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THE EVALUATION OF PHYSICS STUDENTS' PROBLEM-SOLVING ABILITY THROUGH MAUVE STRATEGY (MAGNITUDE, ANSWER, UNITS, VARIABLES, AND EQUATION)

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Abstract

Problem-solving ability is very important to be developed in the process of learning physics especially in understanding the material of physics, both in concept, procedure analyses, and mathematical calculation. MAUVE strategy can help students as well as teachers in evaluating the extent to which students understand the concept of physics in accordance with the stages of problem-solving. The significance of this study are exploiting the way teachers to assess students' work in solving physics problems through MAUVE strategy and knowing physics students' problem-solving skills which were evaluated with the rubric developed by MAUVE. This paper applies descriptive quantitative research. The data collection uses test, observation, and interview. The result of this study is that MAUVE strategy facilitates teachers and students

in evaluating problems on the physics material. Students can evaluate themselves about what deficiencies need to be improved in solving physics problems. For teachers, MAUVE is one of the easiest strategies to resolve problem-solving skills, so it needs to be evaluated for what needs to be improved. MAUVE strategy needs to be further developed on other topics of physics

Keywords

Physics Problem Solving Evaluation, MAUVE Strategy, Physics Problem

1. Introduction

Curriculum changes in Indonesian education system are a form of responses to the demands of the 21st century. Formal education institutions at primary, secondary, and tertiary levels are intensively revitalizing the education system thoroughly in the facing of global competition. The revised 2013 curriculum causes problem-based learning and high order thinking skill a reference to the scientific approach (Kemdikbud, 2016). High Order Thinking Skill (HOTS) is the main capital for a person capable of becoming a competent and successful figure in the future. In school learning, it is needed and continuously developed through problem-solving skills, critical thinking, creative thinking, and also innovative thinking (Carlgren, 2013). Students as target objects are expected to develop intellectual ability in an effort to understand the concept of physics in (factual, conceptual, procedural and application).

Based on the latest ranking from PISA (2015), stated that Indonesian students have an index of problem-solving skills in the field of science, Indonesia is ranked 43 out of 50 countries in the world. This indicates that the literacy of Indonesian students in terms of problem solving skill is still under the need to be addressed. Therefore, problem-solving skills need to improved from an early age in the students. In the process of physics learning, teachers are expected to conduct an evaluation through the provision of problem-solving skills test (Chen et al, 2015). It aims to determine the development of student learning as well as evaluation materials for further learning. In addition, teachers should be able to design an integrated physics learning system with constructivist-based learning, where students seek their own information in solving physics problems (Sak, 2011).

Problem-solving abilities is a form of thinking categories that utilizes high-level reasoning in analyzing problems, evaluating answers and finding the solutions (Solaz-Portolés & López, 2007). Individuals with good troubleshooting, have many solutions when finding the

problems (Bing & Redish, 2009). Especially in the physics problem, the role of problem-solving ability does not only make students as experts in the field of theory but also on problem-solving and its application in daily life (Etkina, 2015). Physics problems have several types to solve namely quantitative problems and qualitative problems. Qualitative problems relate to basic concepts of physics that support mathematical calculations and can be applied to the field of science and technology. Quantitative problems relate to the way students solve physics problems based on mathematical procedures. Therefore, students must be equipped with good thinking skills in order to be able to solve problems quantitatively and qualitatively as well. The study conducted by Sujarwanto & Hidayat (2004) identifies the limitations of Indonesian students in solving physics problems, such as the translation of scientific language, the use of mathematical procedures and the physics concept.

1.1 Problem Identification

Moreover, evaluation on problem-solving skills requires a strategy whereby students and teachers engage simultaneously in evaluating the learning of physics. Adams & Wieman (2015) have reviewed that students have many types of answers in solving physics problems according to their conceptual understanding. However, in relation to this, the teacher has a limitation of the penalty rubric that includes some types of the student's answer. This affected the teachers' inassesing the students. The evaluation rubric of physics problem-solving skills has been widely developed by experts, but this is only limited on the measurement without helping the students and teachers in checking their answers. The involvement of teachers and students is a major factor in the evaluation of problem-solving physics. Some of the indonesian physics teachers did not develope the evaluation rubric to evaluated problem-solving abilities of students in the physics problem. Based on the initial observation was done at Islamic senior high school of pujon that the result in 76% of students answered about difficulties of solving the physics problem.

