Pre-Service Physics Teachers’ Problem-Solving Skills in Projectile Motion Concept

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Abstract. This study is a preliminary research aiming at exploring pre-service physics teachers’ skills in applying the stage of problem-solving strategies. A total of 76 students of physics education study program at a college in Bengkulu Indonesia participated in the study. The skills on solving physics problems are being explored through exercises that demand the use of problem-solving strategies with several stages such as useful description, physics approach, specific application of physics, physics equation, mathematical procedures, and logical progression. Based on the results of data analysis, it is found that the pre-service physics teachers’ skills are in the moderate category for physics approach and mathematical procedural, and low category for the others. It was concluded that the pre-service physics teachers’ problem-solving skills are categorized low. It is caused by the learning of physics that has done less to practice problem-solving skills. The problems provided are only routine and poorly trained in the implementation of problem-solving strategies. The results of the research can be used as a reference for the importance of the development of physics learning based on higher order thinking skills.

1. Introduction
Problem solving is one of the important elements in physics learning. Problem solving defined as a series of procedures that must be completed to solve the problem [1], is a complex cognitive activity that represents mental construction [2], and a movement process in purposing aim in case the way is not possible to be determined immediately [3]. Furthermore, problem-solving skills are defined as someone’s capability to discover solution through a process that involves the information acquisition and organizing [4]. Problem solving depends on experience and people’s perspective according to the problem being faced [5]. The structure of knowledge and problems character being faced are some of the factors that affect problem solving ability [6]. The presentation of the complex and contextual problems that involve laboratory activity and giving structured tasks with variously represented models will help students in practicing problem-solving skills [4, 7].

The research to explore students’ problem-solving skills in physics has been widely practiced [8,9,10]. In general, there are two important parts representing investigative procedures in these studies, which are problem characteristics and problem-solving strategy steps that used to describe problem-solving skills. In general, the problems used are only textbook, in the form of mathematical problems, non-contextual, in the form of routine issues, and in a less appropriate format of presentation. While the steps in implementing the problem solving-strategies used are generally less detailed, usually involving only three to four aspects of problem solving, such as understanding problems, planning solutions,
implementing solutions, and evaluating solutions. The characteristics of the problem used are believed to be less able to encourage students to think more deeply, while the steps applied are less able to describe students' problem-solving skills comprehensively. In contrast, in this study the problem used is contextual, related to the phenomenon of everyday life and presented in context-rich problems format. At the end of the problem presentation, students are directed to use a more comprehensive problem-solving strategy including useful description, physics approach, specific application of physics, physics equation, mathematical procedure, and logical progression.

The study to explore the profile of pre-service physics teachers’ problem-solving skills needs to be done. The results obtained can be used as a reference in developing a physics learning strategy that can train problem-solving skills, both in class and through laboratory activities. Furthermore, the results of the research can encourage teachers to present a variety of physics learning activities that are capable of developing higher order thinking skills.

2. Method

The aims of this study is to explore the problem-solving skills of pre-service physics teachers. The participants of the study were 76 undergraduate students (male 34 and female 43) ranging in age from 19 to 22 years. This study was conducted at Study Program of Physics Education of a college in Bengkulu Indonesia in the even semester of 2016-2017 academic year. Pre-service physics teachers’ problem-solving skills are identified using essay test questions on the concept of projectile motion. This concept was chosen on the consideration that all students in the even semester had already acquired the material’s learning. Problems in the matter are related to the life context related to the principles of physics. At the end of the problem description, pre-service teachers are directed to solve problem using problem-solving strategies. The stages of problem-solving strategies analyzed using the rubric of physics problem solving [11].

