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Representations Based Physics Instruction to Enhance Students' Problem Solving

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Abstract Physicists use multiple representations such as sketches, motion diagrams, force diagrams, graphs, and mathematical equations to represent concepts. This study probed the effect of utilizing multiple representations while learning physics and solving physics problem. The samples of this study are the first year of senior high school (in 2013) in Pontianak district-West Kalimantan. Qualitative and quantitative research methods were applied to identify students' representation, to analyze students' score and to acquire the effect of multiple representations after students learning the concept. The result shows that students who employed more than one representation such as motion diagram, force diagram while solving the problem got higher score than students did not. This indicates that multiple representations can be effective to enhance students' understanding of physics concept as well as problem solving skills.

Keywords: *multiple representations, problem solving, senior high school*

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1. Introduction

Physics is one of the science courses that students generally take in high school or their first year in college or university. As students take a physics course, some of them have difficulties while learning concepts and solving problems. They assume that physics is similar to mathematics because most use equations for problem solving [1]. Moreover, students often move to a mathematics equation while solving several problems in a textbook and also they do not have enough steps or procedures to determine the best solution. For example, while a question is presented in verbal form, the students proceed directly to equations without thinking about strategies to understand the problem. Consequently, most students are not successful at finding out the best solution [2].

Problem solving is an important skill in science, especially in physics. It provides opportunities for application of scientific knowledge. From a pedagogical perspective, problem solving can be used as a tool for assessing student learning [2].In physics and other science disciplines, problems are usually presented at the end of textbook chapters. In addition, teachers also use problem solving to evaluate the understanding of the students at the end of a lesson and at the end of a whole course [3].

Researchers have defined problem solving as "… a sequence of procedures to be completed by the solver" [4]. Based on this definition, students should follow specific steps to obtain the solution. First, they must understand the problem; the students have to notice what the problem is about or what is required to solve it. Second, students must make a plan that shows how to connect unknowns to known variables. Identifying variables using symbols is very helpful to make a plan. Third, students must complete the plan; in this step, they apply equations and students usually spend a longer amount of time to accomplish this step. Finally, students evaluate the solution; reviewing the solution is very important because the students have to know whether the solution is complete and rational.

Jonassen [5] states that problem solving entails mental representation and some manipulation. Mental representation of problem is called problem space that consists of a set of symbolic structures and set of operators over the space. Meanwhile, manipulation is needed to produce a solution.

To help students be successful in problem solving, an educator should equip students with problem solving strategies. Researchers have proposed several strategies that can be implemented while solving a problem, particularly in physics. Teachers generally focus on preparing students to become effective problem solvers by following suggested steps. Heller, Keith, & Anderson [2] developed five-step problem solving strategy. These steps are (1) visualize the problem, (2) describe the problem in physics terms, (3) plan a solution, (4) execute the plan, (5) and check and evaluate.

Problem solving strategy is not enough for student to successfully solve the problems. For instance, while students deal with an abstract concept, they need a tool such as representation to visualize the concept to make a bridge to an appropriate equation to solve the problem. In physics we use multiple representations such as verbal, sketch or pictorial, motion diagrams, force diagrams, graphs, bar charts, mathematical equation [5], and many others such as ray diagrams, field diagrams, circuit diagrams, etc. The aims of this study are to explore students' representation such as students' performance, number of representations that students use and to elicit the effect of using representations in physics instruction.

Ainsworth [7] divides representation into three functions: (1) to complement other representations, (2) to constrain interpretation, and (3) to construct deeper understanding. Each representation has a different form and contains different information; therefore, one representation might not be enough to understand the problem. For example, while students learn Newton's second law, a single motion diagram is not sufficient to find the direction of acceleration; they also require a force diagram to help them know the direction of acceleration of the object. The use of multiple representations is to help students develop a better conceptual understanding. A familiar representation can be used to support interpretation or understand a more abstract representation. For instance, graphs can be used to guide the interpretation of an equation. Teaching students with multiple representations simultaneously helps them learn the concept completely. For example, while students learn Newton's law, students construct a picture/sketch, motion diagram, force diagram, graph, and mathematical equation. These representations prompt students to delve into the concept so that they have clearer understanding [8].