One strategy that can integrate teachers and students to evaluate problem-solving skills is MAUVE (Magnitude, Answer, Units, Variables, And Equation). The MAUVE strategy can help students working on the tasks according to the procedure and evaluating their own tasks through the developed rubric. Evaluation is done by showing the student's lack of answers to be corrected and explained again. The principle of MAUVE strategy evaluation is that teachers and students have an advantage in evaluating the learning of physics. Teachers provide assessment according

to the ability of students with fair, transparent and honest; while students are able to learn independently and satisfied will the assessment provided by the teacher. Therefore, this research wants to explain about:

- Exploring how teachers evaluate the students' problem-solving skills through MAUVE strategy
- Knowing significance the students' physics problem-solving abilities at the various levels evaluated by the MAUVE strategy

2. Theoretical Review

2.1 Student Problem Solving Ability on Physics Problems

The ability of physics problem-solving is the individual ability to solve physics problems both in terms of concept and mathematic through logical and correct procedures (Hegde, 2012). Students should have a basic ability to find solutions to physics problems. Heller (2013) explains some of the problem-solving abilities procedures individuals can pass through in solving physics problems as follows: *First,* the students must understand the problems. *Second,* the students must have alternative plans related to the solution of the problems. *Third,* the students must choose right solutions such as equations, concepts, and facts right. *Fourth,* the students must pay attention to any variables associated to the problem. The procedure assists students to organize the mindset that the direction of the problem solution exists.

There are two types' problem-solving abilities of the students', beginners and experts (Hull, Kuo, Gupta, &Elby, 2013). The beginners tend to understand the problem in terms of quantitative and the experts view the problem in terms of conceptual (Harper, 2012). The experts are able to develop an overview of problems outside of the basic principles and supporting theories. While in beginners are still fixated on facts, principles and rules are in the theory of physics. This difference will be a challenge for teachers in applying appropriate methods and evaluation so that all the students' skills at both low and high levels can be accommodated.

In solving physics problems, students have some help in solving and representing the problems. The assistance is in the form of representation, tables, images, and mathematical equations as a tool (Cock, 2012). Students may choose aids that match the characteristics of the physics problem (Sherin, 2006). Their difficulties are usually a way of identifying the fit between physics concepts and multi-representation (Nguyen & Rebello, 2011). Therefore, some things

need to be exercised in the ability of problem-solving physics. *First*, practice working on a difficult problem. It aims to get the individual accustomed to difficult things, so easy to solve other problems of equal or higher level. *Second*, read regularly. Reading habits become an inspiration as an alternative to finding alternative solutions. *Third*, form a group disscusions. Groups Discussion a means of exchanging opinions, providing advice or solutions through peers. Peer tutors which is included in groups dicussion is helpful increasing the students knowladge. The effectiveness of peer tutors results in a lack of student knowledge. *Fourth*, consult with experts in the field of physics. Students may consult with physics teachers or physics consultants such as astronomer, geologist, instrumentation physicist and theoretical physicist.

2.2 MAUVE Strategy in Evaluating Physics Problem Solving Abilities

Physics material has a very complex branch of science, allowing students and teachers to have misconceptions in understanding and solving problems. Evaluation is required with conformity to each of the physics material topics. The MAUVE strategy was firstly developed by Nicole Breanne Hill of Cornell University. The purpose of evaluation using MAUVE strategy is a basic guide to exercise for students in solving physics problems both topics on basic physics as well as modern or advanced physics. The students are expected to remember easier in the long term without having to memorize so it is not easy to forget. The MAUVE strategy has its advantages as it presents the form of problem representation through direct observation, analogous thinking and supplemented by a judgment rubric according to the need only (Hill, 2016). The teachers only check the student's answers on certain sections that are needed to be evaluated (Mohhotalla, 2016). The learning pattern developed by MAUVE strategy makes the student as a reliable problem-solving agent with all the thoroughness in solving the physics problem.

The MAUVE strategy has five assessment components developed in the rubrics with each contained in Figure 2.1 are as follows (Hill adaptation, 2016).

