Pre-Service Physics Teachers' Problem-Solving Skills in Mechanics

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Abstract

Problem-solving skills in Physics is a crucial process for teaching the subject. This study aimed to study twenty-two pre-service teachers' problem-solving skills in the Mechanics topic. All participants enrolled in School Internship I and II during the fifth year of the course. The data was collected through a two-tier test item with essay form (Mechanics Problem-Solving Skills Test). Content analysis in conjunction with frequency and percentage were used to analyze how teachers solved the physics problem in the test. The four assessment criteria set included: naïve, fair, moderate, and excellent. The findings revealed that all teachers held various ability in problem-solving skills in mechanics. Overall, they ranged from naïve to excellent category. Seven of them held less than fifty percent of the score which was categorized into the naïve whereas three of them were in the excellent category. Our findings not only highlight a need for preparing pre-service physics teachers' problem-solving skills in physics, especially in mechanics concept, but also provide intensive course before they go to school internship in the last year of teacher preparation.

Keywords: Problem-Solving Skills; Pre-Service Teacher; Mechanics

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Introduction

Problem solving occurs when a person needs to find solutions to problems. Problem solving is used as a mechanism for teaching physics content (Bagno, E. and Eylb on, Bat-S., 1997). The integration of 21st century skills on Physics learning were continuously done in order to improve the systematic solving process of the physics students (Kay, K., 2010). The accuracy of the problem-solving process was used as the evaluation for teacher in the class (Erlina, N. et al., 2015; Gunawan, G. et al., 2018). It is used as a teaching indicator whether teachers teach physics related to nature of physics or not. There are many problems in the problem-solving process such as misconception, lack of experience, and difficult problems. When a problem solver tries to solve a physics problem, the misconception of physics content is one of the barriers of the problem solver (Sutarno, S. et al., 2017; Ince, E., 2018). One of the examples of such misconceptions is the Newton's law. The problem solvers always draw the free body diagram when they solve the Newton's law problem. The vector forces that act with the object are shown by the free body diagram. The incorrectness of the answer is often shown when the problem solver cannot draw the free body diagram correctly (Sutarno, S. et al., 2017).

When the problems were not solved, the students tried to solve by using similar method from the experience before or used a different method. The students' success in organizing knowledge occurred more with the students with high problem-solving achievement in physics than those who have fewer problems solving achievement. Expert problem solvers can use the problem-solving strategies efficiently and continuously, but novice problem solvers cannot use problem-solving strategies adequately (Jong, A. L. M. and Hessler, M. G. M., 1986). The difference between expert, medium and novice problem solvers are: an in-depth analysis, decision-making mechanism, analysis based on principles, and approach to solve the problem (Hardiman, P. et al., 1989) the problem solver are separated by the steps of problem solving process. The four Polya is one of the most popular troubleshooting techniques whose processes consist of: 1) problem understanding, 2) planning for problem solving, 3) implementation, and 4) evaluation (Daulay, K. R. and Ruhaimah, I., 2018).

Problem understanding is the process which a problem solver can represent if they have a misconception or no experience (Ince, E., 2018). The examples of problem understanding are: identifying the knowledge variable of the student, guessing the formula to solve the problem, confusion in converting the problem unit, lack of students' ability to remember the appropriate equation, lack of laboratory practice related physics concept, and not understanding the basics related to definitions, principles, and laws in physics concepts

(Heller, P. and Hollabaugh, M., 1992). The students who did not pass this process, were identified as novice problem solvers. When the students understood the problem, they had to plan to solve the problem. Planning for problem solving is the process where students have to determine the theory and equation to solve the problem. The novice problem solvers always guess the formula to solve the problem. There are many reasons that students cannot plan to resolve the problem such as the strategy of teachers, the learning materials, and lack of problem-solving practices. After the students understand the problem, implementation is the next step (Huffman, D., 1997). The mathematics skill of the problem solver is shown in the implementing process. All processes were checked again in the evaluation process.

