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Analysing Students' Problem Solving Skills on The Topics of Modern Physics

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Abstract. The study of problem solving skill has been performed on the subject of Modern Physics. The main objective of this study was to investigate the student's ability in solving physics problems. Here 45 students were involved in this study. The students worked on two essay tests consisting of two numerical problems and two explanation questions within each test. The score distributions were then analysed qualitatively. It was found that the student's achievement in the numerical problem is higher than that of the explanation question. The students possess a low skill in selecting and using the data.

1. Introduction

Physics concepts are often taught through explanation and assignment. The students learn to understand these concepts by recognizing, analysing and constructing conceptual connections on their own. They work on many exercises and problems to achieve the goal of teaching and learning i.e. Understanding the physics concept. Problem solving skills are important in studying physics.

The conception of quantitative problem-solving in physics requires one to integrate conceptual reasoning i.e. A qualitative analysis to select relevant equations and checking the reasonable solution [1]. There are often gaps between the physics concepts and the mathematical expressions. Niss [2] found that physics students are not able to solve real-world problems that involve mathematization. It seems that mathematics and physics concepts are unrelated. Many students following physics courses, learn to solve different types of quantitative exercises, but are often unable to explain the meaning of their own numerical solutions to the problems. They focus on manipulating equations without a physical understanding of the problem. Students often skip the qualitative step and jump to the equation [1-4].

It has been realized that to avoid having students focusing on calculation, qualitative type of problem solving based on the physics concept is required [5-6]. This test in the sense no numerical value is used to strengthen students' understanding of fundamental concepts and processes of physics. The importance of considering the argumentation and explanations has been recognized in the science teaching as a central scientific activity that students must learn. The analysis of students' explanations quality can be used to identify students' misconception [7]. Hernández and Tecpan [8] determined the relationship between the level of conceptual knowledge and the quality of the explanations. Their studies incorporated a multiple-choice answer in the Force Conceptual Inventory test and writing explanation. However, there are relatively few studies on this subject. Here we present a study where students are tested in solving both numerical and explanation types of problem. The purpose of this study is to investigate the students' ability in solving different types of physics problem.



2. Method

This research utilized a descriptive qualitative approach to explore the students' problem solving skills. Participants of this study were 45 students taking part in the Modern Physics course. This course covers the black body radiation, photoelectric effect, Compton effect, and special theory of relativity. Students took two essay tests as midterm test 1 and midterm test 2 after teaches on those subjects. Those two tests had different topics. Each test consisted of two types i.e. Numerical and explanation test. Students were required to solve the problems to determine the unknown using the proper equation in the numerical test. The explanation test asked the student to interpret, classify, interfere, compare and explain physics phenomenon e.g. The difference between photoelectric effect and Compton effect. Students worked on individual written test for 90 minutes.

In the first test students were presented with 4 problems consisting of 2 numeric problems and 2 explanation questions. A maximum score of 25 for each problem was available. The average of the cumulative score was determined for each type of question. In total each student had two average scores, i.e. For the numerical and the explanatory problems. Those maximum average scores were also 25. The distribution of student scores was analysed to obtain the profile of the student's ability in problem solving.

The second test was done on a different topic than the first test. In this second test, 3 numerical questions and 3 explanation questions were asked. Students worked on 4 numbers out of 6 given possibilities. Similar to the first test, students had to work on both numerical and explanation questions. The scoring process in this second test was the same as in the first test.

3. Result and Discussions

The results of student scores for the first and second tests are presented in Figure 1 and Figure 2. Each point in the figure represents the score of one student. These points are a pair of average numerical scores and average explanatory scores. The average score of each type is calculated from two problems or questions, which has a maximum score of 25.

A diagonal line, horizontal and vertical lines are also included in both figures as a guideline for data analysis. The diagonal line in the figure shows the positions of the points with the average numerical score equals to the average explanation score. The horizontal line in the middle is the 50% limit for the student achievement on the explanation. Points that are above the horizontal line indicate the average explanation score as being greater than 50% (12.5 out of 25). In the same sense the vertical line in the middle shows a limit for 50% student achievement in the numerical score. The points to the right of the vertical line show the average numerical score as being greater than 50%.