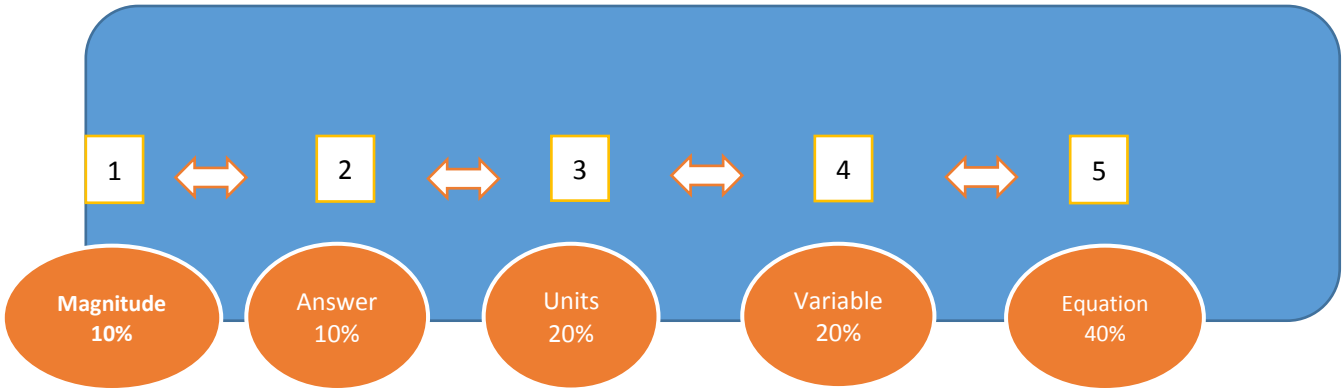


Figure 1: *Component rubric of physics problem-solving skills through MAUVE strategy*

Figure 2.1 explains that the assessment of the work or task students have components with the total number of components up to 100%. In detail, described in the following points:

- Magnitude

  The magnitude component is the overall examination of the sequence of responses according to the reality of the desired answer with a 10% on label number 1. At this level, the students and the teachers check overall deficiencies in the procedures, outcomes, and processes of students in solving physics problems.

- Answer

  The answer component is the absolute truth of an answer with a maximum score of 10% on label number 2. At this level, the students answer the number or logical statement that is the key to the solution of the problem.

- Units

  Component units are in conformity with the size and physics unit set with a maximum score of 20% on labeling number 3. At this level, the students' ability to recognize the magnitudes and units that are universally recognized to find good procedures in solving physics problems

- Variables

  The variables component are the coverage of the required identification of variables and is present in the problem with a maximum score of 20% on label number 4. At this level, this is important for the students to identify the equations that are suitable to follow-up in substitution numbers.

- Equation

  Equation component is the accuracy of using of the formula and its relevance to the concept of physics, entering the numbers and units correctly with the maximum score of 40% on labeling number 5. At this level, students execute the existing problems with the equation in accordance with the concept.

In the process of evaluating problem-solving skills, students and teachers follow several procedures in performing tasks and evaluating student answers. Figure 2.1 explains that students are working on questions starting from points 5-1 and checking their answers starting from points 1-5. The same thing for teachers in evaluating student work starts from points 1-5. This kind of procedure makes the evaluation of student work become regular and easy in calculating students' problem-solving abilities in physics.

According to Hill, (2016) and Heller (2013), there are several cycles that students need to go through in the MAUVE strategy in solving physics problems. *First,* looking at the question of existing solutions. This stage is useful so that students are not biased in interpreting the known concepts of physics. *Second,* using several representations to help such as drawings, graphs, and diagrams so that students are easier to understand the concept of physics based on the analogy of student thinking with some help. *Third,* noting the variables that do not appear in the problem. Students are trained to criticize the problem. *Fourth,* using correct equations in solving problems in accordance with the concept, the facts of the principle that exists. It is useful for students to be able to manipulate equations. *Fifth,* making symbols that are easy to understand, but the values cannot be entered. *Sixth,* analyzing the units, dimensions before cross check with numbers. *Seventh,* substituting the numbers on the variables already identified and perform the calculations. *Eighth,* stopping to the work by circling the final answer and continue the cycle from the first cycle. Teachers can provide an evaluation of the students' answers in two ways: asking some questions about what is written on the answer sheet and giving input to the students answer sheet to recheck the missing answers.

