THE 2015 INTERNATIONAL SEMINAR ON EDUCATION

Theme:
“The Uniqueness of Educational Practices towards Harmonization of the ASEAN Community in 2015”


Organized by

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ABSTRACT

The main objective of the study was to improve student' understanding in concepts physics and problem solving skills of physics students. The main instrument used to collect data was test items. The test items consisted of pre-test and post-test items. A population of 36 students was involved in the study. Duration of three weeks "intervention plan with the class using an innovative method of teaching problem solving method was employed. The data collected from pre -test and post-test were analyzed using mean, standard deviation, and N-gain. The post-test analysis had been an improvement in the way students solve physics problems and in understanding concept. The result of the study were: 1) learning with competent problem solver method can improve students understanding concept in kinematics; and 2) after the implementation of the intervention, students' problem solving skills have improved considerably.

Keywords: Physics problem solving skills, The Competent Problem Solver method, understanding concept, experts and novices' approach to problem solving.

1. INTRODUCTION

Successful learning of introductory college physics requires students to acquire not only the content knowledge of physics, but also the skills to solve problems using this knowledge (Foster, 2000). Some physicist claim that problem solving is viewed as a fundamental part of learning physics (Heller, Keith, & Anderson, 1992). As well as learning major concepts and principles of physics, problem solving skills are considered a primary goal of physics instruction, both in high school and college physics courses (Hsu et al., 2004; Redish et al., 2006). A survey of science and engineering faculty at the University of Minnesota suggests that a primary reason departments require their undergraduate students to take introductory physics is to learn quantitative and qualitative problem solving skills (Heller, Heller, & Kuo, 2004). Problem solving is one method of learning that can be used in teaching physics as physics of matter in accordance with the content (Gok & Sillay, 2008).

The use of Problem solving in teaching Physics in high schools is likely to help improve their academic achievement. Also, in most researches in introductory-level science education, it has been realized that for students to gain conceptual understanding, the instructor must teach conceptual understanding to focus on what concepts students have of the world around them, and on finding ways to bring these concepts in line with those held by physicists (Van Demelon 2008). According to Bogdanov & Kjurshunov (1998), as far as education and teaching are concerned, problem solving is one of the best ways to involve students in the thinking operations of analysis, synthesis and evaluation which are considered as high-order cognitive skills.

Successful physics students are those students who understand complex physics formula in basic terms (Sherin 2001). Understanding the fundamental building blocks of physics and being able to transfer them to understand complex formulas permits students to gain the understanding and flexibility necessary for transference of knowledge to other problems in physics. Research on
Newtonian mechanics problem solving suggests that students can be adept at solving traditional quantitative physics problems while still having an extremely poor conceptual or qualitative understanding of the principles involved (Halloun & Hestenes 1985).

Problem solving is an instructional method, where students are allowed unlimited opportunities to demonstrate mastery of content taught. This involves breaking down the subject matter to be learned into units of learning, each with its own objectives. The strategy allows students to study material unit after unit until they master it (Dembo 1994). Mastery of each unit is shown when the student acquires the set pass mark of a diagnostic test. Hence the method helps the student to acquire prerequisite skills to move to the next unit.

One of the most continual problems in learning physics is the perceived difficulty encountered by students when solving physics problems. This persists due to students' lack of proper and effective methods to tackle these problems. Most topics in physics such as mechanics, optics, electricity and several others involve problems which can be solved simply and effectively using proper problem solving methods. The Competent Problems' Solver is examples of proper problem solving methods.

A. Research Questions

The following research questions guided the study.

1. Will the use of the competent problem solver method increase understanding of students in physics?
2. Will the use of the competent problem solver a of solving physics problems make students have skills to solve problem?

B. How to tackle and solve physics problems

Researchers in physics have come out with various ways of tackling and solving problem in physics, two of which are algorithms and heuristic. Descriptions of methods for solving problems often draw a distinction between algorithms and heuristics (Pretz et al., 2003). The term algorithm is usually applied to step-by-step procedures that will guarantee a correct solution every time, if applied correctly. An example of an algorithm is the mathematical procedure for carrying out long division (Ormrod, 2004). The term heuristic is used to refer to general strategies or "rules of thumb" for solving problems (Ormrod, 2004).