The investigation of students' physics problem-solving strategies in collaborative groups was studied by Heller, P. and Hollabaugh, M. in 1992. The implementation of problem-solving strategies depended on the type of problem (Heller, P. and Hollabaugh, M., 1992). The problem-solving strategies were used with 376 university students on different methods. The sample groups were separated in to experimental group and the control group. Adequate strategies of the solution were shown with the experimental group in terms of the concepts and principles (Dufrense, R. et al., 1997). The impacts of explicit problem-solving on the conceptual perceptions were investigated on 145 high school students. In the experimental group, problem-solving strategies were taught, and the problem solutions were shown with the control group students. The visualization step of the problem-solving strategies appeared with the experimental group students, but the processing skills of formula and mathematics were not different (Huffman, D., 1997). The problem-solving skills of secondary school students were examined by using cognitive awareness strategies. The better problem solving skills of students were found in the students who applied cognitive awareness strategies (Netto, A. and Valente, M. O., 1997). The problem solving skills of 180 high school students on electromagnetism was studied by using conceptual understanding and structuring of knowledge. The concept maps were used to explain the correctness of solutions with the experiment group students. The problem solving and conceptual understanding were represented with the experimental group students (Bagno, E. and Eylon, Bat-S., 1997). The perceived physics equations of university students were studied. The equations produced by the sample students were far from the scientific reality (Sherin, B., 2001). The graphics used to explain the work-energy subject was studied which set up equations more accurately and better evaluated the solutions found (Zou, X., 2001). The effects of mathematical, pictorial, graphical and expressive presentations on problem solving skills of students in physics problems were investigated. The physics problems could be solved easily by using pictorial expressions (Kohl, P. B. and Finkelstein, N. D., 2005).

In order to enhance students' problem-solving skills in the Mechanics concept, the baseline of the fifth year of teachers should be uncovered. In this work, systematic solving process and problem-solving success on mechanics, of teachers, were studied. The systematic solving process had to have correct operational and conceptual information links. The problem-solving strategy rubric was used as a measurement tool. This study could be an empirical evidence of portraying students' problem-solving skills in Mechanics concepts and help physics teachers to prepare student teachers before going to internship in schools.

Materials and Methods

This research was done in the first semester of 2019 academic year at a university situated in Bangkok. In this study, descriptive research conducted by survey method was used to study the state of teachers' problem-solving skills. The participants were twenty-two pre-service physics teachers from College of Teacher Education who enrolled in the School Internship I course in a five-year teacher education program, who were selected by purposive selection method. All participants had completed all course works in physics education program such as Fundamental Physics, Thermal Physics, Classical Mechanics and Advanced Physics Laboratory, etc. before participating in this study.

The instrument used in this study was the Mechanics two-tier test item consisting of two parts in each item with multiple choice and essay form (Mechanics Problem-Solving Skills Test). The test included ten items and covered the following four topics: three items dealing with motion in one dimension, five items dealing with Newton's laws, one item dealing with force of friction, and one item dealing with motion of an object attached to a spring. For each item, the first section was a problem question of multiple-choice, each with four answers, and to provide a more in-depth measure of teachers' problem-solving skills, the second part was a solution which required students to write the solution clearly. The content validity was checked by three physic educators, any errors found were revised in the final version. The data collection was done in the 3rd week of the School Internship I course during the seminar session. The participants were asked to respond to the test which took about 50 minutes.

