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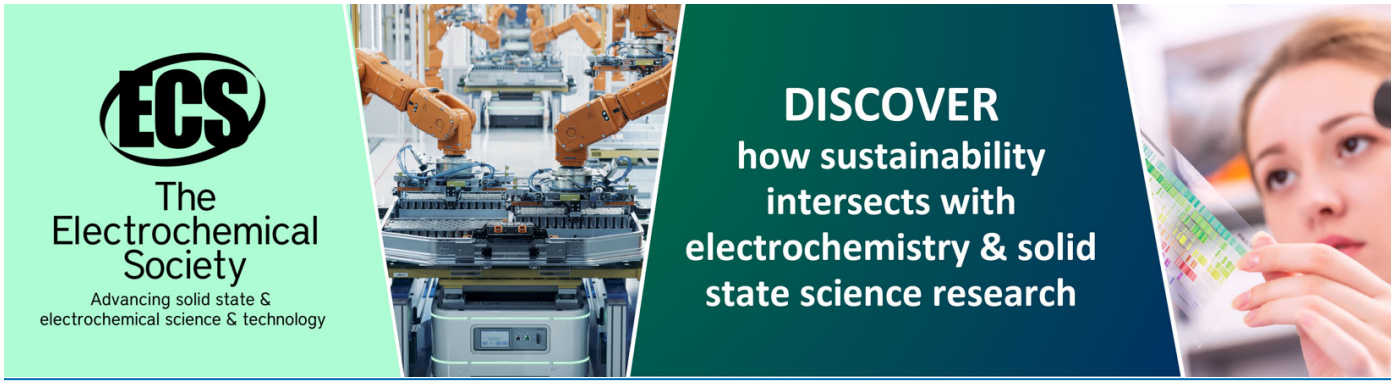

The students' Physics Problem Solving Skills in basic physics course

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Abstract. One important skill that can support the success of learning physics for students is problem solving skills. This study explores the level of Physics Problem Solving Skills (PPSS) of 54 first semester students (11 men and 43 women, age range 16-18 years) in basic physics course in the science and physics education study program at Universitas Bengkulu, Indonesia. In the first lecture, students learn the concept of one-dimensional motion includes uniformly accelerated motion and vertical motion, but the lecturer does not provide examples of problems and how to solve them. In the second lecture, students learn the concept of Newton's Law and its application, and the lecturer gives examples of problems and stages to solve them, however the lecturer does not emphasize that these stages are important procedures in solving physical problems. At the end of each lesson, students are given an essay Physics Problem Solving Skills test. Based on an analysis of student answers, it is known that in general the student PPSS level is still in the novice and transition categories. This indicates the importance of developing and implementing basic physics lecture programs that are able to promote students' higher-order thinking skills including physics problem solving skills.

1. Introduction

Physics is a part of science that studies the behavior of the universe. Most of the natural phenomena studied in physics are directly related to the experiences of daily life. Scientists uncover various natural behaviors through a series of tests and research using a problem solving approach with scientific methods [1]. Although there are some important discoveries accidentally is called serendipity, but most of the findings are made using systematic and measurable problem solving stages. Even though each problem has different characteristics and levels of difficulty, the general problem-solving procedure has a similar pattern, known as the problem-solving strategy [2,3].

Basic physics courses are very important for first semester students in science education and physics education courses at Bengkulu University, Indonesia. This course contains the basic concepts of physics include macroscopic and microscopic phenomena. Students learn these concepts through learning activities in class and experimental activities in the laboratory. Lectures in class are given first to introduce basic concepts and examples of problems and their solutions, followed by practical activities

in the laboratory to improve concept understanding, verify concepts, and provide practical experience to students.

Characteristics of problems contained in basic physics courses stretched between problems that are well structure and ill structure. Problem-solving steps are needed to determine the solution of the problem [4,5]. Through the use of these steps, students basically have replicated the problem solving activities carried out by experts in finding physical products in the form of laws, principles, concepts, and theories. Therefore, learning basic physics must be done using a learning model that accommodates problem solving procedures so as to improve student problem solving skills from the novice level to the expert. This fact requires the lecturer to know the initial profile of problem solving skills of students who take basic physics courses. This information is important for the selection of models and learning methods that must be applied to further learning.

2. Methods

This study is a need assessment phase of a major research to develop and implement learning programs that can promote higher-order thinking skills of students. Subjects involved in this study were 26 students of science education programs (4 male and 22 female, age range 19-20 years) and 28 students of physics education study program (7 male and 21 female, age range 19-21 year) in the odd semester of the academic year 2019/2020 at Universitas Bengkulu, Indonesia. The main data is collected using test methods. The test is done twice with essay questions.

Test items include the concept of vertical motion, projectile motion, and the application of Newton's Law. The first test aims to find out the problem solving stages implemented by students in solving the problems. The second test aims to determine the ability of students to carry out every stage of problem solving. The results of the analysis are used to describe the level of students' Physics Problem Solving Skills (PPSS) into three categories: novice, transition, and expert.