C. Distinction between experts and novices approach to problem solving

Researchers have found that experts (experience) and novices (inexperience) differ considerably in their approaches to problem solving. This is consistent in all aspects of the problem-solving process. Expert problem solvers differ from novices in that they possess deep and connected domain knowledge that allows them to identify meaningful patterns in a problem situation (Bransford, Brown, & Cocking 2000). In physics problem solving, novice students tend to spend little time representing the problem and quickly jump into quantitative expressions (Pretz et al., 2003). Instructors have found that novice students implement problem solving techniques that include haphazard formula-seeking and solution pattern matching (Van Heuvelen, 1991).

Novices, on the other hand, tend to focus on surface features while failing to establish connections between the different issues (Ertmer & Stepich, 2005). Another difference between expert and novice problem solvers is in the evaluation of the problem-solving process. Experts appear not only to continually evaluate their progress when solving a problem, but also evaluate the final answer. These evaluation processes, such as considering limiting cases and checking units, are quite common in experts (Taale, 2011).
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D. The Competent Problem Solver Method

The steps of the University of Minnesota problem-solving strategy include *Focus the Problem*, which involves determining the question and sketching a picture, and selecting an alternative approach (Heller & Hollabaugh, 1992). The next step, *Describe the Physics*, includes drawing a diagram, defining symbols, and stating quantitative relationships. The step *Plan a Solution* entails choosing a relationship that includes the target quantity, undergoing a cycle of choosing additional relationships to eliminate unknowns, and substituting to solve for the target. The step *Execute the Plan* involves simplifying an expression, and putting innumerical values for quantities if requested. The final step is *Evaluate the Answer*, which means evaluating the solution for reasonableness, completeness, and to check that it is properly stated. This process can be thought of as a series of translations, in which each step converts the previous step into a slightly different "language" (Heller, et al., 1992). For example, in *Focus the Problem* the words of the problem statement are translated into a visual representation in the form of a sketch. In the *Describe the Physics* step, the sketch is translated into a physical representation of the problem that includes a diagram and symbolic notation. *Plan a Solution* is a translation from the physics description into mathematical form using equations and constraints, which are further translated into mathematical actions to obtain an arithmetic solution in *Execute the Plan*.

The Competent Problem Solver Method has rigorously shown to work in group settings where the total class size was small enough that the teacher could effectively manage the groups (Heller & Hollabaugh, 1992). There are 36 physics education students in Bengkulu University; hence it was expedient to apply this method. Also the Competent Problem Solver Method is used since it teaches a general strategy with emphasis on the specific methods needed for physics problem-solving. This method helps overall problem-solving skills of students especially in the areas of focusing the problem and checking the results (Heller & Hollabaugh, 1992). Secondly, problem-solving skills are often a limiting factor on students. They may understand the concept or think they understand it but are blocked by inability to do the problem itself. By improving the problem-solving skills of the student population, it may become easier to spot conceptual difficulties that the students have. The purpose of this study is to improve students' understanding of concepts in physics and problem solving skill of physics education students.

2. METHODOLOGY

A. Research design

In this study, One Group Pretest-Posttest Design (Borg & Gal, 1983) was used. This research aimed at improving the problem solving skills of physics education students through the use of the physics problem solving strategy.

B. Participants

The subjects of research consisted of 36 first-grade students who are students of Physics Education in FKIP Unib for the 2014 academic year. 30 female and 6 male took part in this study.

