The correlation between physics problem-solving skill and metacognitive ability from collaboration of socratic dialogue-modeling instruction implementation

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Abstract. Metacognitive ability linked to the problem-solving skill lies in the control of cognitive processes as a guide in problems solving. Problem-solving skill should be trained as a scaffolding for students. Scaffolding can be done through Socratic dialogue. Implementation of Socratic dialogue will be more effective when combined with modelling instruction. Therefore, the research had been conducted to determine the influence of Socratic dialogue in modelling instruction on physics problem-solving skill in terms of students’ metacognitive ability. This research is a quasi-experiment posttest only group design with a 2x2 factorial design. The results showed that: (1) the physics problem-solving ability of students learned by modelling instruction+socratic dialogue are higher than conventional learning, (2) there is an interaction between modelling instruction+socratic dialogue with the metacognitive ability to physics problem-solving skill, (3) the physics problem-solving skill of students with high metacognitive ability learned by modelling instruction+socratic dialogue are higher than conventional learning, (4) the physics problem-solving skill of students with low metacognitive ability learned by modelling instruction+socratic dialogue are lower than conventional learning.

Keywords: metacognitive, modeling instruction, problem-solving skills, Socratic Dialogue

1. Introduction
In the learning process, it is necessary to develop empowerment of thinking skills such as metacognitive abilities [1]. The learning process that is accompanied by the development of metacognitive abilities allows increased student awareness of things that have been learned [2]. Metacognitive abilities can be possessed by all students, both students with higher thinking abilities (expert) and students with lower thinking abilities (novice). Nevertheless, there are differences in the results of metacognitive abilities between the two groups of students. The difference between students’ metacognitive abilities of experts with novice students lies in the structure of knowledge and the ability to solve problems [3]. Good knowledge structure shows that students have the ability to solve good physics problems. As revealed by Corebima that metacognitive ability is a process of thinking about thinking that involves thinking processes and the ability to solve problems [4].

The ability to solve problems is interrelated with metacognitive abilities. Gredler states that to identify students who have high and low thinking abilities can be known based on their problem-solving skill and metacognitive abilities [5]. Students who have metacognitive abilities show tenacity
in solving a problem [6]. Veenman et al. (2006) also argue that metacognitive abilities serve as guidelines for thinking when solving a problem [7]. So, metacognitive ability is one aspect that plays an important role in solving a problem. The teacher as the holder of essential role in the learning process must provide assistance for students to be able to develop their metacognitive abilities. The help given by the teacher to students to achieve independence is called scaffolding. In the scaffolding process, students are given full responsibility for the learning process slowly [8]. The scaffolding process can be carried out by the teacher by choosing the right learning method so that students can control not only their cognitive abilities but also their social interactions.

Learning methods that can help teachers to do scaffolding and bring up students' metacognitive abilities are Socratic dialogue. Socratic dialogue is a method of learning based on constructivism to build and develop the ability to think and active opinions related to knowledge [9, 10]. Therefore, Socratic dialogue activities make it easier for teachers to identify students who experience misconceptions so that they can be directed to the correct concepts. Besides, the application of Socratic dialogue can also make students more active in learning, observing, collecting data, and analyzing a physics problem [11]. This opinion is supported by the results of Lestari's research which states that in the university environment, the application of Socratic dialogue can improve students' problem-solving skill in the field of physics and increase student motivation [12].

Jackson et al. (2008) and Wenning (2010) revealed that Socratic dialogue could be more effective if it is combined with active learning, such as modeling instruction [10, 13]. Modeling instruction is the development of learning programs that are recommended for secondary students in science subjects [13]. The reason is that modeling learning shows the affirmation between the construction and application of the conceptual model of a phenomenon as a major aspect of science learning. Modeling is also one of the important elements for developing metacognitive abilities [14]. In modeling instruction, the teacher can build students' thinking skills and invite students to solve physics problems through the right model. Also, modeling instruction is considered more suitable to be applied in physics learning because it is in accordance with the characteristics of physics that require active student involvement in thinking and acting.

Based on the theoretical studies that have been carried out and the support of previous research, the results obtained about the effectiveness of the use of Socratic dialogue and modeling instruction in learning physics. Besides, it can also be seen that the ability to solve physical problems and metacognitive abilities play an important role in the development of students' thinking abilities. Therefore, this study was conducted to analyze the effect of Socratic dialogue in modeling instruction on the ability to solve physical problems and metacognitive abilities of students and analyze the relationship between the two abilities.