Problem solving stages used in this study are: make a diagram or picture that represents the problem situation (S1), write down the quantities that are known and the quantities to be found (S2), write down the appropriate physics principles with problems (S3), provide or apply definitions, limitations, ideas, and specific principles of physics that can lead to solutions (S4), determine or formulate appropriate physical equations (S5), carry out mathematical procedures (S6), re-check to ensure that the solutions obtained are reasonable, there are no contradictions between parts, and the units used are correct (S7). This last step is usually given in the form of sentence statements aimed at providing reinforcement of the solutions obtained.

For each test item, student performance at each stage of problem solving was assessed using scores 1, 2, and 3. Each score was described using the rubric of the problem solving skills assessment that was adapted from Doctor and Heller [6]. Students are grouped at the PPSS Level with the novice category if the scores obtained are 1-7, the transition category if the scores are obtained 8-14, and the expert category if the students successfully reach a score of 15-21.

3. Results and discussion

Problem solving skills tests are done after students learn the physics concepts related to the test. In the first lecture, students learn the basic concepts of speed, acceleration, uniform straight line motion, and uniformly accelerated motion. The lecturer explains physics material in detail and focus on understanding concepts, however at this first learning the lecturer did not provide examples of problems and stages of their solution. This is intended so that students are not affected by the problem solving patterns provided by the lecturer. These physics concepts are studied first before students take the test, because they must know the basic concepts that underlie the problem. The focus of the test is not to assess the mastery of physics concepts, but rather on the stages of problem solving that are applied by students in solving problems [7]. In most tests of higher order thinking skills related to certain subject matter, the content is only used as the context of the problem [8].

After learning is finished, students are given the first test which contains two items of essay questions. One test item contains the problem of vertical upward and free fall motion, while the other test item

contains a problem of projectile motion. Students are given instructions to solve existing problems using their respective ways. This test aims to find out how the stages of problem solving are used by students in solving problems encountered.

Based on the results of the analysis of students' answers on the first test, it is known that none of the students uses complete problem solving stages to solve the given problem. Students only use a few parts of these stages. There are 65% of students who use stages S2, S5, and S6 in solving problems in the first question. However, only 37% of students in the group produced the correct final answer, while the other students' answers still contained some errors. Meanwhile, there are 37% of students who only use stages S5 and S6 to solve problems. There are 40% of students whose final answers are correct, while the answers of other students are still incorrect. When viewed based on the PSS level, there are 14 students (26%) who are in the transition category, and 40 other students (74%) are still in the novice category.

Meanwhile, there were 70% of students who used the S2, S5 and S6 stages in solving the second question, but only 34% of students from the group produced the final answer correctly, while the other students' answers contain errors. In addition, there were 30% of students who used the S5 and S6 stages. There were 38% of students whose final answers were correct, while the other students' answers were still wrong. When viewed based on the PPSS level, there are 13 students (24%) who are in the transition category, and 41 students (76%) are still in the novice category.

In contrast to the second test, before the test is conducted, the lecturer not only conveys material about the concept of force, Newton's Law and it application, but also provides examples of problems and stages of their resolution. However, the lecturer does not provide an explanation of the procedure and the skills that must be applied at each stage used. Students are not given the understanding that the procedures used by lecturers are standard stages in solving problems.

After participating in learning, students are given a second test containing two items of essays related to the application of Newton's Law concepts. Students are given instructions to answer all questions using the appropriate stages. The structure of question number two is made different from item number one, it is broken down into several questions to identify the ability of students to apply the stages of problem solving.

Based on the analysis of student answers on the second test, it is known that none of the students applied complete problem solving stages to solve the problem. However, if compared with the results of the first test, in this second test it was found that there were some students who made drawings to represent the problem (S1) when solving the first problem. However, all of the pictures still contained errors and there were still contradictions between the pictures and the equation physics used. Only 14.8% of students have used the stages S1, S2, S5, and S6 when solving the first problem. Whereas 50% of students still used stages S2, S5, S6, and even 35% of students only use S5 and S6 stages. Based on PPSS level analysis, it is known that there are 17 students (32%) who are in the transition category, and 37 other students (68%) are still in the novice category.

Something interesting is that there are some students who use S1 stage in the problem-solving procedure. They paint force vectors that work on a system of two objects connected by a string and both are located on a flat, rough plane and drawn by an external force that forms an angle of 30o toward the positive x axis. Among the students who made drawings, there were 3 students (38%) whose pictures were correct, while other students' drawings still contained some errors.

Meanwhile, in the second problem part (a), students are asked to draw force vectors on a system of two objects (m_1 and m_2) connected by a lightweight rope with negligible mass shown in Figure 1, with m_1 located above the rough plane. The skill of drawing or sketching that represents a problem is a very important stage in problem solving procedures because it will lead students to the discovery of appropriate solutions [9].