3. Methodology

This research used a quantitative descriptive method. In collection the data, the researcher uses observation, test and direct interview with the students and the teachers. This research aims to explain the percentage and rank the ability of physics problem-solving student at the level of

magnitude, answer, units, variable and equation and overall total score. The subjects were 30 students of Islamic Senior High School of Pujon who had finished the topic of work and energy in the academic year 2017/2018. The technique of taking the research subject uses purposive sampling. This research used three kind of essay test model by following the standard of the problem-solving rubric. The materials tested topic were the work concept, work-energy theorem, and energy conservation law. In detail, the instrument of question is adopted from Knight's book (2015).

Below is the rubric of evaluation of physics problem-solving skills through MAUVE strategies conducted by teachers adapted from (Hill, 2016), and listed in Table 3.

Table 1: *Distribution of Physics Problem-Solving Rubric by MAUVE Strategy*

Steps Level	**Assessment Indicators**
Magnitude (10%)	Zero is given if the students answer is wrong; the sequence is incorrect starting from the magnitude or the mark and/or direction. Score 0.25 is given if the students answer is wrong, but the sequence is true starting from the magnitude or the mark and/or the direction Score 0.5 is given if the students answers is correct, but the order is wrong starting from the magnitude or the mark and or direction Score 1 is given if the students answer is correct as well as the order
Answer (10%)	Score 0.5 is given if the students answer is correct with absolute number. Score 1 is given if the students answer is correct and circle the answer
Units (20 %)	Score 0.5 is given only if the students answer includes a unit Score 0.5 is given if the students answer only cover of the description the dimensions of problem-solving Score 1 is is given if the students answer covers both the indicators above
Variable (20%)	Score of 0.5 is given if the students are able to construct variables regarding the problem Score 0.5 is given if the students only list the numbers in the equation Score 1 is given if the students answer covers both the indicators above
Equation (40%)	Score 0.5 is given if the students use the equation correctly Score 1 is given if the students use the correct equation according to the relationship between the variables being asked

4. Results and Discussion

4.1 The Teachers evaluate the Students' worksheet by MAUVE strategy rubric

Based on the students worksheet, the teachers showed the evaluation result that follow MAUVE strategy steps and rubrics. The work topic example explains how the students find solutions based on the teacher's built-in answers through the MAUVE strategy. Problem in Figure 2 describes how students describe the workn concept of each image with angle and force variations.