2. Method
The study was conducted using a quasi-experimental research design (quasi-experiment posttest only control group design). This type of quasi-experiment research used was a 2x2 factorial design with two class groups, namely the control class and the experimental class. In the control class, conventional learning is done (modeling instruction) and the experimental class uses modeling instruction accompanied by Socratic dialogue. The design matrix for this study is presented in Table 1.

| Metacognitive Ability (B) | Learning Model (A)    |
|--------------------------|-----------------------|
|                          | Modeling Instruction + Socratic Dialogue | Conventional |
|                          | (A1)                  | (A2)         |
| Higher Metacognitive     | A1B1                  | A2B1         |
| Lower Metacognitive      | A1B2                  | A2B2         |
Prerequisites for normality and homogeneity are performed on metacognitive abilities data and physics problem-solving. The normality test uses the Lilliefors test, and the homogeneity test uses the Bartlett test. The research hypothesis test uses a different analysis with two-way Anava and continued by Tukey's test to find out the effectiveness of Socratic dialogue learning in modeling construction of students' physical problem-solving skill.

3. Results and Discussion
The study began by providing tests of metacognitive abilities in 6 classes before being given learning treatment. Based on test results, students are grouped into high and low metacognitive abilities. Data on metacognitive abilities were obtained before treatment. Metacognitive ability test results are used to classify students higher (expert) and lower (novice) metacognitive abilities. Grouping students is done by taking data as much as 33% of the group of students with higher metacognitive abilities and 33% of the group of students with lower metacognitive abilities. The study continued with the treatment of learning. In the experimental class, modeling instruction learning is combined with Socratic dialogue. In the control class, conventional learning is done, namely modeling instruction without Socratic dialogue. Modeling instruction consists of 2 main stages, namely the Development Model which includes of pre-lab discussion, lab investigation, and post-lab discussion and Deployment Model consisting of worksheets, quizzes, lab practices, and unit tests. The implementation of Socratic dialogue in the modeling instruction at each meeting has different quantities. This treatment depends on the problems that arise for each session.

Based on observations obtained that there are differences in attitudes between students high and low metacognitive abilities presented in Table 2.

| Group of Students | Higher Metacognitive Ability | Lower Metacognitive Ability |
|-------------------|------------------------------|-----------------------------|
| Have a variety of problem solving strategies | Rely on examples of problem solving strategies from the teacher | |
| Analyze problems qualitatively before using mathematical equations (formulas) | Solve problems using mathematical equations that have been taught | |
| Linking problems with other related concepts | Does not provide material links with other concepts | |
| Give reasons for answers using self-composed sentences | Give reasons for copying answers from textbooks | |
| Writing answers is coherent, systematic and complete | Writing the answers is not complete and not complete (for example in unit writing) | |
| Can clarify the quantities of physics related to solving problems | Cannot distinguish the quantities needed in solving problems. | |

The learning treatment is ended by giving a problem-solving ability test in the modeling instruction + socratic dialogue class and the conventional class. Data of problem-solving skill is obtained after treatment.

Hypothesis testing is carried out after the normality and homogeneity prerequisite tests on the metacognitive ability data and physics problem-solving. Based on the prerequisite test results obtained that the ability to recognize data for the entire group is normally distributed and has a homogeneous variant. Hypothesis testing begins with the two-way Anava difference test for data on the ability to solve physical problems, the results of which are presented in Table 3. Hypotheses are accepted if the $F_{count} > F_{table}$ at a significance level of 0.05. After a different test, hypothesis testing is continued with a Tukey test to test the effectiveness of learning Socratic dialogue in modeling instruction on the ability to solve physical problems. The results of the Tukey test are presented in Table 4.
Based on Table 3, $F_{\text{count}} (A) > F_{\text{table}} (20.21 > 3.92)$ was obtained so that it was concluded that there were differences in the physics problem-solving abilities of students who studied with Socratic dialogue in modeling instruction and conventional welding. Further test results Table 4 of the first row ($A_1$ and $A_2$) shows the value of $F_{\text{count}} = 6.36$ is higher than $F_{\text{table}} = 3.74$). So, it can be concluded that the ability to solve physics problems of students who learn with socratic dialogue in modeling instruction is higher than conventional classes. The application of Socratic dialogue has a positive impact on the development of students' thinking abilities. Through Socratic dialogue, students can think actively and constructively in analyzing material to facilitate it in solving problems [9, 15].

The results of this study are consistent with the opinions of Jackson et al., [13] and Wenning [10] which state that Socratic dialogue can increase the effectiveness of learning when combined with modeling instruction. Lam's research [11] shows that the Socratic method can improve higher-order thinking skills, including problem-solving abilities [16].