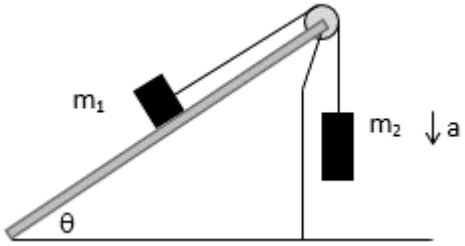
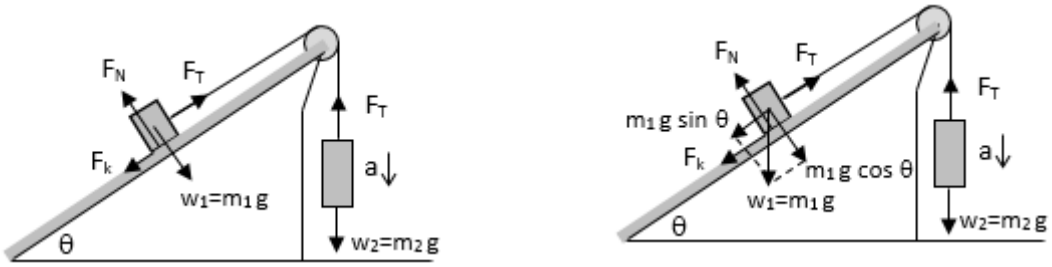


Figure 1. The system of two objects.

To be able to describe the forces acting on a system, students must understand the concepts of friction, normal forces, and Newton's Law of action-reaction. But unfortunately, most students have not been able to describe these forces appropriately. The most common error is inaccuracy in describing the direction of gravity on m_1. Students assume the direction of the gravity force acting on m_1 is perpendicular to the inclined plane as shown in Figure 2a.



a) b)

Figure 2. a) Example student answers, b) Expected answer.

This misrepresentation of force has an impact on students' mistakes when calculating the total force acting on m1, both on the x and y axes, i.e. $\sum F_y = F_N - m_1 g = 0$ so $F_N = m_1 g$, and $\sum F_x = F_T - F_k = m_1 a$ so $F_T = m_1 a + F_k$ with $F_k = \mu_k F_N = \mu_k m_1 g$. Whereas if the direction of gravity w_1 is correct (leads to the center of the earth) then the projection of w_1 on the y axis will produce $m_1 g \cos\theta$, and its projection to the x axis will produce $m_1 g \sin\theta$ so $F_N = m_1 g \cos\theta$ and $F_k = \mu_k F_N = \mu_k m_1 g \cos\theta$ as shown in Figure 2b. Now in m_1 there are three forces in the x-axis direction namely F_T in the positive x-axis, and F_k and $m_1 g \sin\theta$ in the negative x-axis direction.

Based on the analysis of student answers to item number two, where students have been directed to solve problems using complete problem solving steps, it is known that there are 6 students (11.1%) who have reached the PPSS level with the expert category and 48 students (88.9%) are in the transition category. The minimal number of students who have reached the expert category shows that the ability of students to carry out work activities at each stage of problem solving is still weak. These results are in line with the findings of other researcher who show that the problem solving ability of prospective physics teacher students is generally in the low category [10,11].

4. Conclusion

Based on the results of the PPSS test on the concept of vertical motion and projectile motion it is known that in general the skills of first semester students in solving physics problems are still at the novice level. The dominant problem solving stages used are the S2 (writing out the variables that are known and what you want to find), S5 (formulating physics equations), and S6 (doing mathematical procedures to get the final result). This pattern is thought to still be strongly influenced by the way the physics problem was solved while in senior high school, because studying physics in school is generally more

oriented to equip the ability to answer physics questions quickly on national exams. Such learning, of course, does not prioritize understanding the basic concepts of physics, but only emphasizes memorizing formulas and matching them to solve a problem. When memorized formulas are not suitable for use, they will not be able to formulate new equations that are appropriate to the problem situation.

Based on the PPSS test answers to the concept of applying Newton's Law (item number one), it is known that there are already students who apply the S1 stage (drawing pictures that represent problem situations) in addition to the S2, S5, and S6 stages, this may be due to the learning of Newton's Law given Before the test, the lecturer gave an example of the problem and how to solve it, even though the lecturer did not emphasize using that step. The results of the analysis of the answers to these question items are known that in general students are still in the Novice category in solving physical problems. Meanwhile, based on students' answers to test item number two that tests their ability to perform each stage of problem solving, it is known that in general students have not been able to describe the forces that work on the object system. The analysis showed that in general the students' skills in solving physics problems were still in the transition category.

Based on these results it can be concluded that the Physics Problem Solving Skills of the first semester students are still in the novice and transition categories. It takes the development of basic physics course programs that can promote students' physics problem solving skills.

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