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Analysis of Solving Physics Problems Using The Minnesota Model for Mechanics Concepts

Muhammad Syukri [1*)], Elva Sesioria Putri [2], Musdar [3], Lilia Halim [4]
Universitas Syiah Kuala, Indonesia[1,2], Universitas Serambi Mekah, Indonesia[3], Universiti Kebangsaan Malaysia, Malaysia[4]
[*)]Corresponding E-mail: syukri.physics@unsyiah.ac.id

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ABSTRACT
The purpose of this study is to analyze students' ability to solve physics problems in mechanical materials using the Minnesota problem-solving model. The research method used is descriptive qualitative research. The population in this study is class XI IPA MAN I Banda Aceh students with 10 subjects. The instrument in this study uses a description test with 5 questions. The results of this study are shown to analyze the process of students in solving physics problems that require a high level of thinking, the way students understand concepts, describe problem situations, plan solutions, carry out solutions and evaluate answers. Based on the results of the study, the average student could use the Minnesota problem-solving model in answering physics questions and using this model students are skilled at selecting relevant information, then analyzing it and finally re-researching the results.

INTRODUCTION

Education in the era of globalization requires students to have high-order thinking skills, thus to realize this, an update of the educational curriculum is carried out followed by updating exam questions using high-level questions or so-called HOTS questions. School exam questions, final exams, and college entrance examinations are questions that require the ability to analyze, evaluate and create. The ability to think at a high-level trains logical and critical thinking. In solving physics problems, when students are given problems, many of the students are unable to solve these problems. Students do not know how to solve the problem because students tend to have difficulty understanding the problem [1].

Students are able to solve simple quantitative problems in physics learning but are less able to solve complex problems and students have difficulty in solving problems that integrate mathematical abilities. It is contrary to the purpose of learning physics, namely creating individuals who are able to solve complex problems through the application of the knowledge they get. [2] [3] [4]. Every problem requires solving, as well as the difficulty of students in solving physics problems is also needed to solve it. Problem solving is an effort to stimulate learners through the process of analyzing and understanding with strategies to achieve specific goals, namely success [5] [6] [7]. Problem solving

involves recalling the rules and applying steps with a thought process that will lead the learner to the expected answer. In the thought process, students need a series of stages that could solve the problem [8] [9].

The importance of a problem solving is needed for a problem-solving model that appropriates for the problem. Physics learning is learning that requires students to think and process in understanding concepts, analyzing problems, and finding solutions and applying these solutions to solve problems. Problem solving models are widely used in physics learning, one of which is the Minnesota problem-solving model. The Minnesota problem-solving model is a general model of solving physics problems pioneered by two physics education researchers, namely Patricia Heller and Kenneth Heller from the University of Minnesota, USA. In the Minnesota problem-solving model there are five groups of problem-solving strategies: focusing on the problem, formulating physics, designing answers, executing the design and re-examining the answers [10] [11] [12]. The stages and substages of the Minnesota problem-solving model could be seen in table 1.

Table 1. The Stages and Substages of The Minnesota Problem-Solving Model

The Stages of the Minnesota Model	The Substages of the Minnesota Model
Focusing on The Problem	1. Sketching questions 2. Writing down the question information 3. Determining the questions 4. Choosing physics concepts related to the problem
Describing The Physical Situation	1. Illustrating a physics diagram 2. Identifying physics magnitudes on diagrams 3. Determining mathematical-physical relations
Planning Solution	1. Choosing a specific physics formulation 2. Looking for physics formulations for equations of unknown magnitude 3. Substituting the results of an unknown magnitude equation to the initial equation
Implementing Solution	1. Entering numbers and units of equations 2. Converting units if needed
Evaluating Answer	1. Checking that the answer has been stated appropriately 2. Checking that the answer makes sense 3. Stating the final result

This Minnesota problem-solving model is often used at the college level, but this Minnesota problem-solving model is rarely used at high school level, therefore researchers are interested in conducting research by looking at how learners solve physics problems using the Minnesota problem-solving model. Physics subjects have very complex characteristics. Learning Physics involves the ability and skill of physical interpretation, transformation of magnitudes and units, mathematical logic, physics problems that require a high level of thinking such as contextual questions that require visualization / depiction of the purpose of the problem and accurate numeracy skills, a solution model is needed that is able to direct students in solving the problem [13] [14].