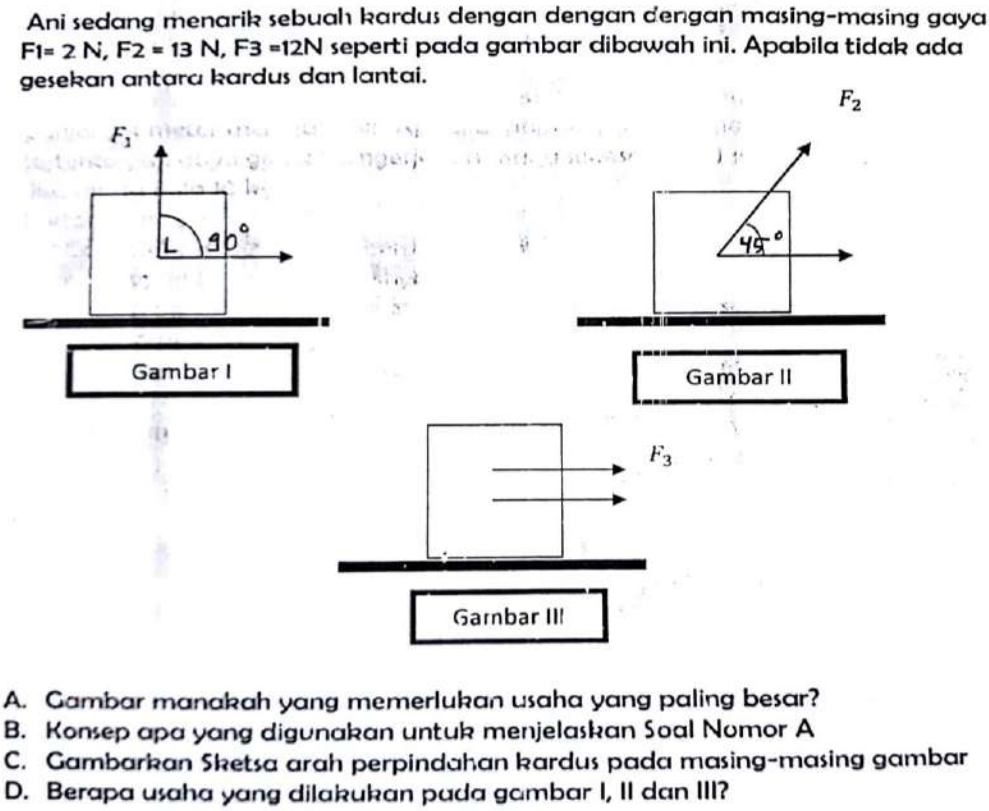
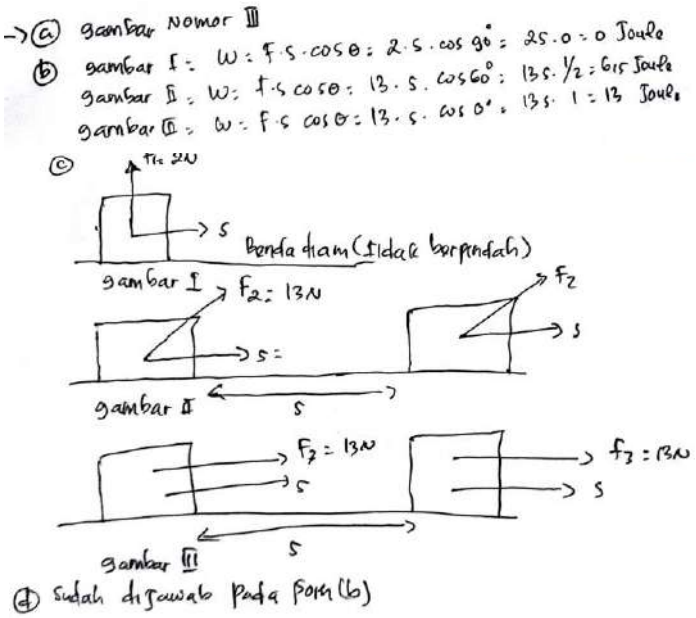


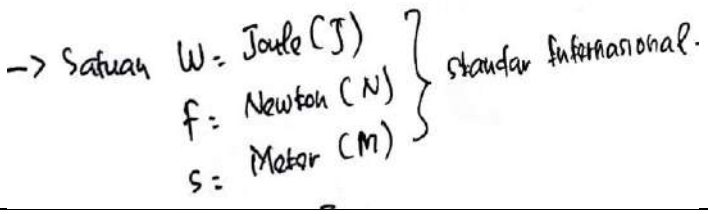
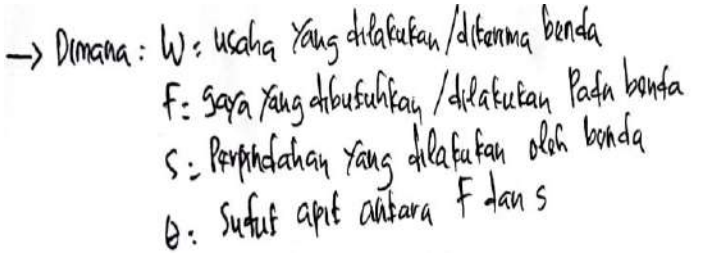
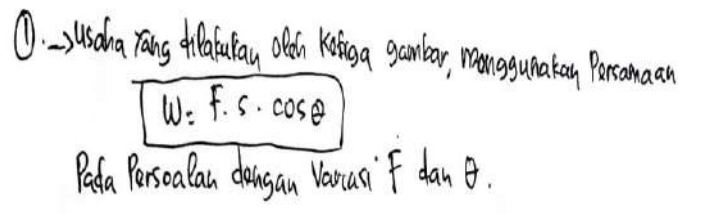
Figure 2: *Examples of Problem about Work Concept Topics*

The steps taken by students in finding solutions to the problems of physics are as follows:

- The students determine the equation through basic concepts
- The students determine variables and analyze dimensions
- The students substitute the numbers into the equation
- The Students evaluate the final solution

