analyzing indicators, namely the ability to analyze valid arguments, recognize mistakes and make conclusions based on strong evidence. In the THB questions given, questions numbered 1 to 4 are HOTS questions with analyzing indicators, the average indicator for analyzing question number 1 is 30%, and only 9 students can analyze questions, question number 2 is obtained an average of 90 % and there were 27 students able to analyze the question, for question number 3 an average of 86.7% was obtained and 26 students were able to analyze the question, and for question number 4 an average of 56.7% was obtained and there were 17 students who could analyze this matter.

Both aspects of Synthesis (C5) with evaluating indicators, namely the ability to evaluate the information collected. In the THB questions given, from questions number 1 to 4 are HOTS questions, the average indicator for evaluating question number 1 is 16.7%, and only 5 students can evaluate questions, question number 2 is obtained an average of 83 ,3% and there are 25 students who are able to evaluate the question, question number 3 obtained an average of 67% and 20 students who can evaluate the question, and for question number 4 obtained an average of 23.3% and there are 7 students who can evaluate questions.

The three evaluation aspects (C6) with indicators of creation, namely the ability to find solutions to new problems, create new things. In the THB questions given, from questions number 1 to 4 are HOTS questions with indicators of creating, the average indicator for creating question number 1 is 13.3%, and only 4 students can write down the correct answer, question number 2 obtained an average of 80% and there were 24 students were able to write the correct answer completion, for question number 3 obtained an average of 47% and only 14 students were able to write down the answer correctly, and for question number 4 obtained an average of 16 ,7% and there are 5 students who can write down the answer correctly.

The analysis of the results of the HOTS test answers based on the indicators can be presented through a bar chart, as shown in Figure 3 below.

Volume 1, No.3, November 2021, Pages: 1-18
ISSN 2775-4928 (Print) ISSN 2775-8893 (Online)
http://internationaljournal.unigha.ac.id/

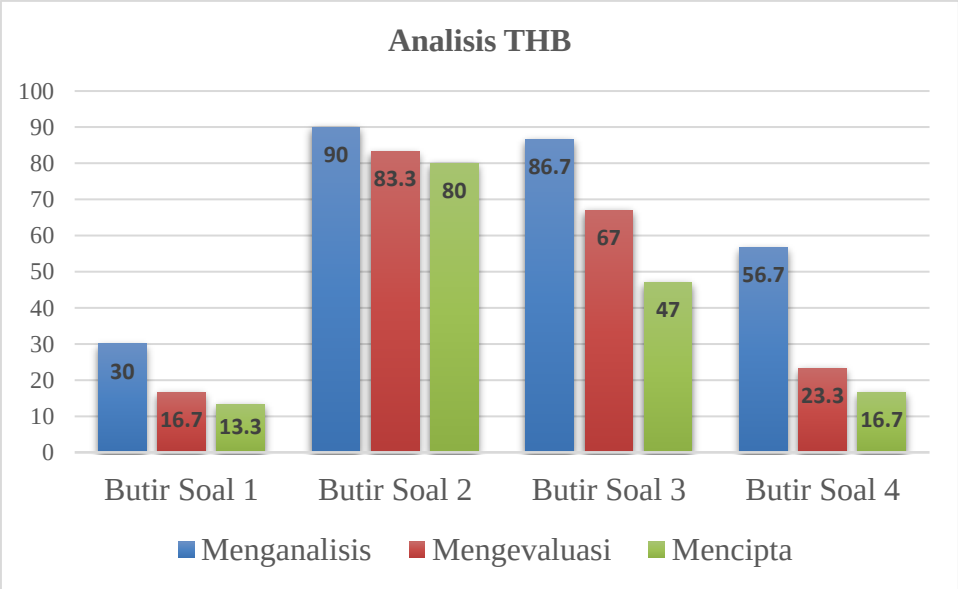


Figure 3. THB answer analysis diagram of SMAN 5 students

Discussion

Metacognitive Strategy indevelop on the basis of constructivism theory that emphasizes the active role of students in finding knowledge and metacognition theory that prioritizes the process of student self-reflection in determining a problem, and determines strategies in problem solving, analyzes the effectiveness of the strategies used and in the end is able to change the strategy if it is felt that the strategy is the right one. used incorrectly.