To identify the state of teachers' problem-solving skills, an interpretation of the result was used to analyse the data. The data were analysed by using the criteria with frequency and percentage in each category for evaluation adapted from Hardiman, P., Dufresne, R., and Mestre, J. R. in 1989. The criteria detailing qualitative descriptions of problems included 4 elements: 1) Definition of variables, 2) Match of equations, 3) Solutions,

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and 4) Units. Table I presents an overview of the criteria and scoring rubric. Responses to the test were analysed in 3 steps. Firstly, the written responses were interpreted and classified into logical criteria, then each category was assigned a ranked score- scored using a three points rubric for a total maximum score of thirty points (Table 1) and finally, the individually analysed data was calculated for the total score of each item. In short, the scoring rubric was set as; three points if the answers were correct in the four categories, to two points if the answers were correct in any three categories, to one point if the answers were correct in any two categories, to zero point if the answers were not correct or written in any category. In order to examine the level of problem-solving skills, individuals were assigned to excellent group if their total score was greater than or equal to twenty-six, to moderate group if their total score ranged from twenty to twenty-five, to fair group if their total score was ranged from fifteen to nineteen, and to naive if their total score was less than or equal to fourteen. (Table 2)

Table 1 Problem-solving scoring rubric

	Criterion							
Points	**Definitions of Variables**		**Match of Equations**		**Solutions**		**Units**	
	Correct	**Incorrect**	**Correct**	**Incorrect**	**Correct**	**Incorrect**	**Correct**	**Incorrect**
3	√		√		√		√	
2	√		√			√	√	
2		√	√		√		√	
2	√		√		√			√
1	√		√			√		√
1	√			√	√			√
1	√			√		√	√	
1		√	√		√			√
1		√	√			√	√	
1		√		√	√		√	
0		√	Nothing written		Nothing written		Nothing written	
0	Nothing written		Nothing written		Nothing written		Nothing written	

Table 2 Score rating chart of problem-solving skills level

No.	Score Range	Category
1	0 - 14	Naïve
2	15 - 19	Fair
3	20 - 25	Moderate
4	26 - 30	Excellent

Results

To determine the level of their problem-solving skills, the gained scores on doing Mechanics two-tier test with essay form are calculated in Table 3 including; Motion in one dimension (1, 2, 3), Newton's Law (4, 5, 6, 7, 8), Force and Motion (9), and Motion of an object attached to a spring (10). This comprised four topics of Mechanics including; Motion in one dimension (1, 2, 3), Newton's Law (4, 5, 6, 7, 8), Force and Motion (9), and Motion of an object attached to a spring (10). The top three highest rank of Problem-solving skills score gain was "Motion of an object attached to a spring" (10) (81.8%), "Motion in one dimension" (2) (72.7%) , and "Newton's Laws" (4) (68.2%), respectively. The top bottom rank was "Newton's Laws" (8) (81.8%), "Newton's Laws" (6) (54.5%) and "Forces of Friction" (9) (54.5%), and "Newton's Laws" (5) (50.0%), respectively.

Table 3 Problem-solving skills scores

Item	Gain Scores (N = 22)			
	3 (Points)	2 (Points)	1 (Point)	0 (Point)
1. Motion in one dimension	11 (50.0%)	9 (40.9%)	2 (9.1%)	0 (0%)
2. Motion in one dimension	16 (72.7%)	4 (18.2%)	0 (0%)	2 (9.1%)
3. Motion in one dimension	5 (22.7%)	3 (13.6%)	4 (18.2%)	10 (45.5%)
4. Newton's Laws	15 (68.2%)	4 (18.2%)	0 (0%)	3 (13.6%)
5. Newton's Laws	9 (40.9%)	2 (9.1%)	0 (0%)	11 (50.0%)
6. Newton's Laws	8 (36.4%)	2 (9.1%)	0 (0%)	12 (54.5%)
7. Newton's Laws	11 (50.0%)	2 (9.1%)	1 (4.5%)	8 (36.4%)
8. Newton's Laws	4 (18.2%)	0 (0%)	0 (0%)	18 (81.8%)
9. Forces of Friction	10 (45.5%)	0 (0%)	0 (0%)	12 (54.5%)
10. Motion of an object attached to a spring	18 (81.8%)	1 (4.5%)	0 (0%)	3 (13.6%)

1. Motion in one-dimension problem results

This topic consisted of items 1 - 3 which were assessed “Acceleration (1, 3)” and Velocity (2). The majority of students (72.7%) gained full score on item (2) whereas 10 (50%) of them had a 0 score on item (3) as shown in Table 4. Figure 1 and 2 show the solution of teachers’ answers. It can be concluded that they did not understand the question clearly. This problem required complex solving skills by finding the time taken by a man running at a constant speed to catch up with a bus that was moving at a constant acceleration.