The horizontal and vertical lines divide the data distribution into 4 quadrants. Quadrants I and II show the average score of explanatory questions above 50%, in contrast to quadrants III and IV whose score are below 50%. Students who have a numerical score above 50% are represented in quadrants I and IV, while those scored below 50% are represented in quadrants II and III.

Figure 1 shows the random distribution of all data points; there is no tendency to approximate the diagonal line. This fact indicates that in general the achievement on numerical problem is not followed by the achievement on explanations and vice versa. There is no correlation between the explanation understanding and the numerical ability. Indeed, there are some cases in which students achieve the maximum points in both numerical score and the explanation score i.e. 25. One must note that most of the data points in figure 1 are below the diagonal line; which reveals the tendency of the numerical score to be greater than the explanation.

A clear data representation of individual quadrant is shown in figure 1. There are only a few data points in quadrant II, which results in almost no data in a high explanation score with a low numerical score. On the other hand, many data points are represented in quadrant IV. This is a sign that many students achieve a higher score in numerical problems as compared to the explanation ones. In one extreme case, we found that some students whose numerical scores reaching a maximum of 25, would have a very low explanation score, namely 5. These two quadrants confirm the fact that there is a tendency for students to be better at numerical problems than in explanations question. This finding is also supported by the fact that many students achieve maximum score in numerical problems, but only two students scored maximum on the explanatory question.

There are eight students in quadrant III. These students have a low achievement in both problems. Many students are represented in quadrant I; this indicates their achievement in both problems is more than a half of the maximum.

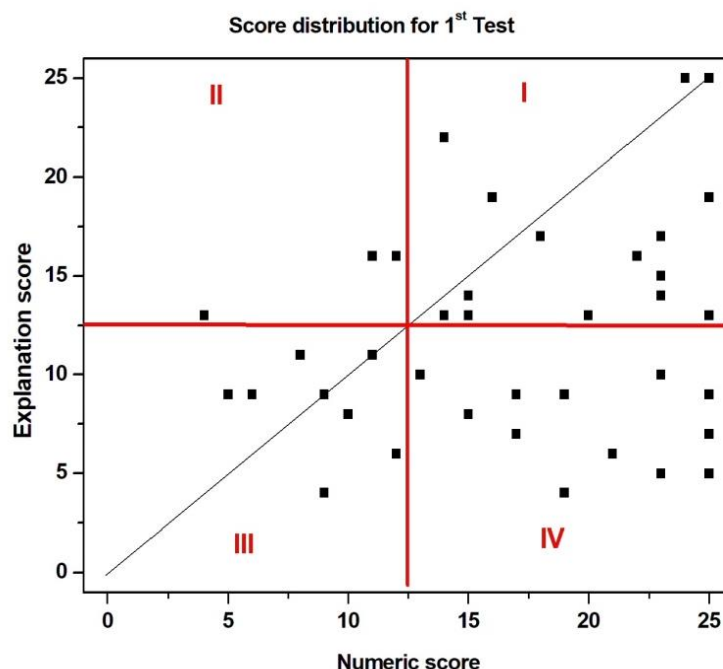


Figure 1. Distribution of average student numerical score and explanation score in the first test.

A similar situation in the first test is observed in the second test as in Figure 2. The same pattern can be observed in this figure, namely the data do not show a relationship between the explanation and the numerical score. The number of students having explanation scores of more than 50% is almost equal to those with explanation scores of less than 50%. Many students achieve a maximum numerical score of 25. In fact, only two students achieved the maximum score for explanation problem. A small number of data points are shown in quadrant III. Many students represented in quadrant IV show an indication of having a higher ability in solving numerical problems than explanation questions. Both test results agree that students tend to score higher on numerical questions than on the descriptions. This situation is summarized in table 1.

Table 1 shows the mean and standard deviation of the 45 students' score. Here the maximum score should be 25. In the first test the mean score of numerical and explanation questions are 17 and 12, respectively. The same behaviour is found in the second test, from a maximum score of 25, the mean score of the numerical and explanation problems are 19 and 13, respectively. Overall, if we compare to the maximum score, the mean numerical score in the two tests is about 70%, while the mean explanation score is 50%.

