Improving mathematical problem solving ability of senior high school students through learning with metacognitive scaffolding approach

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Abstract. Problem solving is an important skill that need to be developed in mathematics education. Sharpening problem solving skills enable students to improve their ability to analyze and train students to think creatively. However, in reality the students were less facilitated in sharpening the development of problem-solving abilities. Consequently, the problem solving ability of students has not been satisfactory. One of the efforts that could be done to overcome his problem is applying metacognitive scaffolding approach in learning. Metacognitive scaffolding is an approach that emphasizes self-monitoring capability. Monitoring is the way a person monitors what students know and do not know. While scaffolding is a help given by the teacher to the students. When students feel able to work independently, teachers slowly reduce scaffolding. This study aimed to determine whether the approach of metacognitive scaffolding could improve problem-solving abilities. The research applied quasi experiment research with Nonequivalent Control Group Design. This research took place in one of State Senior High School in Padang Pariaman District, West Sumatera. The results show that metacognitive scaffolding approach could improve mathematical problem solving ability.

1. Introduction
Mathematics is one of field of study that has an important role in life. By studying mathematics, a person will be familiar with logical thinking, analytical activity, systematic, critical and creative thinking, and has the ability to solve problems in the field of mathematics and other fields. The importance role of mathematics makes mathematics as a compulsory subject for all levels of education ranging from kindergarten, elementary, high school to college. One of the objectives of mathematics learning is to develop students' mathematical problem solving abilities. National Council of Mathematics Teachers (2000) mentions five important abilities that need to be developed in learning mathematics, namely: (1) learning to communicate (mathematical communication); (2) learning to reason (mathematical reasoning); (3) learning to solve problems (mathematical problem solving); (4) learning to link ideas (mathematical connection); (5) learning to represent the idea (representation) [1]. Moreover, the importance of mathematical problem-solving skills for students according to Branca because: (1) problem-solving ability is the general goal of teaching mathematics; (2) mathematical problem solving may include methods, procedures and strategies or methods used are core and major processes in the mathematics curriculum and (3) mathematical problem solving is a very meaningful basic skill in thinking and can make problem solving strategies for next problem [2].

But the reality in the field shown that, the problem solving ability of students were still low. The presence of the 2013 curriculum carries a scientific approach in learning which has led teachers to invite students to be actively involved in developing problem-solving skills. Nevertheless, it was still...
less effective in developing problem solving ability, so students’ ability in solving problems was not well developed. The preliminary study was conducted in grade X in Mathematics of Natural Sciences program at Senior high school one (SMA) in West Sumatra. The researcher gave a problem solving test on Linear Equation System and Linear Equations Mix Equations in Two Variables.

Problem: A and B worked together to complete their work in 4 days. B and C worked together. They could finish their work in 3 days, while A and C worked together, they could finish their work in 2.4 days.

Question:

a. If they work independently, how would you use strategy to calculate the number of days that they could complete the job?

b. Let use this strategy to determine number of the days the students worked independently.

Here’s one of the student’s answers

![Figure 1. Student's Answer in Problem Solving](image)

Around 20 out of 33 students gave similar answers to those answers presented in Figure 1. Based on the picture, students were not able to reach the problem solving indicators; (1) understanding the problem by identifying the elements known, questioned, and the adequacy of the necessary elements and indicators (2) e.g. formulating a mathematical problem or composing a mathematical model. Based on the answers presented, it could be seen that students had difficulties in understanding the facts about the given problem. In fact, the information written on the matter was very clear and could be observed by students. The obvious issue mentioned that "A and B worked together to complete their work in 4 days, B and C worked together to complete the work in 3 days, while A and C worked together to complete their work in 2.4 days." Students did not understand the relationship between the number of days with the job, so the students mistakenly formulate or model the problem of "A + B = 4, B + C = 3, and A + C = 2.4".

It was hoped that if students had a good problem solving skills they would be able to find that there was a relationship between their work and the number of days in completing it. So if A, B and C needed each x days, y days, and z days to complete the work individually, in one day they could complete \( \frac{1}{x} \) \( xy \) and \( \frac{1}{z} \) jobs. Thus, the students were expected to be able to formulate or model into the correct mathematical form, such as:

\[
\frac{1}{x} + \frac{1}{y} = \frac{1}{4} \quad \ldots (1)
\]
\[
\frac{1}{y} + \frac{1}{z} = \frac{1}{3} \quad \ldots (2)
\]
\[
\frac{1}{x} + \frac{1}{z} = \frac{1}{2.4} \quad \ldots (3)
\]