PaAt the beginning of the application of learning with cognitive strategies, students still feel confused, because they are not used to the process of self-reflection in order to solve problems, so teachers need to direct students to understand metacognitive questions properly. This can be seen when students answer comprehension questions. Students have not been able to answer understanding questions correctly. Students answer these questions only based on fragments of words from the editor of the question, not understanding the problem. Similar to students' answers to connection questions, students have not been able to answer these questions correctly. This can be seen from the results of students' answers based only on fragments of words from the editor of the question, not focusing on the differences and

Volume 1, No.3, November 2021, Pages: 1-18
ISSN 2775-4928 (Print) ISSN 2775-8893 (Online)
http://internationaljournal.unigha.ac.id/

similarities between the current problem and previous problems that have been solved. Meanwhile, on the results of students' answers to strategic questions, students have been able to write down the strategies that will be used to solve the problem, although in writing the strategies to be used are not appropriate and do not include the reasons, generally the completion of exercise 1 is still not correct. or not in accordance with the answer key. However, students have consistently solved problems based on the planned strategy. In general, the completion of exercise 1 is still not correct or not in accordance with the answer key. However, students have consistently solved problems based on the planned strategy. In general, the completion of exercise 1 is still not correct or not in accordance with the answer key. However, students have consistently solved problems based on the planned strategy.

PaIn the next few meetings, it was seen that there was student development in

meanswer metacognitive questions. Based on the results of students' answers to comprehension questions, it appears that students are able to understand the problem, besides that students are also able to explain the problem in their own words, even though the answer is incomplete. Similar to the results of students' answers to connection questions, students were able to explain the difference between the current problem and the previous problem correctly, even though it was less precise in answering the similarities between the two problems. This shows that students only focus on the differences between the current problem and previous problems that have been solved, but have not focused on seeing the similarities between the two problems. While the results of students' answers to strategic questions (strategic questions), students are able to explain the strategy that will be used to solve the problem, although it is not complete. Even in answering the problem solving, students have done the calculations correctly according to the answer key, but in writing the steps for solving it have not been systematic.

The metacognitive strategy of appreciatingencourage students to study in heterogeneous groups consisting of students with high, medium and low abilities. All group members are required to help each other if there are friends in their group who have difficulty, so that students' difficulties in understanding problems both at the introducing new concepts stage and

Volume 1, No.3, November 2021, Pages: 1-18
ISSN 2775-4928 (Print) ISSN 2775-8893 (Online)
http://internationaljournal.unigha.ac.id/

at the practicing stage can be resolved. In addition, when they are faced with difficult math problems to solve, they do not hesitate to ask the teacher or their group mates.

PaAt the end of the meeting the teacher gave a formative test/practice to determine students' understanding. Students who get test results 75 are given a follow-up task, namely doing the LKT (Assignment Worksheet) enrichment questions at home and asking them to collect the enrichment questions at the next meeting. Students who get quiz results <75 are given corrective activities that are carried out after the learning process is complete with mentoring by the teacher.

TeThe final THB is given after the second meeting is over, after the formative test is given twice the learning takes place. The following discusses the obstacles experienced by students on THB in solving HOT questions based on the indicators.

Analyze the problem, indiProblem analysis is a measure of students' ability to identify problems, structure problems into smaller parts, recognize patterns or relationships from complex problems, formulate questions and manipulate algebraic forms. In the results of student answers, it can be seen that in general students have been able to identify problems and structure problems into smaller parts. However, there are still some students who cannot find the patterns and relationships contained in the questions to solve the problem. In addition, some students have difficulty in manipulating algebraic forms.