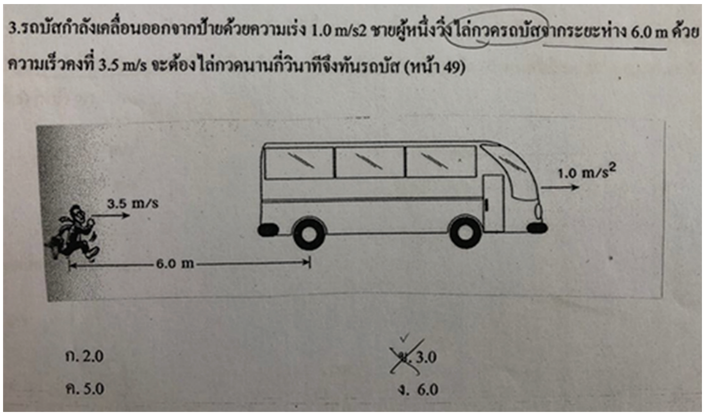

Figure 1 Item 3 problem (Translated Problem: A bus is traveling out of a bus stop station at a constant acceleration of 1.0 m/s^2. A man sets out from the distance of 6.0 m to catch it with a velocity at a constant rate of 3.5 m/s. How long does it take him to overtake the bus?)

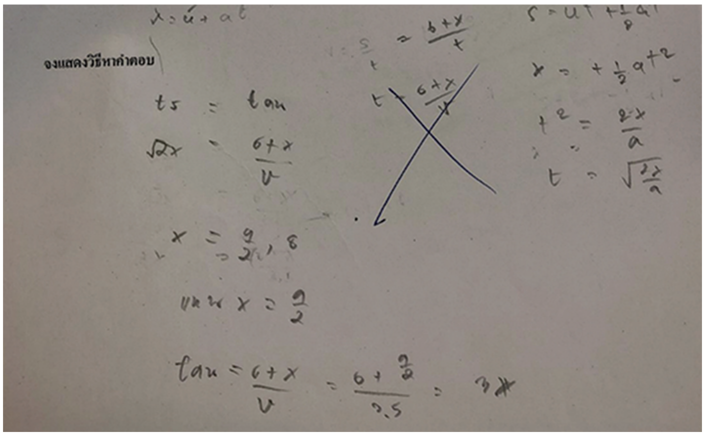

Figure 2 One of the teachers’ answer

Table 4 Motion in one-dimension score gains

Item	Gain Scores (N = 22)			
	3 (Points)	**2 (Points)**	**1 (Point)**	**0 (Point)**
1. Motion in one dimension	11 (50.0%)	9 (40.9%)	2 (9.1%)	0 (0%)
2. Motion in one dimension	16 (72.7%)	4 (18.2%)	0 (0%)	2 (9.1%)
3. Motion in one dimension	5 (22.7%)	3 (13.6%)	4 (18.2%)	10 (45.5%)

2. **Newton's law problem results**

This topic consisted of 5 items that were mainly assessed "Newton's second law and motion in one-dimension. From Table 5, most students (50%) had 0 point in item 5 - 8 while most of them (68.18%) gained 3 points on item 4.