Based on Table 3, $F_{\text{count}} (A \times B) > F_{\text{table}} (4.30 > 3.92)$, so it is concluded that there is an interaction between Socratic dialogue learning in modeling instruction with metacognitive abilities of students' physical problem-solving skill. Modeling instruction can build students' knowledge structures for the better. Students who have high metacognitive abilities have good knowledge structures so that students' ability to solve problems is getting better [3]. This fact is supported by Geiwitz [17] and Abdullah & Sulaiman [18], who state that metacognitive abilities affect the ability to solve problems. Its influence lies in controlling cognitive processes in students so they can think systematically in carrying out the stages of problem-solving [4]. In order to think systematically, students need to be guided using structured questions through the method of Socratic dialogue. This result is relevant to the statement of Redhana et al., [19] that in the process of problem-solving students use some thinking skills that can be guided by Socratic questions. The following graph presents the interaction between learning models, metacognitive abilities, and problem-solving abilities.
Based on testing using two-way ANOVA in the group of high metacognitive abilities, obtained $F_{\text{count}} > F_{\text{table}}$ (16.54 > 3.99), so it was concluded that there were differences in the ability of solving physical problems of students who studied with Socratic dialogue in modeling instruction and conventional classes in groups high metacognitive ability. Table 4 of the third row (A1 and A2 for B1) shows that the value of $F_{\text{count}} = 6.57$ is higher than $F_{\text{table}} = 2.76$, so it is concluded that the problem-solving skill of students who learn with Socratic dialogue in modeling instruction is higher compared to conventional class students in the high metacognitive ability group.

Socratic dialogue and modeling instruction are included in active learning. If students who have high metacognitive abilities do active learning, their ability to analyze and solve problems will improve. The reason is that students with high metacognitive abilities are accustomed to thinking actively and systematically so that active learning can support the students' skills. This result is in accordance with the opinion of Kingsley which states that Socratic dialogue is a method of learning based on constructivism that enhances student activity both thought and opinion [9]. Kingsley's view is supported by Asrori, who revealed that the level of metacognitive ability is not only influenced by internal factors, but also external factors in the form of environmental conditions [19]. So in the learning process, the types of models and methods used in class can affect the students' metacognitive abilities.

Based on testing using two-way ANOVA in the low metacognitive abilities group, $F_{\text{count}} > F_{\text{table}}$ (4.22 > 3.99) was obtained, so it was concluded that there were differences in the physics problem-solving skill of students learning with Socratic dialogue in modeling instruction and conventional classes in the group low metacognitive ability. Table 4 of the third row (A1 and A2 for B1) shows the value of $F_{\text{count}}$ lower rather than $F_{\text{table}}$ ($F_{\text{count}} < F_{\text{table}}; 2.42 < 2.73$) so that it is concluded that the problem-solving skill of students who learn physics with Socratic dialogue in modeling instruction lower than conventional class students in the high metacognitive ability group.

Learning by Socratic dialogue in modeling instruction is learning that requires students to think and communicate in solving problems actively. As a result, students with low metacognitive abilities have not been able to use the knowledge they have with maximal and do not have enough awareness of their abilities. This condition is in line with Piaget's thought [20] which states that the intellectual development of individuals is 90% influenced by heredity (self-potential / interests and talents) and 10% from environmental influences. Therefore, someone who has high self-potential will quickly develop even if they are in an unfavourable environment. However, for someone who has low self-potential, it is often challenging to create also though they are already in an excellent environment. Another factor that is thought to influence students' problem-solving skill is the lack of time for conducting research so that they cannot guide students in the low metacognitive abilities to the maximum. Therefore, students who have low metacognitive abilities in the modeling class instruction + Socratic dialogue do not show the results of the ability to solve physics problems better than conventional class students.
4. Conclusions
Based on the results of research and the results of hypothesis testing that has been done, it can be concluded as follows.

• The ability to solve physics problems of students who learn by modeling instruction + Socratic dialogue is higher than students who study with conventional learning.
• There is an interaction between modeling instruction + Socratic dialogue and students' metacognitive abilities of problem-solving skill.
• The ability to solve physics problems of students who have high cognitive abilities who learn by modeling instruction + Socratic dialogue is higher than students who study with conventional learning.
• The ability to solve physics problems of students who have low cognitive abilities who learn by modeling instruction + Socratic dialogue is lower than students who learn by conventional learning.

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