Table 2: *The Teacher Evaluates one of the Students' Answers on the Work Topic*

Steps level	The Students' Answer	The Teachers' Evaluation
Magnitude (10%)	This section explains the final answer of the students who are already believed to be true. The teacher evaluates the students to sort the answers according to the rubric developed by MAUVE. Rubric on the MAUVE strategy helps the systematic thinking process for students when solving physics problems	From this part, The teacher gives a complete score for the students because the student has answered in sequence from an equation to answer level.
Answer (10%)	The students substitutes the number and gives the  correct answer according to the problem	From this part, The teacher gives a complete score for the students because the students have answered absolutely in accordance with the problems that ask.
Units (20 %)	The Students write an international unit and analyze the dimensions of all the variables according to the solution	From this part, The teacher gives score 0.5 because the student simply describes the units of the variable without dimensional

	of the problem  	analysis on each variable. The variables' unit in accordance with an international unit that is a joule
Variable (20%)	 The students describe the physical meaning of any variables that exist in the problem	From this part, The teacher gives a complete score for the students because the student writes the complete and describes the physical meaning of the variable asked on the problem solution
Equation (40%)	The students write down the equations that fit the problem  	From this part, The teacher gives a complete score for the students because the students wrote the complete equation that is asked about the problem

4.2 Evaluation Results of Physics Problem Solving Ability at MAUVE Strategy

The evaluation of students' physics problem-solving ability is done through 3 essay test questions. The researcher categorizes several students' problem-solving abilities into three scoring categories: *First*, for magnitude and answer are categorized as follows: 7% -10% for a very satisfactory category, 4% -7% for a satisfactory category, and 0% -4% for category less

satisfactory. *Second*, for units and variables are categorized as follows: 14% -20% for very satisfactory category, 7% -14% for satisfactory category, and 0% -7% for less satisfactory category. *Third*, for equation is categorized as follows: 28% - 40% for very satisfactory category, 14% -28% for satisfactory category, and 0% -14% for less satisfactory category. Assessment of students' problem-solving abilities using the categories developed in the assessment rubric through the MAUVE strategy.

Based on the results of data processing, obtained the average percentage of students physics problem-solving abilities in some category level and weight assessment as in table 4.1.

Table 3: *Category of student problem-solving abilities on work and energy topics based on MAUVE strategy*

No	**MAUVE Strategy of Level**	**Percentage Ability of Students to Solve The Physics Problems**			**Average**	**Category**
		The Topic of Work Concept	*The Topic of Work-Energy Theorem*	*The Topic of Energy Conservation Law*		
1	Magnitude (10%)	6.76%	6.98%	6.55 %	**6.77%**	Satisfying
2	Answer (10%)	6.93%	7.03%	6.89%	**6.95%**	Satisfying
3	Units (20%)	14.02%	14.01%	14.11%	**14.1%**	Very Satisfying
4	Variable (20%)	14.93%	14.50%	15.06%	**14.83%**	Very Satisfying
5	Equation (40%)	27.93%	27.73%	29.94%	**28.53%**	Very Satisfying
Total of percentage					**71.13 %**	

Table 4.1 shows almost all of the student Islamic Senior High school of Pujon have the ability in category in solving problem in satisfactory level or good (71,13% from 100%). The

achievement proves that MAUVE strategy is effectively used in evaluating students' physics problem-solving abilities. At magnitude and answer levels, students have problem-solving abilities with satisfactory predicates. It indicates that the student is able to digest the truth information of the physics concept, but it is less precise in ordering the magnitude and direction. At the unit and variable level, students have a problem-solving ability with a very satisfactory predicate. It indicates that the student is able to identify the right variable, analyze the unit and physics dimension well. At the equation level, students have problem-solving skills with very satisfying categories. The majority of students is able to use appropriate mathematical equations, but cannot describe with their physics conditions based on existing problems, so that the score achieved by students is not maximum. The MAUVE strategy basically distinguishes evaluation in terms of mathematical equations and the elaboration of physics concepts. These two important points are used as the basis for the direction of problem-solving physics for a problem solver.