Table 5 Newton's law score gains

Item	Gain Scores (N = 22)			
	3 (Points)	**2 (Points)**	**1 (Point)**	**0 (Point)**
4. Newton's Law	15 (68.2%)	4 (18.2%)	0 (0%)	3 (13.6%)
5. Newton's Law	9 (40.9%)	2 (9.1%)	0 (0%)	11 (50.0%)
6. Newton's Laws	8 (36.4%)	2 (9.1%)	0 (0%)	12 (54.5%)
7. Newton's Laws	11 (50.0%)	2 (9.1%)	1 (4.5%)	8 (36.4%)
8. Newton's Laws	4 (18.2%)	0 (0%)	0 (0%)	18 (81.8%)

Figure 3 shows the problem and the teachers' answers. 50% of them gained 0 points on item 5. It could be concluded that they did not apply the Newton's law in this situation and were not able to determine the direction and sign of vector which normally uses the + sign in direction of the object's movement.

Moreover, on items 6 - 8 more than 50% of teachers gained 0 point in each item. Figure 4 and 5 show the problem of Newton's second law and motion in one-dimension on item 6. This item required complex thinking in two steps including finding the acceleration of the monkey from motion's equation and use the answer in the Newton's second law. Most of them got the wrong acceleration of the monkey and used incorrect value in the Newton's equation.

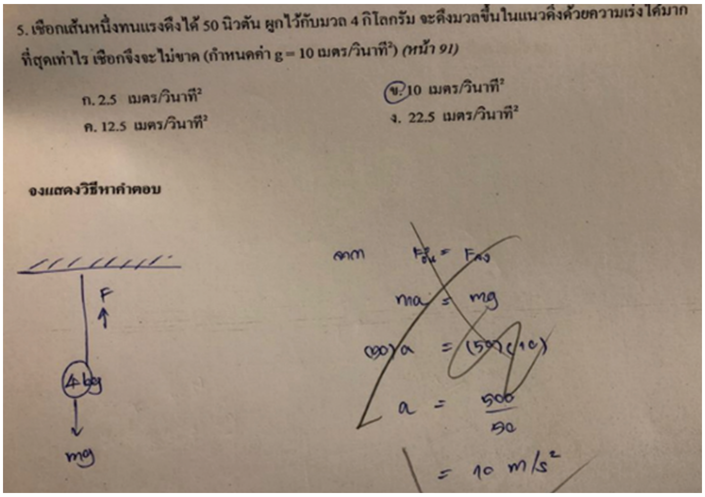

Figure 3 Item 5 problem and a student's answer (Translated Problem: A string will break if the tension in them exceeds 50 N. An object of mass 4.0 kg is connected by a massless string. Find the maximum magnitude of the acceleration when pulling the string upward and without it breaking?)

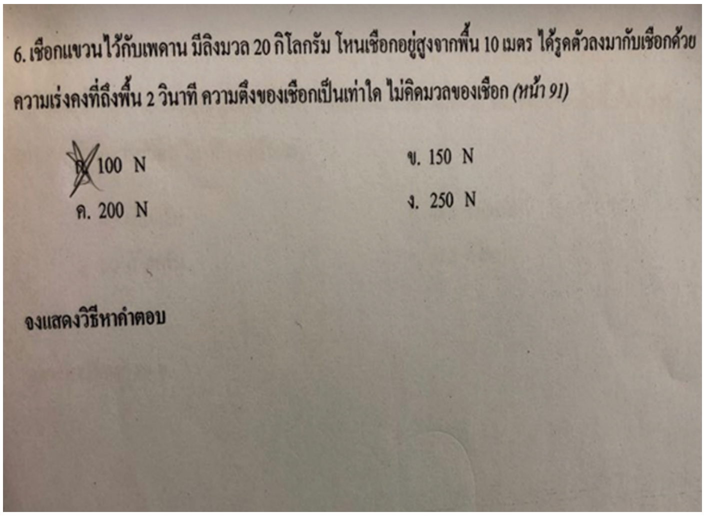

Figure 4 Item 6 problem and teacher's answer (Translated Problem: A monkey with a mass of 20 kg holds onto a massless rope 45 m above the ground. It then slides down the rope at a constant acceleration. At time t = 2 s, what is the tension in the rope?)