METHOD

This research is a qualitative research that is observed is the process of students in solving problems to get research results. The qualitative approach also allows the researcher to gain a deep understanding of the case. The subjects in this study are 10 MAN 1 Banda Aceh students who are selected based on similar ability levels. The data collection technique is a written test, students are given 5 essay questions in a test of understanding concepts about mechanics. The student's steps in solving the problem will be analyzed based on each stage of the Minnesota problem-solving model. The data is

analyzed by examining the accuracy of students' responses using the Minnesota Model stages. The questions provided are solved by students using the Minnesota Model, and researchers will analyze students' answers based on the accuracy and appropriateness of each stage and its respective sub-stages in the Minnesota Model. The students' answers will be analyzed in detail for each sub-stage. Overall, the analysis aims to determine whether students' responses using the Minnesota Model stages can lead to correct answers and guide students in the thinking process.

RESULTS AND DISCUSSIONS

Minnesota's problem-solving model has five stages. The following will be analyzed the results of the learner's answers based on each stage of the Minnesota problem-solving model.

Focus on The Problem

The focus on the problem includes the activity of qualitatively describing the problem, namely visualizing the situation using sketches, writing down what is known and what is asked. Each student's response in this stage is analyzed by examining whether the student correctly incorporates all four sub-stages and obtains a coherent result for the next stage. On average, the students performed well in the problem-focused stage. They were able to select relevant physics concepts related to the problem, create a problem sketch, write down the given information, and formulate questions. Their ability to do so indicates that they have a good understanding of the problem and can effectively engage in the problem-solving process. The following are the results of students' answers at the stage of focusing on the problem.

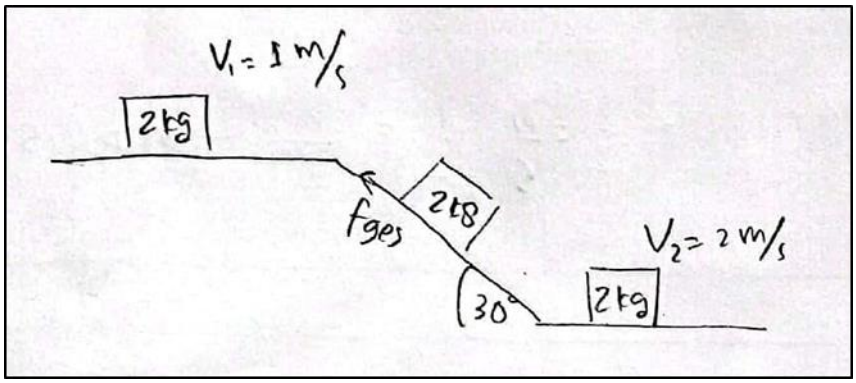

***Fig 1**. The Sample of The Students' Answers Results at The Stage of Focusing on The Problem*

Based on figure 1 at the stage of focusing on the problem, students are able to visualize images based on the problem. This problem contains three states, at first the 2 kg mass object is in a slippery flat plane with an initial speed of 1 m/s then the second state of the object descends the rough inclined plane with a friction force, in this second state students are able to describe the presence of a friction force that goes against the direction of motion of the object. The third state, the beam is in the second slippery flat plane at a speed of 2 m/s. In the picture, there is a difference in the height of state one and state two which is the question on the question, hence students are able to visualize the question in the question.

Good understanding of physics concepts and literacy skills create students who are able to visualize the situation of the questions and translate the question information into pictures. Cognitive activities by collecting information and organizing in the form of understanding the concept of the problem and connecting the concept to the question could help students easily answer the question. The first stage of this model involves deepening the problem situation, selecting facts, connecting facts and making questions strongly influenced by the knowledge that a person has. If the question information is consistent with knowledge, then the problem could be solved easily. This is in accordance with the

statement that the step of understanding the problem strongly emphasizes the success of obtaining a solution to the problem. The stage of focusing on the problem requires students' understanding of physics concepts, thus it is correct in the next stage, namely describing the situation and planning solutions. [15] [16] [17] [18].