Based on the results of observation and interviews with students, there is information about students' physics problem-solving abilities on work materials and energy. Identification is done through direct questioning and observation shortly after doing the test. Like the following question, *"Teacher: What do you use the concept to solve the problem in the three images above? Student answer: the concept used is the concept of force, with the force is the result of multiplication between the mass and acceleration"*. After matching analysis between the answer sheet of students with questions when interviewed was different from that already done. An inconsistent answer illustrates that the student has not used the concept as a basis for solving a physics problem. They assume that mathematical equations are the only way to solve problems without going through qualitative analysis first. One suitable solution to apply to this problem is through changing student strategies in solving physics problems.

The researcher identified that students were difficult to get the maximum score in solving the problem due to the low of the independence learning, cheating habits, difference learning force, and understanding the problem. The same thing also conveyed by Lorenzo, M (2005). He states that the students are difficult to solve the problem because of the low cognitive structure. Cognitive structures play an important role in helping to direct students' reasoning, displaying critical thinking ideas in addressing conceptual and mathematical issues in physics (Ibrahim &Robello 2012, Pol et al, 2008). Through the MAUVE strategy, it directs the cognitive

structure of students through the combination of long-term and short-term memory. Students become accustomed to procedural steps so that the concept of physics is not easy to forget.

4.3 Total Scoring of Student's Physics Problem Solving Ability

Besides measuring each level of MAUVE strategy, teachers can also ranking the students' problem-solving abilities by making table of the total score for each topic. The discussion aims to make students and teachers know the overall test results problem-solving ability. In addition, students who get the score still need less improvement. In detail, the distribution of students' problem-solving abilities described in Figure 4.2 is as follows

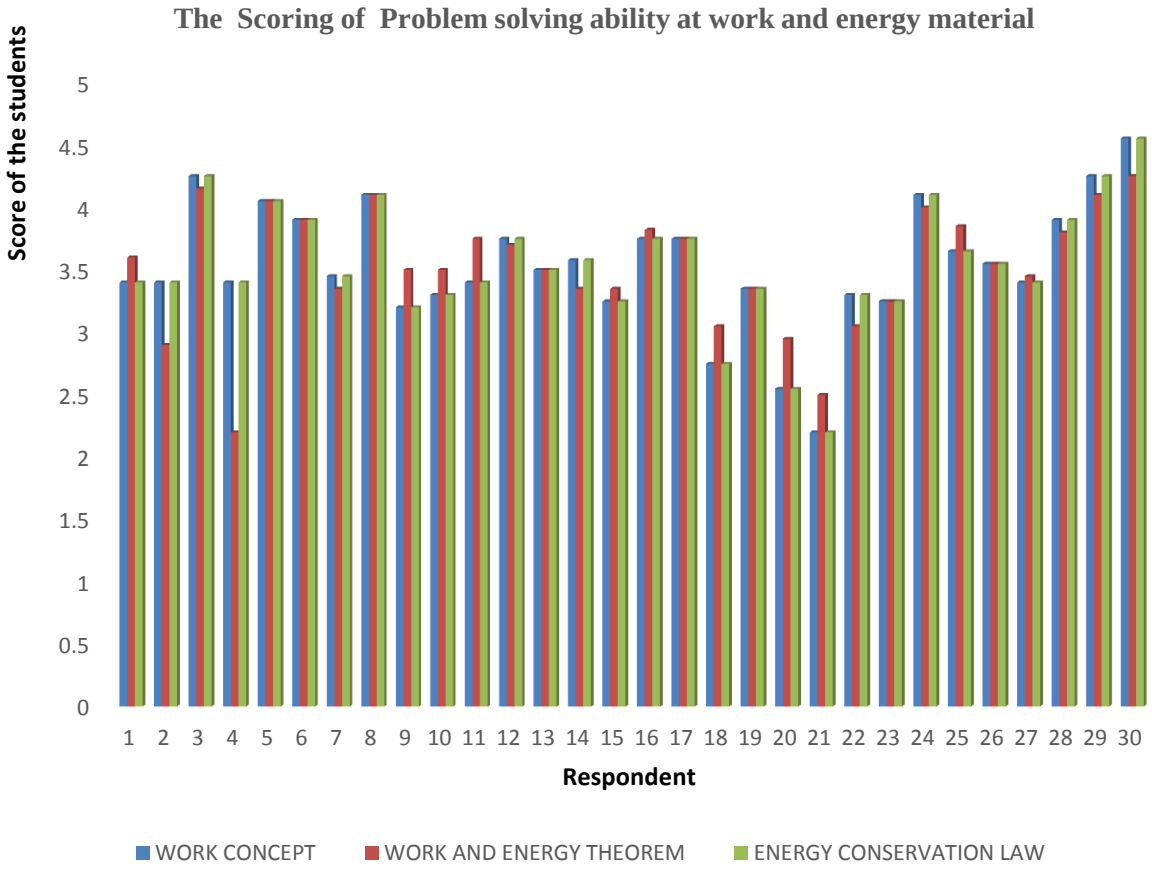


Figure 3: *Graph of the score achievement ability of Student Physics Problem Solving*