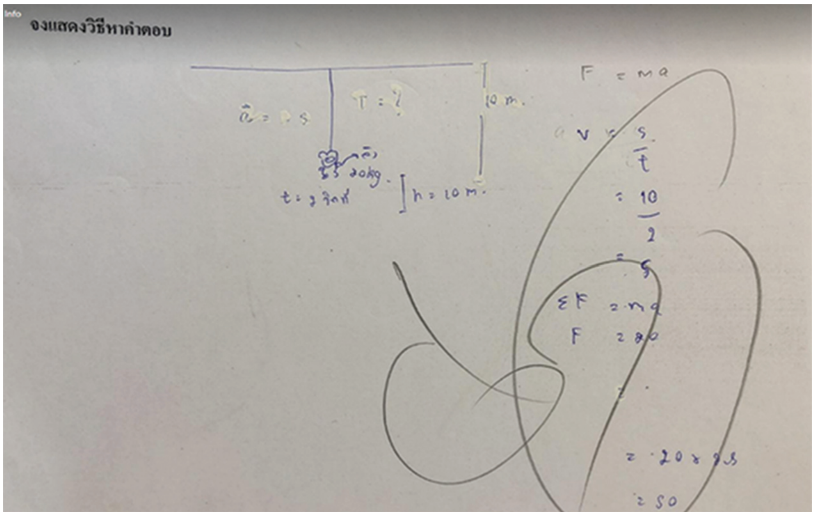

Figure 5 One of teachers' answer in item 6

Similarly, in item 7, Figure 6 shows an incorrect sketch of the interpretation of problem and without any solution. Most of them got 0 point because they did not draw the picture to illustrate their thinking well. It affected their steps in the calculation. They determined the wrong direction and sign of vector similarly in item 5.

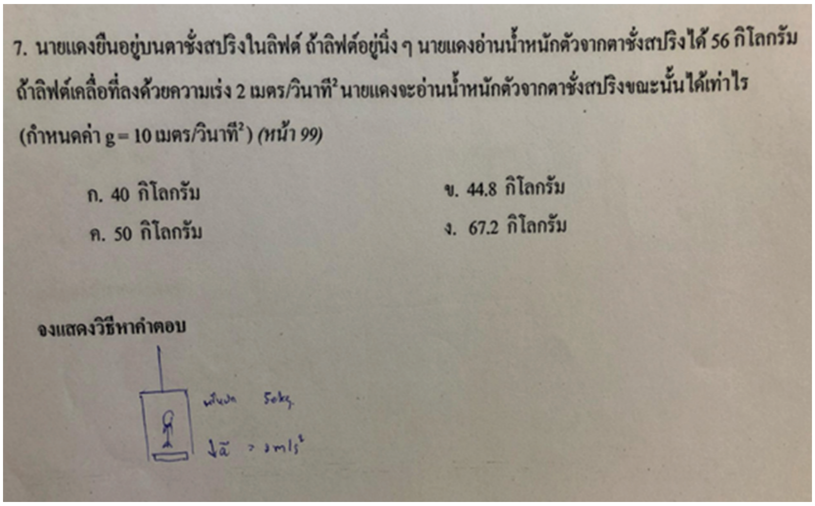

Figure 6 Item 7 problem and some teacher's answer (Translated Problem: Daeng of mass m = 56 kg stands on a spring scale in an elevator. What does the scale read if the elevator has a downward acceleration of magnitude 2 m/s^2? (g = 10 m/s^2))