Describing The Physical Situation

Describing a physical situation is related to using qualitative understanding to prepare quantitative solutions. In this case, first simplify the situation in the form of a physics diagram equipped with known physical magnitudes, then complete it with the question using specific mathematical variables or necessary physics concepts. Each student's answers are analyzed at this stage by examining whether the students correctly include all three sub-stages and obtain consistent results for the next stage. On average, students are able to complete their answers in this stage. The following are the results of students' answers at the stage of describing the physical situation.

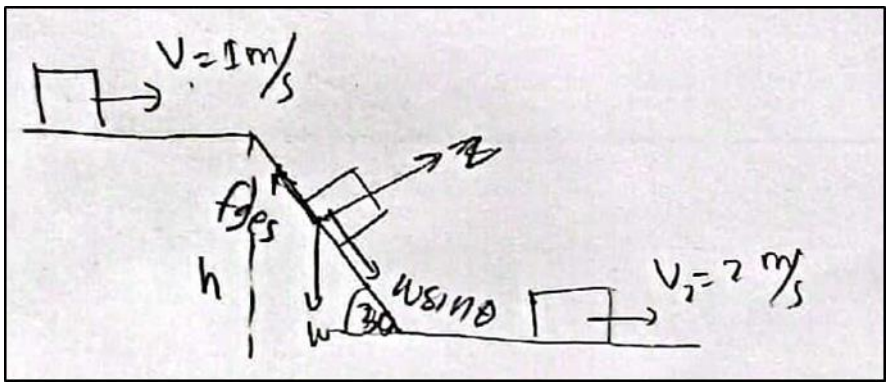

Fig 2*. The Sample of The Students' Answers Results at The Stage of Describing The Physical Situation*

Based on figure 2 at the stage of describing the physical situation, students are able to draw physics diagrams for the magnitude of the initial velocity (vo), the final velocity (vt), the mass of the object (m), the friction force (Fges), the normal force (N), the weight force opposite the friction force (w sin θ), the length of the trajectory of the inclined plane (s) and the height of the inclined plane or the difference in the height of the trajectory one and two (h). Students are able to write down and identify known physics quantities, namely vo,vt,m, Fges and unknown quantities, namely N, w, w sin θ, s and write down question questions in physics magnitudes, namely h. Students are also able to write down mathematical equations based on the principles of physics, Newton's law II equations $\sum F = ma$, and GLBB equations $v_t^2 = v_0^2 + 2as$. The students take this equation because before looking for the height of the inclined plane, it is necessary to find the length of the inclined plane, that is s, and use the sine formula to find h (height).

The stages of planning a solution by describing a physics diagram and writing down the question information in the form of a known magnitude, asked and unknown magnitude help the student in solving the problem, could be observed from the student's answer process by describing a large diagram could help students discover the principles of physics, such as student answers that describe objects moving on an inclined plane and experiencing frictional forces so that the selected physics concepts and principles true that is particle dynamics and frictional force at a later stage. This is in line with the opinion that the format of visual representation in images, graphs, and models could reduce some misconceptions in students because students are able to understand concepts optimally and create a good mindset and communication so that a structured perspective is formed [19].

This stage also allows students to connect mathematical principles with the principles of physics, seen from student answers that connect the heights, trajectory and angles of inclination of inclined planes with the concept of sine in mathematics. Solving physics problems couldnot be separated from understanding mathematical concepts. This is in line with the opinion that mathematics is a tool to be able to solve physics problems, in looking for physical magnitudes the need for mathematical skills so

that to be able to master physical sciences, you must be able to master mathematics first. Physics is a part of science that has a correlation with mathematics. Mathematics and physics have a close relationship, namely mathematical methods are used in physics and concepts, opinions and ways of thinking physics are used in mathematics [20] [21] [22].

Planning Solution

Planning solution includes translating physics images into mathematical equations and physics concepts according to steps, looking for relationships between or deriving existing equations, as a result a new equation is obtained and examining whether the new equation gives the correct units. Each student's answers are analyzed at this stage by examining whether the students correctly include all three sub-stages and obtain consistent results for the next stage. On average, students are able to substitute the results of unknown quantity equations into the initial equations, obtaining a new equation, and examine the units of the new equation. They also select specific physics formulations to answer the questions and search for physics formulations to obtain the results of the unknown quantity equations. The results show that, on average, students are able to solve problems using this sub-stage. The following are the results of students' answers at the stage of planning solution.