3. Result and Discussion

3.1. Result Description

Pre-service teachers’ problem-solving skills in this research are explored through one quantitative problems with the longest allocation completion time of 60 minutes. The answers are analyzed with problem solving-strategies rubric. Their problem-solving skills then identified based on each problem-solving strategies used. The physics problem used in this study is given in the following context rich problem: in a war game, a soldier was asked to fire cannonball off with velocity 100 m/s to the enemy’s ship that moves closer with 20 m/s of velocity. The position of the cannonball provided with distance detector is on the cliff with 20 meters height from the sea level (as shown in figure 1). Unfortunately the soldier is confused, when should he start to fire the cannonball off so that it exactly hits the ship in P position? The soldier is asking your help to solve the problem as a reference in improving his shooting ability. To help the soldier, you must take these steps: (a) draw a physical sketch that indicates the situation, (b) determine the most appropriate physics concept and principles, (c) determine the specific situations that must be implemented so that the solution gained effectively, (d) according to physical sketch, the specific situation as well as the physics principles, formulate the proper physics equation, (e) do a mathematical procedure using known equation and units, (f) does your solutions clear, focus, and one part to each other is not contradicting? does the mathematical procedure accurate? does your answer rational?

![Figure 1. The cannonball and the ship position](image-url)
The first stage being explored is a useful description, consists of pre-service teachers skills in drawing a physical sketch that illustrates the problem situation. The physical sketch that represents the problem shown in figure 2. The physical sketch includes: (a) the representation of cannonball position, the cliff is used as horizontal reference point, ship position when the projectile starts to shot (e.g in C), and ship position when it’s shoot (in P), (b) the cannonball track uses dotted line forming parabolic trajectory, (c) vector of the initial cannonball velocity (not forming a specific angle with horizontal line) and vector of ship velocity, (d) physical quantity sign for the cliff height ($h_o$), cannonball velocity ($v_p$), ship velocity ($v_s$) with value and units, and (e) the representation of ship’s distance from the bottom of the cliff when the cannonball starts to fired off that shows distance that must be determined. Target quantity sign can use alphabet such as x along with emphasizing sentence to indicate that this distance has to be determined, he sentence used could be: what is distance $x$ so the cannonball hit the ship at P?

According to the answer analysis, it can be concluded that generally the physical sketch doesn’t illustrate the problem situation exactly. One of the physical sketches produces by the student is shown in figure 3. Based on the analysis of the physical sketch, there are some errors identified, such as: (a) the initial velocity of cannonball curves a particular angle to the horizontal line, (b) analyzing the vector force doesn’t needed, such as the description of weight and normal force acting on the cannonball, the description of weight and floating force acting on the ship, as well as the potential energy and kinetic energy acting on the ship in point P, (c) doesn’t represent the ship distance that must be determined, (d) doesn’t give the emphasizing sentence related to the targeted the quantity that will be searched, (e) the cannonball motion doesn’t create parabolic trajectory, (f) the cannonball trajectory illustrated with solid line, not with the dotted line, (g) misinterpreting the ship's distance to be determined. Students interpret the distance to look for is the distance when the ship is hit by the cannonball, (h) the ship velocity vector illustrates longer than the cannonball velocity vector, whereas the value of the vector is vice versa.

![Figure 2. Physical sketch according to problem situation.](image)

![Figure 3. One of the physical sketches produces by the pre-service teacher.](image)

The ability to implement problem-solving strategy steps in the second stage is physics approach, that contains student’s ability in determining physical concept and principles accordance with the physical sketch made. The appropriate physics concept and principles in accordance with the problem are: (a) parabolic trajectory, it occurs when the cannonball is started to fire off until it hits the ship, and (b) linear motion, when the ship hasn’t been shot, during the ship goes from C to P. Based on the answer identification given in Physics Approach stage, there are some errors done by the student. The physics concept and principles expressed are mostly unimportant and not directed to the solution. For example, the principle of energy conservation, Archimedes’ Law, the principle of resultant vector, and the principle of free fall.