Evaluate, indiEvaluation is to measure students' abilities, collect several possible solutions to the problem, provide an assessment of the solution plan using suitable criteria, accept or reject a solution plan, and assess the problem information or statements given. In general, students have been able to collect several possible solutions to the problem, but few are able to provide an assessment of the solution plan using suitable criteria, in addition to having difficulty understanding the information or statements given and solving the equations they have made.

Create, indiThe creative function is to measure students' ability to understand images for information on a solution, make links between problem information and previous solutions and solutions, design a way to solve problems, elaborate a solution and perform calculations. In

Volume 1, No.3, November 2021, Pages: 1-18
ISSN 2775-4928 (Print) ISSN 2775-8893 (Online)
http://internationaljournal.unigha.ac.id/

general, students are still not able to understand images for information on a solution, present images in the form of symbols, but have been able to design a way to solve problems, and few students are able to make connections between problem information and previous solutions and solutions concepts and due to inaccuracies still exist. There are students who make errors in calculations.

Of the three indicators that have been measured from the diagram, it can be seen that the highest value is in the problem analysis indicator of 68.2% (SMAN 3) and 65.9% (SMAN 5), while the lowest value is on the creative indicator of 54.5% (SMAN 3) and 39.3% (SMAN 5). This means that students' scores at both meetings have the highest ability in the aspect of analyzing the problem. However, it has the lowest ability in the aspect of creating, designing and finding solutions. This is natural, because from the first meeting to the last, students are generally constrained by connection questions. However, in other metacognitive questions, students seem more familiar even though the results achieved have not been maximized.

Sconclusion

The tendency of the development of students' higher order thinking skills after being taught with metacognitive strategies and the difficulties faced by students are as follows. Students' higher order thinking skills in solving HOT questions tend to develop from the first to the second treatment with an average score of 74.8 to 77.8 and 72.8 to 76.3. Meanwhile, the average THB scores were 73.3 (SMAN 3) and 71.2 (SMAN 5). Of the three indicators that have been measured, it can be seen that the highest average value is on the problem analysis indicator, while the lowest value is on the creation indicator. Of the three indicators, the dominance of student difficulties is in the evaluation indicator, namely students find it difficult to provide an assessment of the solution plan using suitable criteria, and difficulty understanding the information provided and some students find it difficult to solve the equations they have made. Another difficulty is the creative indicator, which is still not able to understand images and present images in the form of symbols, but have been able to design a way to solve problems, and very few students are able to make connections between problem

Volume 1, No.3, November 2021, Pages: 1-18
ISSN 2775-4928 (Print) ISSN 2775-8893 (Online)
http://internationaljournal.unigha.ac.id/

information and previous completion concepts. There are some students who are less careful so that they make mistakes in calculations. Overall, the implication of this study is that higher order thinking skills with metacognitive questions have met the feasibility to be applied to class X high school students with linear equations with three variables. Another difficulty is the creative indicator, which is still not able to understand images and present images in the form of symbols, but have been able to design a way to solve problems, and very few students are able to make connections between problem information and previous completion concepts. There are some students who are less careful so that they make mistakes in calculations. Overall, the implication of this study is that higher order thinking skills with metacognitive questions have met the feasibility to be applied to class X high school students with linear equations with three variables. Another difficulty is the creative indicator, which is still not able to understand images and present images in the form of symbols, but have been able to design a way to solve problems, and very few students are able to make connections between problem information and previous completion concepts. There are some students who are less careful so that they make mistakes in calculations. Overall, the implication of this study is that higher order thinking skills with metacognitive questions have met the feasibility to be applied to class X high school students with linear equations with three variables. and very few students are able to make connections between problem information and previous solution concepts. There are some students who are less careful so that they make mistakes in calculations. Overall, the implication of this study is that higher order thinking skills with metacognitive questions have met the feasibility to be applied to class X high school students with linear equations with three variables. and very few students are able to make connections between problem information and previous solution concepts. There are some students who are less careful so that they make mistakes in calculations. Overall, the implication of this study is that higher order thinking skills with metacognitive questions have met the feasibility to be applied to class X high school students with linear equations with three variables.

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Volume 1, No.3, November 2021, Pages: 1-18
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