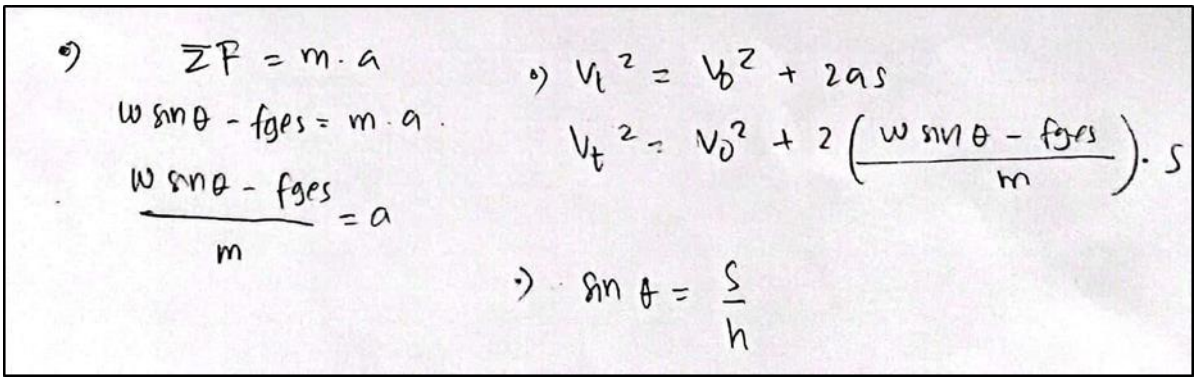

Fig 3*. The Sample of The Students' Answers Results at The Stage of Planning Solutions*

Based on figure 3 at the stage of planning a solution, students get the specific equation needed for the problem, namely $\mathrm{w}\sin\theta - fges = ma$, this equation is obtained following the physics diagram in the second stage, the direction of the $fges$ is opposite to $\mathrm{w}\sin\theta$ and the system experiences a movement in the direction of $\mathrm{w}\sin\theta$, then the student gives positive and negative signs to distinguish the direction of the two magnitudes. The equation is used to find the value of the equation (beam acceleration) which is then subtituated into the equation of straight line motion with constant acceleration, that is $v_t^2 = v_0^2 + 2as$. This straight line motion with constant acceleration equation is used because there is a difference in initial velocity with final speed and the system experiences acceleration when descending an inclined plane. The way for students to find unknown quantities is the magnitude s (the length of the trajectory of the inclined plane) and to find the quantity asked is obtained by the sine triangle formula, namely $\sin\theta = \frac{\boldsymbol{perpendicular\ angle}}{\boldsymbol{hypotenus\ angle}} = \frac{h}{s}$, so that students get the value of $h = s\sin\theta$.

This third stage students must think of physics formulations that are in accordance with the specified physics principles. At this stage, students are able to choose physics formulations, this happens because of students' understanding and mathematical abilities. In line with the opinion that in planning solutions requires the ability to transform problems into mathematical models and corrects solving strategies. The students who have solved problems with the right process could solve problems correctly. The students who have high understanding and mathematical ability will easily understand physics concepts and solve physics calculation problems and connect various information [23] [24] [25] [26].

Implementing Solution

Implementing solution is to solve the problem by entering the umbers (quantitative) within the complete problem with the units used, thus that what is the target of the problem is obtained. Each student's answers are analyzed at this stage by examining whether the students correctly include the two sub-stages and obtain consistent results for the next stage. On average, students are able to input the given information correctly in the problem. However, on average, students do not use units for each quantity, resulting in some students being unable to check whether the units for the new equation are correct or if unit conversion is necessary for specific problems. The following are the results of students' answers at the stage of Implementing solution.