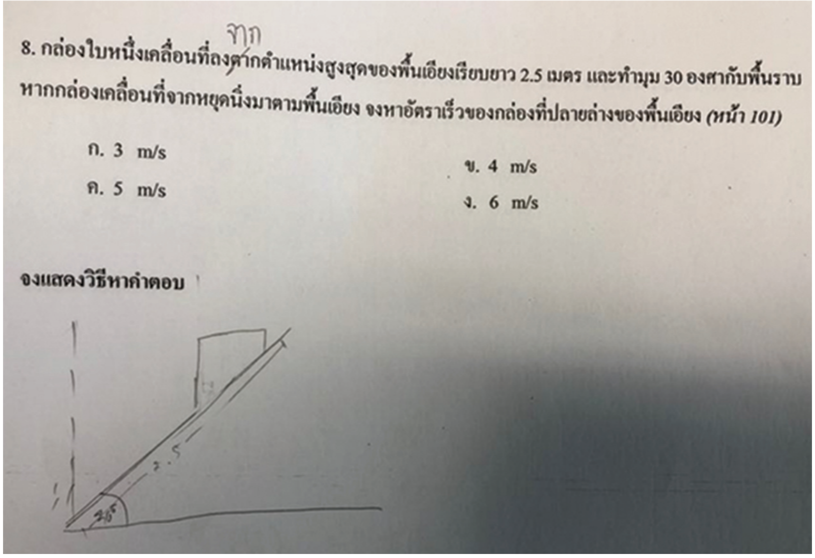

Figure 7 Item 8 problem and some teacher's answer (Translated Problem: A box starts at rest and slides a distance of 2.5 m down a frictionless 30^{o} incline. Determine the speed of box at the bottom of the incline.)

Item 8, Figure 7 shows a sketch of a frictionless 30^{o} incline and without any calculation step. Most of them (81.8%) got 0 point because this item required the basis of force components and Pythagoras's theorem. They needed to solve the two problems by finding the acceleration value from Newton's law and then use motion's equation. Interestingly, some students forgot the motion equation and did not draw the force component.

3. Forces of friction and motion of an object attached to a spring problem results

This topic consisted of 2 items which were mainly assessed "Forces of friction and motion of an object attached to a spring. From Table 6, most teachers (54.54%) had 0 point in item 9 while most of them (81.8%) gained 3 points on item 10.

Table 6 Forces of firction and motion of an object attached to a spring

Item	Gain Scores (N = 22)			
	3 (Points)	2 (Points)	1 (Point)	0 (Point)
9. Forces of Friction	10 (45.5%)	0 (0%)	0 (0%)	12 (54.5%)
10. Motion of an object attached to a spring	18 (81.8%)	1 (4.5%)	0 (0%)	3 (13.6%)

Item 9 showed that most teachers only drew a car in curve street and with forces of friction's equation without any calculations (Figure 8). This problem's solution required centipetal force, coefficient of friction ,and Newton's law. The other teachers gained 3 points for solving and expressing all concepts step by step to gain the correct answer.

