The effectiveness of metacognitive learning in enhancing student’s mathematical analysis

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Abstract. The aims of this study are to determine and to examine the problem of enhancing student’s mathematical analysis who receive metacognitive learning. The research method has used quasi experimental with pretest and posttest design on experimental group and control group. The subject of research are 70 students of one senior high school in Cimahi, West-Java, Indonesia. Technique of sampling was using purposive sampling. Early learning of both classes was given pretest, then in the experimental class was given metacognitive learning and control class was given traditional learning. The instrument of research was a written test. The results concluded that the achievement and improvement of mathematical analysis ability of senior high school students using metacognitive learning better than students using traditional learning. Metacognitive learning can be used as an alternative to mathematics learning and improves students’ mathematical analysis ability.

1. Introduction

One area of study that supports the development of science and technology is mathematics. Mathematics occupies an important role in the field of education. Mathematics is taught formally from elementary to college level. Mathematics is also taught because it can grow the ability to develop analytical thinking systematic, logical and critical in communicating ideas or ideas to solve problems.

[1] mentions there are five standard processes in mathematics learning namely problem solving, reasoning and proof, communication, connection, and representation. Among the five standard processes, the process of reasoning and problem solving is important to play in developing high-order thinking skills [2]. High-order thinking is an important skill for students to master along with the increasing demands of the age of the skills that must be mastered by individuals. As'ari in [3] states that the development of the era demands an individual who is capable of inventive thinking and has a high level of productivity. To accomplish this the student must at least have characteristics as an analytical thinker, problem solver, as well as innovative and creative.

High-order thinking allows a person to think critically when receiving information, then make the right conclusion, and be able to see the gaffe in the information [4]. High-order thinking is needed in the learning process because without a high power of reason then it will be difficult to achieve the purpose of learning. This is in line with the statement [5], required certain requirements that must be fulfilled by learners in order to gain success in learning, among others, have high-order thinking skills are characterized by critical thinking, logical, systematic, and objective. The role of educational institutions, especially formal education is very influential...
in developing high-order thinking skills because the process that directly interacts with the learning experience received by students.

[6] states that one of the alternatives used by math teachers to assess high-order thinking is to use Bloom's taxonomy. The indicator of high-order thinking ability in Bloom's taxonomy is at the stage of C4, C5, and C6. Bloom's taxonomy before the revision mentions the cognitive stages of high-order thinking is analysis, synthesis, and evaluation. After going through revisions, the ability to think in Bloom's taxonomy is to analyze, evaluate, and create. The difference between the two is the form of the noun is converted into a verb, as well as evaluation and synthesis exchange place then synthesis changed its name to be creative [7].

Ability analysis is a capability that supports reasoning ability and problem-solving. This can be seen in one of the indicators of problem-solving capability proposed by [8] that is able to solve problems that are not routine. This capability in the cognitive stage of Bloom's taxonomy is at the analytical stage (C4) is the ability to transfer learned mathematical knowledge to a new context so that students are able to solve non-routine problems [9].

However, the mastery of this high-order thinking ability has not become an endowed destination in the education system in Indonesia [10]. Schools encourage students to give correct answers rather than encouraging them to come up with ideas or rethink existing conclusions by analyzing, drawing conclusions, linking, synthesizing, criticizing, creating, evaluating, and rethinking. A preliminary study conducted by [2] shows that the proportion of students' analysis and synthesis capability based on the order from highest to lowest is low, medium, very low, high, and very high.

One of the alternative learning that supports to improve the various analytical skills is the metacognitive learning. This is because metacognitive learning guided students in realizing and controlling the process of interaction in thinking. Metacognition emphasizes the awareness of one's thinking about the thought process itself. An awareness of what is known and what is unknown. The metacognitive approach strategy refers to ways to raise awareness of thought processes, so this approach is very well used to improve students' reasoning abilities. Analyzing is essentially the essence of mathematical activity.

Activities on learning mathematics through metacognitive learning are designed to improve the clarity and stability of new learning materials so that missing ideas are not so much simply because of the uncertainty of each other. Students should dissect the material as they embrace it by connecting new learning materials with personal experience, cognitive structure and critical attitudes to knowledge. Learning through metacognitive learning is investigated as an alternative in an effort to improve students' mathematical analysis ability.

2. Theoretical study

2.1. Ability of mathematical analysis

Analytical thinking is the ability of students to think, describe, and analysing the information used to understand a knowledge by using logical reason and thought, not based on feelings or guesses. To be able to think analytically necessary logical thinking ability in drawing conclusions to various situations.