Research on students’ difficulties in solving problems was also done by Tias and Wutsqa. Both researchers were analyzed the difficulties of high school students’ in problem solving. They found that students' mathematical difficulties were in difficulty in remembering facts about 1.77%, difficulty in understanding facts about 3.54%, difficulty in applying facts about 3.54%, difficulty in analyzing facts about 10.18%, difficulty in remembering concepts about 1.33%, difficulty in understanding the concept about 13.27%, the difficulty in applying the concept about 11.95%, the difficulty in analyzing the concepts about 4.42%, the difficulty in understanding the procedure about 7.52%, the difficulty in
applying the procedure about 15.49%, the difficulty in analyzing procedures about 16.37%, the
difficulty in recalling the concept of visual-spatial about 1.33%, difficulties in understanding visual-
spatial about 3.54%, difficulties in applying visual-spatial about 3.10%, and difficulties in visual-
spatial analysis about 2.65% [3].

The description above clearly shown that the problem solving ability of high school students was
still not optimal, so that problem solving skills in mathematics need to be familiarized as early as
possible to the students, because this ability will be needed by students in solving problems in
everyday life. One of the solutions was through learning Metacognitive Scaffolding approach. The
metacognitive scaffolding approach involved four stages of activity: the awareness stage, the planning
stage, the monitoring stage and the reflection stage (4). The essence of metacognitive was in one's
consciousness about his own thought process, thinking about how to learn and how to obtain certain
goals. While learning by using metacognitive scaffolding was an approach that emphasized the ability
of self-monitoring [5]. Monitoring was one way to monitor what was known or what was not known
[6]. Scaffolding played a role in providing encouragement in the form of questions that led students
in understanding a condition of the problem and chose an effective solution in solving it. When
students were able to work independently, teachers slowly reduced scaffolding, so that learning by
using metacognitive scaffolding was able to develop the thinking process of students, especially in
solving problems.

Based on the description above, this research was conducted to see whether the approach of
metacognitive scaffolding can improve the mathematical problem solving ability of senior high school
students. Indicators of mathematical problem solving skills used were an understanding of students' abilities in (1) understanding the problem by identifying known elements, questioning and adequacy of the required elements; (2) formulating mathematical problem or arranging mathematical model; (3) selecting and using appropriate strategies for solving problems (new types or problems) and (4) checking it again, explaining or interpreting the results according to the original problem [1].

2. Experimental Methods
The type of this research was a quasi-experimental study or a study approaching a real experiment, but
it was impossible to control / manipulate all internal and external variables within the limits [6]. The
design of this study was Nonequivalent Control Group Design [9]. The population in this study were
all X grade students at SMA Negeri 1 in Padang Pariaman regency West Sumatra registered in
2017/2018 academic year. The independent variable in this research was metacognitive scaffolding
approach, while the dependent variable was students' mathematical problem solving abilities. Research
sample was selected from the population by using purposive sampling technique. Two classes were
chosen that consisted of experimental class and control class. The selection of these two classes were
done with a lottery system using coins.

The research procedure was divided into three stages, namely the preparation stage, the
implementation stage and the final stage. The preparation stage included, composing the research
instrument. The research instrument used a matter of mathematical problem solving test in essay. The
final test was assessed in accordance with the mathematical problem solving rubric that was adapted
from the previous researcher [7]. To get a good test instrument, there were some steps: making a grille
test questions, preparing the questions according to the grid about the test, validating the test
questions, fixing the test questions based on suggestions provided by the validator, carrying out test
runs. The test results shown that all test questions could be used as a matter of mathematical problem
solving test in the experimental class and control class.

Then the implementation stage was done by applying the learning with metacognitive scaffolding
approach in the experimental class and conventional approach in the control class. The final stage was
to test the ability to solve mathematical problems with the prepared instruments in both classes. The
problem formulation of this research was whether the learning with metacognitive scaffolding
approach can improve students' mathematical problem solving ability?

3. Results and Discussion
Metacognitive Scaffolding is a learning design that combines metacognitive and scaffolding approaches. Essentially metacognitive is a component of metacognition, in which metacognitive is a person's knowledge of his own cognitive processes. Metacognitive is divided into three components: metacognitive knowledge, metacognitive awareness and metacognitive control. Therefore learning with metacognitive approaching emphasizes activities that show intentional awareness in planning, monitoring and evaluation [5]. Paris, Cross, Lipson and King reinforced the theory that students would master lessons or solve better problems if they ask themselves [8]. Scaffolding means giving a child a great deal of help during the early stages of learning and then reducing the aid and giving the child an opportunity to take greater responsibility immediately after being able to do it on his own.