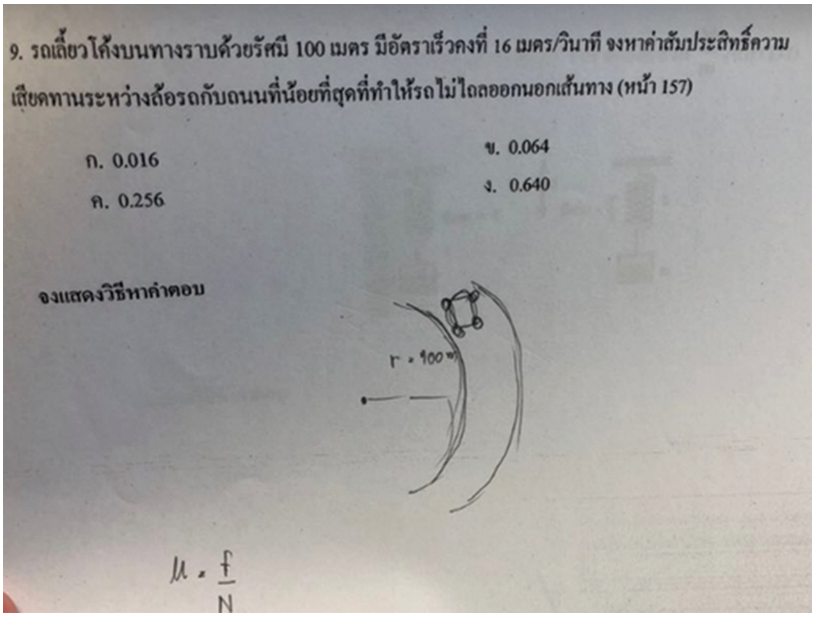

Figure 8 Item 9 problem and some teacher's answer (Translated Problem: A car moves on a flat curve at constant speed of 16 m/s. If the radius of the curve is 100 m, find the coefficient of static friction the car can have and still make the turn successfully.)

Discussion

Based on the analysis of the steps of evaluation in problem-solving skills applied by pre-service physics teachers, it can be seen that most of them held zero score in five items from all items. However, they gained 3 points in item 2, 4 and 10. The motion of an object attached to a spring (10) had the highest problem-solving score (81.8%). This might be associated with three possible causes including; 1) the teachers' prior experiences about the spring's problem, 2) having the correct equation or mathematical skills, and 3) the teachers always do the essay test and that requires them to write the unit. Problems related to Newton's Laws (4) and Motion in one dimension (2), were not complex when compared with the other items. It was just defining the variables and matching them to the correct equation.

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The lowest ranked score was Newton's Laws (8), 81.8% of them could not solve this problem because it required an angle and more complex equation in conjunction with incline concept. Item 9 (Forces of Friction) added friction force that made it more sophisticated. For items 5 and 6, most teachers were familiar with the basis equation instead of adding friction and Newton's Laws' topic in these questions. They also needed to consider the movement equation of the objects. The lack of revision was considered another possible cause. The teachers who had high scores in problem-solving skills were tutors and this allowed them to reread and redo.

These findings are consistent with the findings of (Sutarno, S. et al., 2017) who found that pre-service teachers are in the moderate and low categories of problem solving skills. Most teachers neither defined any variables nor matched the equations to find out the solution and unit. In the lowest ranked score, for example, they used incorrect variables in the definitions and did not write the equations, solution or unit in Newton's Laws in item 8. Some teachers did not write and express their ideas in its item at all. All causes made half of the teachers fall in zero point. The four steps of problem-solving were a continuous process. In the defining of variables step, only teachers who remembered the equations could correctly define the variables. This process required revision of the problems to determine some variables or find the answer. Only thirty percent of the teachers were found to have read and written the variables due to the problem. In the second step (matching of equations), the teachers' answers were broadly categorized in to two groups. The first group remembered and wrote the equation whereas other did not write it correctly. Only forty percent of them wrote the correct equation, however, sixty percent of the teachers did not write or express some items that required a complex equation or used more than one equation to solve. In solution and unit step, most teachers used correct values in the equation but fifty percent of them failed in calculating and defining the wrong unit. The four step process of problem-solving in physics quiz could help teachers to easily solve and find the answer in a systemic way. It might be the external factors that affected their problem-solving skills in physics including prior knowledge, physics content, and well-structured steps of their solutions. These findings also suggest that teacher institutes should prepare their pre-service teachers well in problem-solving skills before they intern in schools. Based on these findings, problem-solving skills varied and will affect learning activity and their confidence in the classroom. Finally, this will influence their ability in problem-solving (Ince, E., 2018).

Conclusion

It can be concluded that most pre-service physics teachers are categorized into the naïve category in all items in problem-solving skills. They lacked problem-solving skills in the logical and systematic steps. The findings can be used as a basic information for lecturers, teacher developers, and science educators to train and provide intensive course before the pre-service teachers go to school internships in the last year of teacher preparation.

Recommendations

Future work will include teachers' interviews to probe students' problem-solving strategies on these problems as well as further elucidate the reasons for using the chosen formats. We hope that this and other works will contribute to a more complete characterization of physics teachers' problem-solving skills and in other topics.

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