2. Methods

Study 1: Identification Students' Representations

The first step was to obtain students' performance such as students' score and number of representations that student use while solving the problems. Three types of problems-motion, Newton's Law, and electrostatic- were designed and validated by expert. Every type of problems has two different formats-verbal and verbal and picture. This study involved 235 senior high school students of four districts in West Kalimantan province. Data were collected through students' work of solving the problems.

Study 2: Implementation Representation Based Physics

Based on the students' performance, the study was continued to the next step. The second step was developing lesson plan with multiple representations-base physics learning. It was then implemented in the experiment group whereas the control group was taught by using teacher's lesson plan. Before the instruction begun, pre-test was administered to acquire students' performance. Finally, after students finished the lesson, they did post-test. This study involved 37 senior high school students in experiment group whereas 36 students in control group.

3. Result and Discussion

Study 1

In order to obtain the performance of students while solving the problems, three types of questions were administered to the students. The type of the question depends on the grade of the students. Type 1 was given to grade 10 and the topic is motion. For the grade 11 and 12, students solved application of newton's laws and electrostatics respectively. Students were asked to solve all problems after they have learned the topics. Table 1 shows the average of students' score for all grades as well as for different format of questions. The score was rated from 0 to 100.

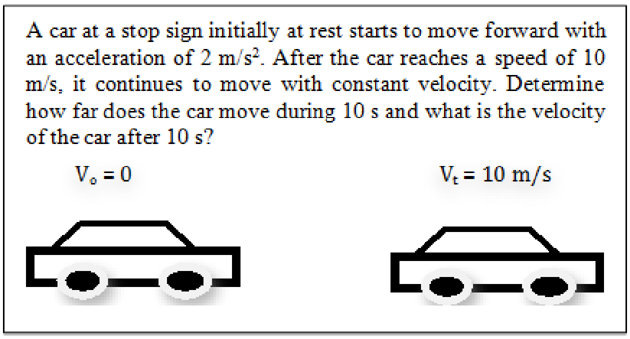


Figure 1. Question 1 with verbal and picture format

Table 1. The average of students' score while solving the problem

Type of question	Question's format	
	Verbal	Verbal and picture
1	70 (N=40)	74 (N=40)
2	74 (N=38)	75 (N=40)
3	68 (N=39)	72 (N=38)

The Table 1 shows that the score of students who solve verbal and picture format is higher than the score of students who solve only verbal format for all types of the questions. Students who solved question 1 with verbal format, they generally jumped to mathematical equation without visualizing the problem by sketch or picture. Most students started to identify known and unknown variables and then wrote down the equation. They could not analyze the type of motion before deciding the appropriate formula. Consequently, some of them could not successfully solve the problem. An example of student's answer of verbal format for question 1 is presented on Figure 2.

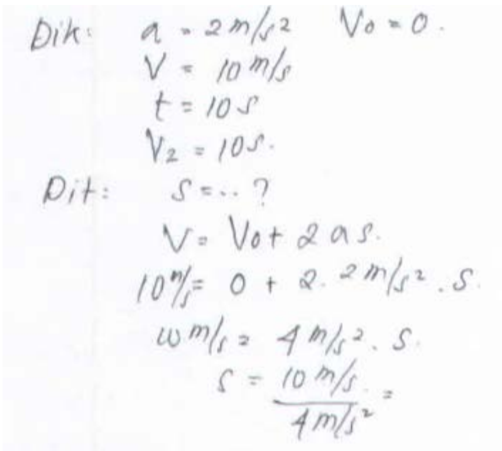


Figure 2. Question 1 with verbal and picture format

Students who solved verbal and picture format, however, began with analyzing the type of motion of the car by helping the picture then continued presenting known variables and unknown variables. It enabled them to pick the appropriate equation to find the solution. Even though not all students could solve perfectly, yet most of them could successfully analyze the type of motion.

Furthermore, students who solved problem 2, students in verbal format and verbal and picture format have almost the same score. Based on the students' work, students could solve the problem by using net force concept, and then they applied newton's second law. Students in verbal and picture format have a little higher than students who solved verbal format because the arrow on the question helped them to decide the direction of the acceleration. It indicates that representation-sketch/picture-can help students to understand the problems rather than only one representation.