C. Instrumentation

The researcher used pretest and a posttest to collect data for this study by Physics Achievement Test (PAT) and Problem Solving Skill Test (PSST) to assess problem solving skill. The instrument is developed by researchers. Students were made to take a test which consisted of 40 five-option, multiple-choice questions (PAT) and four open-ended problem (PSST) in Kinematics before students were taught the concepts. A posttest was conducted to measure their physics achievement and Problem solving skill. This test also consisted of forty items PAT and four items PSST similar to pretest. Major topics on test were respectively as follows: Kinematics
in One Dimension and Kinematics in Two or Three Dimensions. The following rubric is a coding guide to assess problem-solving performance. Ratings are based on characteristics of expert-like problem solutions in four distinct categories: Physics Approach (PA), Translation of Physics Approach (T), Appropriate Mathematics (AM), and Logical Progression (LP). This scoring design was modified from earlier schemes used by physics education researchers at the University of Minnesota. Physics Approach assesses an initial conceptual understanding of the problem statement. Translation of Physics Approach assesses a student's success in converting stated physics principles and situation representations into symbolic form as specific physics equations. Appropriate Mathematics assesses the performance of mathematical operations on specific physics equations to isolate the desired quantity(s) and obtain a reasonable numerical answer without fundamental mathematical errors. Logical Progression assesses the overall cohesiveness of a problem solution.

Rubric:

Physics Approach (from problem statement to physics description)
0 Nothing written can be interpreted as a physics approach.
1 All physics used is incorrect or inappropriate. Correct solution is not possible.
2 Use of a few appropriate physics principles is evident, but most physics is missing, incorrect, or inappropriate.
3 Most of the physics principles used are appropriate, but one or more principles are missing, incorrect, or inappropriate.
4 (Apparent) use of physics principles could facilitate successful solution; missing explicit statement of physics principles.
5 Explicit statement of physics principles could facilitate successful problem solution.

Translation of Physics Approach (from Physics Approach to specific equations)
0 Nothing written can be interpreted as a translation of the specified physics approach.
1 Fundamental error(s) in physics, such as treating vectors as scalars
2 Missing an explicit symbol for a physics quantity or an explicit relationship among quantities essential to the specified physics approach.
3 Misunderstanding the meaning of a symbol for a physics quantity or the relationship among quantities.
4 Limited translation errors (i.e. sign error, wrong value for a quantity, or incorrect extraction of a vector component).
5 Appropriate translation with a correct but not explicitly defined coordinate system (such as x-y coordinate axes, current direction in a circuit, or clockwise/counter-clockwise rotation).
6 Appropriate translation with explicitly defined coordinate system.

Appropriate Mathematics (from specific equations to numerical answer)
0 Nothing written can be interpreted as mathematics.
1 Mathematics made significantly easier (than a correct solution) by inappropriate translation from problem statement to specific equations.
2 Solution violates rules of algebra, calculus, or geometry. "Math-magic" or other unjustified relationship produces an answer (with "reasonable" units, sign, or magnitude).
3 Careless math or calculation error or unreasonable answer or answer with unknown quantities
4 Mathematics leads from specific equations to a reasonable answer, but features early substitution of non-zero numerical values for quantities.
5 Appropriate mathematics with possible minor errors (i.e. sign error or calculator error) lead from specific equations to a reasonable answer with numerical values substituted in the last step.

Logical Progression (entire problem solution)
0 Nothing written can be interpreted as logical progression.
1 Haphazard solution with obvious logical breaks.
2 Part of the solution contradicts stated principles, the constraints shown in the explicit statement of the problem situation, or the assumptions made in another part of solution.
3 Solution is logical but does not achieve the target quantity or haphazard but converges to the target.
4 Solution is organized but contains some logical breaks.
5 Progress from problem statement to an answer includes extraneous steps, and consistent progress from problem statement to answer.

D. Intervention Materials

Indonesian translated version of book Physics Principles with Application by Giancoli (3rd edition) was used as a textbook. During the instruction process, researcher scripts containing example problem solution (one per session) and problem solving work sheets developed by the researcher were used in the group.

E. Implementation of the intervention

The duration of the implementasion of the intervention was three weeks in September 2014 in Basic Physics I. Pretest measures of physics achievement and problem solving skill used were collected in the first week. During the intervention, students received strategy for 150 minute for a week. The first phase of the intervention involved the strategy acquisition training. The strategy acquisition training was implemented during the first week for 50-minute. The second phase of the intervention, students were given a problem solving work sheet with contained open ended problem. The student worked individually. The lecturer provided assistance in this process. Problem solutions were presented on the board by the students. All completed work sheets were collected and examined to determine the extent to which students effectively used strategies taught.