According to [11] Analytical ability is the ability of students to decompose or separate things into their parts and can look for links between the parts. It is also reinforced by Bloom who argued that analytical thinking emphasizes the breaking of matter into more specialized or small parts and detects the relationships and parts and the parts are organized.

[12] analytical thinking is to subdue a situation, subject matter or decision on a rigorous and logical step by step examination. Testing a statement or proof or proposal in front of objective standards. Swooping down the surface to the root of the problem. Consider and decide on the basis of logic and tracking possible biases. The use of analytical thinking is in making decisions, solving problems, analysing and assessing various situations and conditions.

Bloom in [13] divides the analytical aspects into three categories: 1) the analysis of parts (elements) such as doing fact formatting defined elements, arguments, axioms (assumptions), propositions, hypotheses, and conclusions; 2) analysis of relations (relations) such as connecting between elements of a mathematical system (structure); 3) analysis of the system as it is able to recognize the elements and its relation to the organized structure. The description of these three categories according to [13] includes various skills, namely: detailing, sharpening diagrams, differentiating, identifying, illustrating, concluding, demonstrating, and dividing.
Based on the above statement, it can be concluded that the ability of mathematical analysis is the ability to reason to decipher a problem by identifying the problem, using a known concept and able to solve it quickly.

2.2. Metacognitive learning
Metacognitive learning is a learning that instills awareness of how to design, monitor, and control what they know, what it takes to do and how to do it; focusing on student learning activities; help and guide students if there are difficulties, and help students to develop what self-concept is done at the time of learning math.

When metacognitive is involved in the learning process, students will automatically be active in thinking. This active process gives effect for students to interact both internally and externally. Metacognitive plays a role to guide students in realizing and controlling the interaction process in thinking. Internally students will build knowledge by interprets ideas in their mind based on prior knowledge that they have and externally build their knowledge through interaction with their environment including with their friends to achieve a perfect understanding.

Thus the learning process will be more effective in achieving the goal. Learning in the effort of cognitive awareness and cultivating beliefs through questions and controlling the thinking process in building intact knowledge is learning with metacognitive learning.

Students need a process long enough to master metacognition skills gradually. However, teachers can start early in school by specifically training students in specific skills and strategies (such as designing, evaluating problem evaluation) and with the teacher's teaching structure in such a way that students are focused on how they learn and also on what they learn. Therefore, the role of teachers as educators to design, monitor and revise the work of the students not only make students aware of what they know but also what they need to do if they fail to understand.

Learning is a metacognition skill through activity that is used to organize and monitor the learning process. The activities include planning, monitoring and checking results. The planning activities in question are predicting the results, scheduling the strategies used, and various forms of trial and error. Monitoring activities are monitoring, checking, testing, revising.

The application of metacognitive learning in mathematics learning is one of the concrete efforts to answer the challenges of Education Unit Curriculum Level and Curriculum 2013. Metacognitive learning can be used as an alternative effort in improving the quality of mathematics learning in schools. To anticipate this situation requires a form of learning that instills metacognition awareness.

The metacognitive concept proposed by [14] refers to the thought of what one knows - the so-called "metacognitive knowledge", what one can do - the so-called "metacognitive skills", and what one knows about his metacognitive ability - the so-called "metacognitive experience ".

Students need a process long enough to master metacognition skills gradually. However, lecturers can start early on campus by specifically training students in special skills and strategies (such as designing, evaluating problem analysis) and with the teaching structure of teachers in such a way that students are focused on how they learn and also on what they learn [15].

Metacognitive learning directs students' attention to what is relevant and guides them to choose appropriate strategies for solving questions through questions. This question leads students to focus on specific steps to solve math problems and to raise awareness of the difficulties students may experience during the process.

According to [16], the metacognitive learning stages are as follows:
1. The first phase of the initial discussion
   At this stage the teacher explains the purpose of the topic being studied, the concept builds by answering the underlying questions.
2. The second stage students work independently
   In the second phase, students work independently to complete the training questions provided. Teachers give feedback individually (feedback), around guiding students in solving problems by providing stimulus in the form of questions that are metacognitive such as questions to control and monitor the thinking process of students.
3. The third stage is reflection and summary.
At this stage, reflection is done by teachers and students. Teacher reflection leads to more consolidation and broader application so that students get meaningful learning. Student reflection leads more to what he has understood from learning and the possibility of application in a wider problem.