The ability to implement problem-solving strategy steps in the third stage is specific application of physics, consists of student’s ability to identify and specify specific conditions that must be implemented based on physics principles. The specific conditions that must be implemented in the given problem are: (a) the time the cannonball takes to hit the ship in point P has the equal time for the ship to move from point C (when the cannonball shoot) to point P, (b) the projectile velocity in the horizontal axis is always constant, has the same value as the initial projectile velocity, and (c) when the projectile hits the ship, the last projectile height ($h$) equals zero. Based on the result of the answer analysis, it can be obtained
that the illustration of specific conditions applied by the student is generally not important since it doesn’t lead to the problem solution. Student defines specific condition by stating that the time needs by the projectile to hit the ship is equal to the time when the projectile is dropped to the bottom of the cliff, the ship initial velocity is equal to the projectile velocity in free fall. Some of those statements are true, but they’re not related directly to the context of the problem. The statement given doesn’t identify the specific conditions that able to direct into the solution attainment of the problem.

The ability to implement problem-solving strategy steps in the fourth stage is physics equation, consists of student’s ability to define and determine the proper physics equations according to the principle and the implemented specific conditions. The written physics formulation must be relevant to physics approach aspect and drawn the physical sketch in useful description aspect. The suitable physics formulation according to the problem shown in figure 4. Based on the answer analysis, it can be resulted that some student’s error descriptions are: (a) written physics formulation is not suitable with the physical sketch, (b) misinterpretation, the distance counted by most of the students is the horizontal distance when it was hit by the projectile, and (c) physics formulation written is not complete yet.

| in projectile motion from A to P: |
|----------------------------------|
| $h = h_0 - \frac{1}{2} gt^2$  |
| with $h = 0$ when the projectile hits the ship, so that: |
| $h_0 = \frac{1}{2} gt^2$ and $t = \frac{2h_0}{g}$ |
| Projectile horizontal distance $(x_{\text{BP}})$ is: |
| $x_{\text{BP}} = v_p \cdot t = v_p \sqrt{\frac{2h_0}{g}}$ |
| traveled distance by the ship before it’s hit $(x_{\text{CP}})$ is: |
| $x_{\text{CP}} = v_s \cdot t = v_k \sqrt{\frac{2h_0}{g}}$ |
| so that the distance of the ship from the bottom of the cliff when the projectile is begin to shoot $(x)$ is: |
| $x = x_{\text{BP}} + x_{\text{CP}} = (v_p + v_k) \sqrt{\frac{2h_0}{g}}$ |

**Figure 4.** The suitable physics formulation according to the problem.

The ability to implement problem-solving strategy steps in the fifth stage is mathematical procedure, consists of consists of student’s ability to do mathematical procedure right after the student formulates the proper physics equation. The mathematical procedure expected from this stage shown in figure 5. Based on the pre-service teachers’ answer analysis can be found some weakness, those are: (a) mathematical procedure used is not appropriate because of wrong physics formulation, (b) doesn’t input the physics quantity units in every processes of the calculation, the student only writes the units in the final obtained value, and (c) the student doesn’t give strengthening sentences upon the obtained solution.

| $x = (v_p + v_k) \sqrt{\frac{2h_0}{g}}$ |
|----------------------------------|
| $= \left(100 \frac{m}{s} + 20 \frac{m}{s}\right) \sqrt{\frac{120 \frac{m}{s}}{2\frac{m}{s}}} = \left(120 \frac{m}{s}\right) 2s$ |
| $= 240 \frac{m}{s}$ |

So, in order the projectile hits the ship exactly in point $P$, the projectile must be shot when the detector instrument in the cannonball shows the ship position in 240 m from the bottom of the cliff.

**Figure 5.** The expected mathematical procedure
The ability to implement problem-solving strategy steps in last stages is logical progression, consists of student’s ability to do reflection the overall obtained solution. There are three reflection questions given related to the review whether the solution given has met the explanation, focus, and not contradictory; does the description given has been proper and beneficial; does the mathematical procedure done has been correct; and does the answer obtained rational. Based on the answer given in logical progression stage, identified the inconsistency between the answer given by the student related to reflection question with the written the reality in the answer. For instance, the student answered that all the solutions have been clear, focus and rational, while actually there spotted the discrepancy between physical sketch and the equation used. The student state that the description made has been proper and beneficial, but in fact, they wrote unneeded descriptions, such as writing force vectors acting on the ship, energy conservation law when the projectile hits the ship, and other errors were done.