F. Method of data analysis

The collected data from the PAT were analyzed by SPSS, 16 versions, and the data from PSST were analyzed by hand. To find out the problem solving skill enhancement of students is done by calculating the normalized gain (N-gain/g). The equation to calculate N-gain (Hake, 1999):

\[ g = \frac{S_{post} - S_{pre}}{S_{max} - S_{pre}} \]

g is normalized gain (N-gain), Smax is the maximum score from the initial test and final test. Spost is the final test score, while Spre is the initial test score. N-gain can be classified as follows: 1) if N-Gain > 0.7 is higher categories; 2) if 0.3 ≤ N-Gain ≤ 0.7 is medium categories, and 3) if N-Gain < 0.3 is low categories.

3. RESULTS AND DISCUSSIONS

There are two sections to the presentation of the results. These sections answer the research questions.

<table>
<thead>
<tr>
<th>Tabel 1. Data Pretest and Postest (PAT)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Measures</td>
</tr>
<tr>
<td>-----------</td>
</tr>
<tr>
<td>Pretest</td>
</tr>
<tr>
<td>Posttest</td>
</tr>
</tbody>
</table>

A posttest was administered to students. The test was conducted to find out whether students really applied the „competent problem solver method“ in kinematics. The questions in this test were similar to those in the pretest. The posttest were well attempted by students.
From Table 1, understanding of student about physics concept in kinematics is increased from 40.6 to 76.8 with N-gain is 0.61 (in categories medium).

From Tables 2 the problem solving skills students increase in all aspect of problem solving skills with the increase in N-gain score is about 0.53 (or 53%). The result from the tables shows that majority of the students exhibited improved problem solving skills. From the above results, it can be concluded that students have really become competent in solving problems considering their performance in the posttest.

Table 2. Data Problem Solving Skills (PSST)

<table>
<thead>
<tr>
<th>No</th>
<th>Sub Problem Solving Skills</th>
<th>Mean</th>
<th>N-gain</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Pretest</td>
<td>Posttest</td>
</tr>
<tr>
<td>1.</td>
<td>Physics Approach (PA)</td>
<td>3.2</td>
<td>5.1</td>
</tr>
<tr>
<td>2</td>
<td>Translation of Physics Approach (T)</td>
<td>2.2</td>
<td>4.3</td>
</tr>
<tr>
<td>3</td>
<td>Appropriate Mathematics (AM)</td>
<td>2.1</td>
<td>3.2</td>
</tr>
<tr>
<td>4</td>
<td>Logical Progression (LP)</td>
<td>2.0</td>
<td>2.5</td>
</tr>
<tr>
<td>Σ</td>
<td></td>
<td>9.5</td>
<td>15.1</td>
</tr>
<tr>
<td>S = Σ x5</td>
<td>47.5</td>
<td>75.5</td>
<td></td>
</tr>
</tbody>
</table>

The following observations were made before the implementation of the intervention are:
1. Students were found jumping vital steps without showing workings. They arrived at the final answer without caring about the procedures and steps needed to arrive at that answer. Hence they lost about 1/4 of the total marks for the question.
2. Those who were able to work to the final answer attached wrong units to them and some even ignored writing the units all together.
3. It was also observed that some students rushed into solving physics problems but got stacked along the way perhaps due to improper analysis before tackling the problem.
4. Students appeared to forget the steps needed to solve physics problems after they have been taught.

4. CONCLUSION

The conclusion of this study are as follow: 1) learning with competent problem solver method can improve students understanding of concept in kinematics; and 2) after the implementation of the intervention, students’ problem solving skills have improved considerably. This was manifested in how students presented their class exercises and assignments and how they went about solving problems given them. It appears students have developed interest in solving physics problems since they could remember and use the steps needed to solve the problems. Problem solving in physics commonly involves the appropriate mathematic, so lecturer should focus on proactive ways of presenting subject material so as to guide students’ learning efforts, while students strive to become active, self-monitoring constructors of knowledge.

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