Two forces of 184 N and 60 N are exerted on an object in the opposite directions. The acceleration of the object is 2 m/s^2. Determine the mass and the direction of the object.

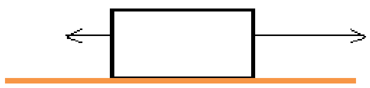
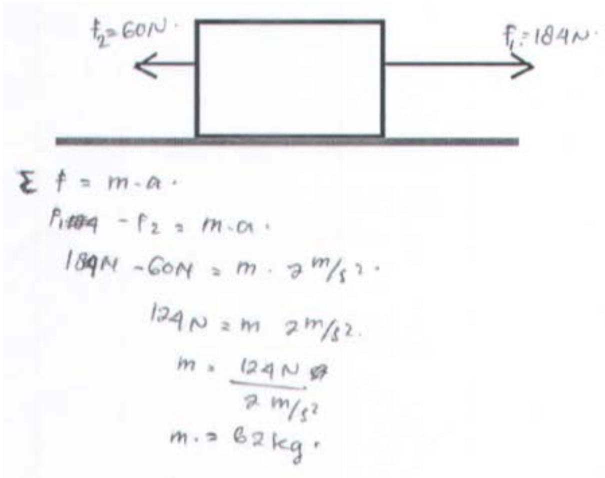


Figure 3. Question 2 with verbal and picture format

Question 3 is the lowest score of three questions. Based on the students' work, most of students had difficulties in deciding the direction of electric force and e-field and also students made mistake while using the sign of charge object in formula. As a result, some of them could not successfully solve the problem. Interestingly, students who precisely drew the force diagram for this problem outperformed than students who did not.



Studies that have done by Mason & Singh [9] found that students who drew diagrams while solving a physics problem had higher score than students who did not, no matter students learn either in peer reflection group or traditional group (Mason). This gives information that multiple representations are very useful to grasp physics concept.

Two objects with charges –q and +3q are placed on horizontal line. The distance between the charges is 8 cm. (q = 2 μC).

a. What are the magnitude and direction of the forces that we would have to apply to each object to keep them 8 cm apart?
b. What are the magnitude and direction of the electric field between two object 2 cm from the first object?

Figure 4. Question 3 with verbal and picture format

We also analyzed number of representations that students used in verbal format. Table 2 shows that students who employed more than one representation achieved higher score than students who used only one representation. Based on these findings we developed an instruction that focuses on using representation during learning process.

Table 2. Number of representations and score in verbal format

Number of representations	Score	N
1	67	65
2	72	30
≥ 3	73	22

Study 2

We applied the multiple representation-based physics in a senior high school-Pontianak city. Grade 10 was the sample of this research; two classes were randomly chosen as experiment and control group. The lesson plan covered motion as fundamental concept in physics. Experiment group was taught by using lesson plan that was developed by the authors whereas control group was taught by using lesson plan that was made by the teacher.

At the beginning of the lesson, both experiment and control group got the pre-test to acquire students' ability before learning the topic. Teacher then taught motion concept that involves distance, velocity, and acceleration. Students spent three hours every week and they finished it during four weeks. Students were then administered post-test. Table 3 shows the average of students' score for pre-test and post-test.

Table 3. Pre-test and Post-test

	Experiment (N =37)	Control (N= 36)
Pre-test	53	55
Post-test	78	75
Gain	25	20

The result shows that the gain score of the experiment group is higher than gain score of the control group. Students who drew picture or sketch and also motion diagram in the experiment group achieved higher score than students who did not. Arons [10] says that students who have enough skills to draw diagram of physical situation and identify positive and negative direction are more successful solving kinematics problems. This indicates that multiple representations-based instructions can help students to understand the concept as well as solve the problem. Moreover, we also analyzed students' answer in control group. It gave us information that students who solved pre-test and post-test by utilizing representations had higher score than students who did not.

4. Conclusion

Multiple representations can be used as an alternative instruction to teach physics because it is very useful for students to help them understand the concept and visualize the problem before going to mathematical equation. This study has still been implemented for one topic. Therefore, we needmore studies to apply multiple representation-based physics for other topics to obtain the effect. In addition, the results of the study are needed more statistical analysis to obtain more information.

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