3.2. Discussion

Based on the analysis of the stages in problem-solving strategies applied by the pre-service teachers in solving the problems, it can be seen that result has not been like what expected. The pre-service teachers’ skills are in the moderate category for physics approach and mathematical procedures stages, and in low category for useful description, the specific application of physics, physics equation and logical progression stages. Their problem-solving skills are still low although the problems given are only related to the fundamental concepts of physics. The students generally only recognize the problem based on the surface feature. They are less able to link the various information contained in the problem description with other information required. Students fail to build relationships between known and unknown variables.

They are not able to deliver beneficial description as a starting point in problem-solving strategy. They still don’t have a good ability in drawing a physical sketch to represent the problem. This inability affects the weakness of their ability to define key concepts or principles so that the formulas that are formulated do not show the right relationships. The formulated physics equation is less proper to the physical sketch, physics concept, and principles, as well as the set specific conditions. Some of the students are able to draw a physical sketch and determine the proper physics principles, but they are not able to formulate the equations that direct them to the expected solution.

Generally, the pre-service teachers haven’t been able to view the problem completely, their comprehension is fragmented into separated pieces. They are not able to construct the relations in physics concepts. They tend to rely on the information contained problem as their asset in solving the problem. The pre-service teachers’ characteristic is more identified as a novice rather than the expert. Novice doesn’t need knowledge structure obtaining, their comprehension consists of random facts and equation with less conceptual meaning and they access the principle individually from memory [12].

Student’s skills in solving a problem are affected by several factors, among others the problem characteristics and their prior knowledge [13]. The problem characteristics are referred to the problem structure given. Based on the structure, the problem differs into well-structure problem and ill-structure problem [2]. The well-structure problem represents all information needed in solving a problem, needs implementation some of ordered and perspective ways, convergent answer, and determined solution. While the problems in everyday life are more disordered, undefined, the problem elements are usually unknown, needs a various solution, has various criteria to evaluate solutions, as well as doesn’t have the certainty in needed concept and principle for finishing and organizing the problem [14].

A person's prior knowledge also affects their ability to solve problems. A person who is able to keep the principles of physics in their memories as a piece of information that is inseparable and can be used together will tend to be more able to solve the problems faced [15]. Students’ skills in solving a problem are affected by their prior knowledge and experiences in solving problems. Learning strategies that are deliberately designed to train problem-solving skills can improve students’ problem-solving skills [16]. The activities both in the classroom as well as in the laboratory are obviously potential to get that skills. A learning strategies that can be used for those purposes are problem-based learning. In a laboratory environment, problem-solving skills can be given through practical activity based in problem solving laboratory [17].
The low student ability to solve problem can be caused by several factors, such as students are not accustomed to using problem-solving strategy steps, the exercises are not yet using new nonroutine problem and the application of problem solving strategy, the applied learning strategy has not been deliberately designed to train problem-solving skills both in class and in laboratory activities. The development of problem-solving skills will be successful when it involves specific skills in problem solving, contextual assignment, practical process in problem solving, discussion related to troubleshooting process, and teaches how to solve problems before students complete all the subject matter [18].

4. Conclusion
Based on the data analysis, it can be concluded that the pre-service physics teachers' skills in solving physics problems are still in the low category. The lack of student skills in applying the problem-solving strategy steps can be caused by the students are not accustomed to using the problem-solving strategy steps in solving the problem, the physics study has not yet presented various nonroutine issues that are rich in context and the practice of implementing its solving strategy, and the applied physics learning have not been deliberately designed to solve problem-solving skills. The results of this study can be used as a basis for the importance of the development of physics learning strategy that is able to train and provide higher-order thinking skills, either through classroom learning or laboratory activities.

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