The maximum score achieved by students in 3 test questions is 5. In topic of work concept, it shows that the highest score obtained by 1 person, scored 4.55. While the lowest (2.55) was obtained by 2 people. In the topic of work-energy theorem, the highest score was obtained by 1 person, 4.25. While the lowest (2.55) was obtained by 1 person. In the topic of

conservation energy law, it shows the highest score obtained by 1 person, scored 4.25. While the lowest (3.00) was obtained by 1 person. The category of students who get the lowest position will be enriched with test models of the same type as before. For students who are able to answer the problem correctly become a tutor for their friend.

Several issues related to the identification of the effectiveness of MAUVE strategy implemented in evaluating the ability of problem-solving physics in high ability students. The results of interviews and review of worksheets, it was identified that the students who had higheset score could be able to be evaluated by MAUVE strategy. Belows are the descriptions of the students' condition:

- They have good motivation in learning through the MAUVE rubric given by the teacher. Students are satisfied with the assessment that gives the teacher and be motivated to learn well again.
- They are making to check their own answers independently through the MAUVE strategy rubric. In checking the process, students become familiar with the precision taught by the MAUVE strategy
- They are expanding their concepts to link that other complex for the physics problems.
- They are changing of their mind that physics is not considered to be difficult to learn anymore and there is no fear of students when faced with an exam.
- They are accomodating the mathematical equation and the physics concept to solve the physics problem.

5. Limitations of Research

The limitations of this study based on field fact analysis experienced by researcher while doing research. Some of the weaknesses when doing the research were obtained through interviews on students who received the lowest score when answering the matter of physics. That was as follows:

- The students were not ready yet in finding the alternative solutions for solving physics problems
- The students faced difficultees in analyzing units and dimensions contained in the preceding material on quantities and units.

- The students are fail to understand the correct procedure in solving physics problems. The pattern of problem-solving is only found in mathematical calculations without explaining the concept used unexplored.
- The students did not apply optimmally MAUVE strategy an accurally to evaluate their problems. They did not relate their cognitive ability to resolve physics problem.
- The MAUVE strategy can not evaluate a qualitative problem physics. So that, the other researcher can develope it with another methods.

6. Conclusions and scope the scope of future research

The MAUVE strategy is able to evaluate students' physics problem-solving abilities on work and energy materials. It is characterized by the success of students in solving the problem through a total score obtained the percentage of 71.13%. Based on each category level, the students get the average score on each assessment indicator as follow as: The magnitude level has effectiveness of 6.77% from 10%, the answer level is 6.95% from 10%, the unit level is 14, 1% from 20%, variable level 14.83% from 20%, and equation level 28, 93% from 40%. The above indication illustrates that students' physics problem-solving skills are in very satisfactory or good enough category. Some of the advantages that the MAUVE strategy is able to assess on each component of the answer as well as to resolve the student's answers objectively. Students feel satisfied with the results of the teachers' assessment and evaluate their own answers. Physics learning becomes effective when using MAUVE strategies in evaluating individual student abilities either through formative or summative evaluation.

The research that has been done makes MAUVE strategy a reference in evaluating students' problem-solving abilities. MAUVE Strategy have strength to evaluate of certain the students worksheet who teachers need. Beside that, it can grow the students' spirit to try in solving the physics problem (Hill, 2016, Teodorescu et al, 2013). The long-term memory effect of the students is more honed with the MAUVE evaluation strategy. The teachers and the students will work together in evaluating problem-solving abilities. For future researchers, The MAUVE strategy can be a reference to other physics materials, especially in analyzing the problems of physics that are qualitative. The teachers can mix MAUVE strategy with the other methods in evaluating the students ability.

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