Thus metacognitive learning designs a learning model that integrates metacognitive questions related to the topics learned and controls the thinking process in learning. Metacognitive questions are integrated into teaching materials in writing and or directly through oral to cultivate beliefs and awareness of learned mathematical concepts and principles as well as controlling the thinking process undertaken. Orally the question of teachers stimulates students to be able to ask themselves in relation to the topics being studied.

3. Methodology
The study was conducted on two sample groups consisting of one experimental group and one control group. The experimental group was a group of students who received metacognitive learning, while the control group was a group of students who received traditional learning. Furthermore, at the beginning and end of the learning, the two classes are given a test. The design used in this research is quasi-research.

This research was conducted in one of the senior high schools in Cimahi, West Java, Indonesia. Subjects in this study as many as 70 people are grouped into 2 classes, namely 1 experimental class or experimental group that gets metacognitive learning. While the other 1 class used as a control class or a control group, who get regular learning. Determination of sample is done by using technique purposive sampling. Purposive sampling is a sampling technique in which the researcher determines the sample by specifying a specific characteristic in accordance with the research objectives. The selection of senior high schools is done because the ability of mathematical analysis is considered to have grown in senior high school.

The instrument developed in this study is a written test totaling 6 questions in the form of a description. In this case, a written test will be used to determine the students' mathematical analysis. Here 2 questions from 6:

1. Find the value of $b$ that satisfies the interval in the equation $\sin^2(x) = \frac{2b-7}{b+1}$.
2. Investigate whether the maximum value of $1 + \frac{1}{1+\cos^2(x)}$ for $0 \leq x \leq 360^0$ is achieved when $x = 90^0$ or $x = 270^0$. Explain your reasons and conclusions!

The data in this study were collected through the test. The data to be analysed is quantitative data in the form of a test result of students' mathematical analysis ability. All data of research result is processed using SPSS 22.0 software.

4. Result and discussion
Data were obtained through the test of students' mathematical analysis ability at the beginning and end of learning. In this study obtained pretest, posttest and N-gain scores. Pretest scores were used to determine the initial ability of the students before treatment was administered, posttest score was used to determine students' end-ability after treatment and N-gain were used to determine the improvement after treatment.

Table 1. Recapitulation of pretest, posttest and N-gain of mathematical analysis

| Variable                     | Statistic of data | Experiment class | Control class |
|------------------------------|-------------------|------------------|---------------|
|                              | N                 | Pre-test         | Post-test     | N-gain        | Pre-test | Post-test | N-gain |
| The ability of mathematical  |                   |                  |               |               |          |           |        |
| analysis                     | N                 | 35               | 35            | 35            | 40       | 40        | 40     |
| ($\overline{x}$)            | 5,23              | 13,87            | 0,58          | 6,1           | 11,43    | 0,37      |
| (%)                         | 21,79%            | 57,79%           | 36%           | 25,42%        | 47,63%   | 22,21%    |
| Dev. Sta                    | 2,64              | 2,79             | 0,20          | 1,99          | 2,10     | 0,18      |

Based on the Table 1, The number of students in each group is 35 and the ideal maximum score (IMS) = 24. The average initial or experimental grade of an experimental grade is 5.23 while the initial average or pretest the control class is 6.1 then the difference in experiment class and control class is 0.87 so it can be concluded that the average for initial ability or pretest of the two classes is not much different.

In the Table 1 also shows the average posttest value for the experimental class is 13.87 whereas the mean posttest for the control class is 11.43. Also seen in the experimental class the average student obtained pretest
student mathematical analysis ability of 21.79% and an increase in posttest of 57.79% of the average ideal score. While in the control class the average students get pretest mathematical analysis ability of student equal to 25.42% and have increased 47.63% from the mean of an ideal score. From the data, it can be seen that the improvement in the experimental class is 36% and the control class is 22.21%. So from the data it can be concluded that the experimental class has better mathematical analysis capability than the control class.

To test the truth, statistical calculations for pretest, posttest, and gain are performed by normality test, homogeneity test, and significance test of the mean difference. In this research has been done an analysis of the achievement and improvement of the ability of mathematical analysis.

4.1. Analysis of pre-test
4.1.1. Normality test
In this normality test use Shapiro-Wilk statistical test with 95% significance level or significant \( \alpha = 0.05 \).

The null and alternative hypotheses to be tested are:

\( H_0: \) The sample comes from a normally distributed population.