The application of metacognitive scaffolding approach was done in experiment class, which was divided into 4 stages; (1) the conscious learning stage (awareness). At this stage the teacher awakened the students’ learning consciousness by recalling the previous material that have been learned; (2) planning stage, at this stage the teacher directed students to find the concept of learning, which later could facilitate the students to find solution of problem given. Teachers also provided scaffolding to form a precise representation of the given problem; (3) Monitoring stage (monitoring), at this stage students used the concepts obtained to solve similar problems or new problems for students. This stage became the focus of metacognitive, in which students trained to be able to ask themselves questions about their understanding, for example: 1) what information can I take from the problem?; 2) does the strategy that I use good enough to solve the problem? etc; (4) the reflection stage, at this stage students and teachers reflected works done by the students, if there was a mistake the teacher would evaluate them.

Based on the application of metacognitive scaffolding approach, the following picture presented one of the students’ answers to the experimental and control class in completing the problem solving test.

![Figure 2. One of the students’ experimental class response to indicator 1 and indicator 2](image1)

![Figure 3. One of the students’ experimental class response to indicator 3](image2)

![Figure 4. One of the students’ experimental class responses to indicator 4](image3)
The pictures above were the answer of one of the students in the experimental class and the control class in solving the same problem. Every problem solving questions covered all indicators, so the researcher chose the answers of one student in the experimental class and the control class. Here’s an analysis of the answers for each troubleshooting indicator.

Indicator 1 was understanding the problem by identifying the elements that were known, being questioned and the adequacy of the necessary elements. In Figure 2, it was shown that the experimental class students were able to identify all the elements of the given problem. The information contained in the problem was represented in the form of the image. They could write all themathematical information correctly. So, students declared the information needed to determine the water surface length and water depth in the tunnel was acceptable and the score obtained by students for indicator 1 is 2. Students’ answers in control class could be seen in figure 5. Based on the answers presented, control class student represented all known elements of the given problem, but the description given in the image did not exist. So, students’ reason to declare the information needed to determine the water surface length and water depth in the tunnel was not acceptable, because the evidence submitted was not sufficient and the score obtained by students for indicator 1 is 1.

Indicator 2 was to formulate mathematical problem or to compile a mathematical model. Figure 2 shown that the experimental class students were correct in formulating the problem. The first student determined $\angle A$ and $\angle B$ to determine the water depth because that was triangular triangle so $\angle A = \angle B = 30^\circ$. So the score obtained by students was 2. While in figure 5 that was answer of control class students. There was no student answered for formulating or composing a mathematical model of the given problem. So the score obtained by the control class students was 0.

Indicator 3 was choosing and using the right strategy to solve the problem (a kind or new problem). This indicator was a follow-up after the students collected the relevant information and formulated the problem mathematically. The answers presented by the experimental class students as shown in Figure 3, could be observed that the students chose the right strategy to determine the water surface length and water depth in the tunnel. The water surface length of the tunnel could be determined by the cosine rule and the water depth in the tunnel could be determined by the sinus rule. So, this strategy was the right choice. Based on this strategy, students performed calculations correctly and precisely found the water length and water depth values in the tunnel. So that according to the scoring guidelines of the students' answers, they got 4 points. While the students in control class answers could be seen in Figure 6. Students chose the rule of cosine to determine the water surface length and it was the right choice. Then the students did the calculations and got the correct results. But the strategy chosen to determine the water depth in the tunnel was not appropriate so that students could not do the calculation. Consequently, they did not get the answer. Based on the scoring guidelines the students’ score was 2.

Indicator 4 was to do re-check, by explaining or interpreting the results according to the original problem. Figure 4 shown the answer of the experimental class students in fulfilling indicator 4. It shown that the students were less precise in interpreting the results, because the conclusions that was made by the students were not the results obtained but the strategies they used to solve the problem. So, based on the scoring guidance for indicator 4, the score obtained by the students was 1. While the control class students did not write the conclusion. So, the score obtained was 0.
Based on the learning of metacognitive scaffolding that has been done, as well as the analysis of the answers of the experimental class and control class students, it was found that the experimental class students had better problem-solving skills than the control class students. It was also supported by research conducted by Multahada in 2015. She obtained the result that the problem solving ability and motivation of high school students were better after learning with metacognitive scaffolding technique [10]. The same result conveyed by Zubaidah that found through learning with metacognitive approach students could control the learning process starting from the planning stage, choosing the right strategy according to problems encountered, then monitoring the progress in learning and simultaneously correcting themselves if there were mistakes that occur during understanding the concept, and analyzing the effectiveness of the chosen strategy. Then they did the reflection of changing learning habits and strategies if necessary [11]. So it could improve students’ problem solving skills.

4. Conclusion
Based on the research results, it could be concluded that the problem solving ability of mathematical students who learned by using metacognitive scaffolding learning approach was better than students who learned by using conventional learning approach in class X MIPA SMAN in 2017/2018. This shown that the metacognitive scaffolding approach could improve students' mathematical problem solving abilities.

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6. References
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