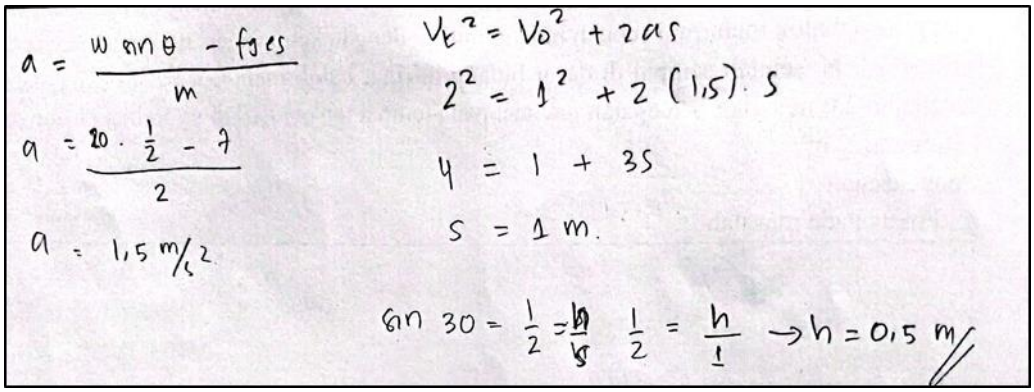

***Fig 4**. The Sample of The Students' Answers Results at The Stage of Implementing Solution*

Based on figure 4 at the stage of planning solution, students are able to enter known numbers in the problem into the equation made, but students write down the numbers with the units. The writing of complete quantities with units is very important for equations, as to know the right and wrong of an equation obtained could be proven by the similarity of the final unit obtained with the units in literacy. The student's answer in the figure 4 only writes the unit at the end of the result following the unit in literacy. The process of answering the question by entering a complete number with units makes the answer more accurate. At this stage, the average students are able to enter numbers and units into the equation.

Evaluating Answer

Evaluating answer is to double-check all the work that has been done, see the accuracy of the answers, the completeness of the answers, whether the answers are well-founded or not and the suitability of the answers to the questions in the problem. Each student's answers are analyzed at this stage by examining whether the students correctly include the three sub-stages At this stage, on average, students are able to write and state the final answer. However, on average, students are not yet able to check whether the answer has been stated appropriately and whether the answer makes sense. The following are the results of students' answers at the stage of evaluating answer.

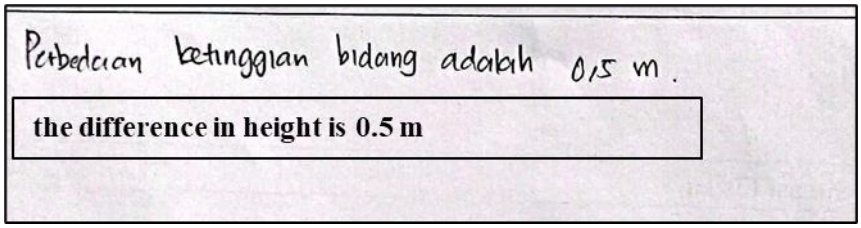

***Fig 5**. The Sample of The Students' Answers Results at The Stage of Evaluating Answer*

Based on figure 5 at the stage of evaluating answer, the students only state the result of the answer, namely "*the difference in height is 0.5 m"*. Evaluating answer does not only write a statement of the final result, but what is meant by evaluation is to re-examine the answers with consideration of logical

answers, according to the request of the questions and could be proved. In the question above, students could evaluate by paying attention to the final unit obtained. If the unit obtained for the difference in height in meters, hence the answers could be said to be correct, then the evaluation of the answers could also be done using proof. The principle of conservation of mechanical energy on the top of an inclined plane could be used to prove that the result of the answer obtained is correct.

The essence of education is how students could solve physics problems and understand literacy, therefore they can present problems into various forms of solving. Students who have a high level of thinking ability are learners who can understand and evaluate problem solving appropriately [27] [28].

CONCLUSION AND SUGGESTION

Students are able to solve physics problems using the Minnesota problem-solving model. Minnesota's problem-solving stages allow learners to be skilled at selecting relevant information, then analyzing it and finally re-researching the results. Minnesota's problem-solving model is appropriately used to solve contextual questions and high-order thinking questions. The author hopes that the results of this study could be used by teachers in discussing physics problems in the form of questions.

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