\( H_1: \) The sample comes from a population that is not normally distributed.

Criteria testing [17] namely: 1). If \( \text{sig} < \alpha = 0.05 \), then \( H_0 \) is rejected, 2). If \( \text{sig} \geq \alpha = 0.05 \), then \( H_0 \) is accepted.

The results of the pretest normality test data in Software IBM SPSS Statistics 22 are presented in Table 2:

| Class            | Shapiro wilk Statistic | Df  | Sig. |
|------------------|------------------------|-----|------|
| Experiment class | 0.935                  | 34  | 0.018|
| Control class    | 0.935                  | 39  | 0.018|

Based on Table 2 it can be seen that the significance value is 0.018 for the experimental class and 0.018 for the control class. Thus the significance value of the two classes is smaller than 0.05 then \( H_0 \) is rejected, meaning that the two samples are not normally distributed, then followed by Mann-Whitney nonparametric test.

4.1.2. Mann-Whitney test
After the pre-test normality, the samples were not normally distributed so that the Mann-Whitney test was performed. Formulation of the hypothesis on the test of students' mathematical analysis skills pre-test score.

\( H_0: m_1 = m_2 \) {there is no difference in the initial (median) ability of mathematical analysis of senior high school students significantly, between those using learning through metacognitive learning models with students using Traditional learning}.

\( H_1: m_1 \neq m_2 \) {there is a difference in the initial (median) ability of mathematical analysis of senior high school students significantly, between those using metacognitive learning with students using Traditional learning}.

Criteria testing [17] namely: 1). If \( \text{sig} < \alpha = 0.05 \), then \( H_0 \) is rejected, 2). If \( \text{sig} \geq \alpha = 0.05 \), then \( H_0 \) is accepted.

The results of the Mann-Whitney pre-test data in Software IBM SPSS Statistics 22 software are presented in Table 3:

|          | Pre-test |
|----------|----------|
| Mann-Whitney U | 922,500   |
| Wilcoxon W | 18,685,00 |
| Z         | -0.17    |
| Asymp. Sig. (2-tailed) | .986      |
| Monte Carlo Sig. (2-tailed) | .988^b    |

95% Confidence Interval

|        | Lower Bound | Upper Bound |
|--------|-------------|-------------|
|        | 966         | 1,000       |
Based on Table 3 it appears that Monte Carlo sig. (2-tailed) Mann-Whitney test is 0.988. Thus, the significance value > 0.05 then H₀ is accepted. This means there is no significant difference in the initial ability of mathematical analysis of students between using learning through metacognitive learning models with students using traditional learning.

4.2. Post-test analysis of ability of mathematical analysis

4.2.1. Normality test
In this normality test use Shapiro-Wilk statistical test with 95% significance level or significant α = 0.05.

The null and alternative hypotheses to be tested are:
H₀: The sample comes from a normally distributed population.
H₁: The sample comes from a population that is not normally distributed.

Criteria testing [16] namely: 1). If sig < α = 0.05, then H₀ is rejected,
2). If sig ≥ α = 0.05, then H₀ is accepted.

The results of the posttest normality test data in the IBM SPSS Statistics Software are presented in Table 4.

| Class          | Shapiro Wilk Statistic | Df | Sig. |
|----------------|-------------------------|----|------|
| Experiment Class | 0.885                   | 34 | 0.000|
| Control Class   | 0.962                   | 39 | 0.168|

Table 4 shows that the significance value is 0.000 for the experimental class and 0.168 for the control class. Thus the significance value of the experimental class is less than 0.05 then H₀ is rejected, meaning that the two samples are not normally distributed, followed by Mann-Whitney nonparametric test.

4.2.2. Mann-Whitney test
After the posttest normality test, the sample was not normally distributed so that nonparametric test, Mann-Whitney test was performed. Formulation of hypothesis on a test of student's mathematical ability of posttest score as follows:
H₀: m₁ ≤ m₂ (Achievement of mathematical ability of senior high school students significantly, between those using learning through metacognitive learning model, is no better or equal to students using traditional learning).
H₁: m₁ > m₂ (Achievement of mathematical ability of senior high school students significantly, between those using metacognitive learning, is better than students using traditional learning).

The results of the Mann-Whitney posttest data with the help SPSS Software are presented in Table 5.

|               | Posttest |
|---------------|----------|
| Mann-Whitney U | 472,500  |
| Wilcoxon W     | 1418,500 |
| Z              | -3,946   |
| Asymp. Sig. (2-tailed) | .000    |
| Monte Carlo Sig. (1-tailed) | .000    |
| Sig. 95% Confidence interval | Lower bound .000 |
|               | Upper bound .034 |

Based on Table 5 it appears that Monte Carlo sig. (1-tailed) Mann-Whitney test is 0.000. Thus, the significance value < 0.05 then H₀ is rejected. This means that the achievement of mathematical analysis of senior high school students significantly, between those using learning through metacognitive learning model, is better than students using traditional learning). The results of this study agree with [18] study which
indicated the effectiveness of using metacognition strategies in Teaching Mathematics among Innovative Thinking Students. This generally agrees with many previous studies which indicated the effectiveness of using metacognition strategies in improving innovative thinking for ordinary and talented students. It also agreed with [19] study, assessed the cognitive and metacognitive strategies during Algebra problem solving for university students. The results of the study revealed that the metacognitive strategies have a great effect on the students’ mathematical performance in comparison with the cognitive strategy.

4.3. Gain analysis of mathematical analysis ability

4.3.1. Normality test

In this normality test use Shapiro Wilk statistical test with 95% significance level or significant α = 0.05.

The null and alternative hypotheses to be tested are:

H0: The sample comes from a normally distributed population.
H1: The sample comes from a population that is not normally distributed.

Criteria testing [17] namely: 1). If sig < α = 0.05, then H0 is rejected, 2). If sig ≥ α = 0.05, then H0 is accepted.

The results of the test data on posttest normality by IBM SPSS Statistics Software are presented in Table 6.

| Class          | Shapiro wilk Statistic | Df | Sig. |
|----------------|------------------------|----|------|
| Experiment class | 0.946                  | 34 | 0.043|
| Control class | 0.901                  | 39 | 0.001|

Based on Table 6 it can be seen that the significance value is 0.043 for the experimental class and 0.001 as well for the control class. Thus the significance value of the two classes is less than 0.05 then H0 is rejected, meaning that the two samples are not normally distributed, followed by a non-parametric Mann-Whitney test.

4.3.2. Mann-Whitney test

After the Gain normality test, it turns out that the two samples are not normally distributed, so the nonparametric test, Mann-Whitney test. Formulation of hypothesis on a test of mathematical analysis ability of student gain score as follows:

H0: m1 ≤ m2 (The increased ability of mathematical analysis of senior high school students significantly, between those using learning through metacognitive learning model, is no better or equal to students using traditional learning).
H1: m1 > m2 (The increased ability of mathematical analysis of senior high school students significantly, between those using metacognitive learning, is better than students using traditional learning).

Criteria testing [17] namely: 1) If sig < α = 0.05, then H0 is rejected, 2) If sig ≥ α = 0.05, then H0 is accepted.

The results of the Mann-Whitney gain test data with the help of IBM SPSS Statistics 22 software are showed in Table 7.

| Gain          | Sig. |
|---------------|------|
| Mann-Whitney U | 446,000 |
| Wilcoxon W    | 1392,000 |
| Z             | -4.138 |
| Asymp. Sig. (2-tailed) | 0.000 |
| Monte Carlo Sig. (1-tailed) | 0.000 |
| 95% Confidence Interval Lower Bound | 0.000 |
|                Upper Bound | 0.034 |
Based on Table 7 it appears that Monte Carlo Sig. (1-tailed) Mann-Whitney test is 0.000. Thus, the significance value less than 0.05 is then rejected. This means an improvement in students' mathematical analytical ability that use learning through better than students using traditional learning. The results of this study agree with [22]. The study reveals that in terms of overall, mathematical critical thinking skills enhancement and achievement of students who received the 5E Learning Cycle with Metacognitive technique is better than students who received the 5E Learning Cycle and conventional learning. Mathematical critical thinking skills of students who received the 5E Learning Cycle is better than students who received conventional learning.

5. Conclusion
Based on the results of research analysis that has been discussed, then obtained the following conclusions:
1. Achievement of mathematical analysis ability of senior high school students with metacognitive learning is better than students using traditional learning.
2. Improved mathematical analysis ability of senior high school students with metacognitive learning is better than students using traditional learning.

The findings of this study confirm the importance of metacognitive learning in mathematical analysis ability. It is observed that metacognitive learning provides a more promising platform to set goals, and to perform actions to achieve those goals, during solving the problem of mathematical analysis.

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