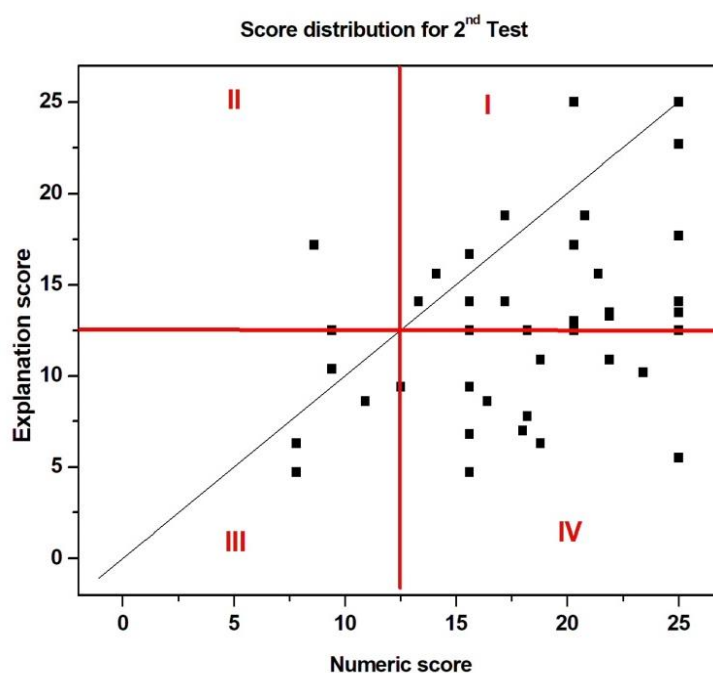


Figure 2. Distribution of average student numerical score and explanation score in the second test.

Table 1. Mean score and standard deviation for numerical and explanation problem. The maximum score is 25.

Test		Numerical	Explanation
Test I	Mean	17	12
	SD	6	5
Test II	Mean	19	13
	SD	3	5

The number of students who obtain scores greater than 12.5 from the maximum of 25 is shown in table 2. A positive result is observed in the numerical problems. In the first test 38 out of 45 students, achievement score greater than 12.5 of the maximum 25. Overall for the two numerical tests, about 70% of students obtain scores greater than 12.5. Whereas in the explanation problem, only about half of the students obtain a score greater than 12.5.

The numerical problems used in this study are intended to strengthen the student's understanding of the physics concept rather than the matter of calculation. Here is one example of the numerical problems:

The threshold wavelength for the photoemission of electrons from a metal surface is 2400 Å. Calculate the work function of electron on this metal expressed in a unit of electron volt!! Determine the speed of photoelectron emitted when light of 1200 Å is incident on the same metal!

The student should understand the concept and the process of the photoelectric effect before doing the calculation. First, they learn different quantities and unit e.g. Wavelength, frequency, photon energy, kinetic energy, speed, electron volt, and angstrom. Afterwards, they use the relevant equation that relates the unknown and the known quantity. Furthermore, they must understand the connection between the first illumination (wavelength 2400 Å) and the second illumination (wavelength 1200 Å).

Table 2. Number of students and their score. The total number of students is 45, and the maximum score is 25

<i>Test</i>	<i>Score</i>	<i>Number of students</i>	
		<i>Numerical</i>	<i>Explanation</i>
Test I	$\geq 12,5$	38	24
	$< 12,5$	7	21
Test II	$\geq 12,5$	32	20
	$< 12,5$	13	25

Figure 1 and 2 shows plenty of students who managed to achieve perfect scores in numerical problem. The obstacles faced by students to solve the numerical problems, are related to students' attitude and motivation [9]. In this study the obstacles are connected to the lack of conceptual understanding and computing skills. As an example in this study, some students do not understand the fact that the calculated work function of the same metal would remain constant. Due to this lack of understanding, they are unable to complete the subsequent question. Problem solving involves conceptual reasoning to facilitate the manipulation of the equation itself [1].

We expect the student who has solved such kind of numerical problems to really understand the concept and process of the photoelectric effect. They should also be able to explain all aspects related to the photoelectric effect in the explanatory question. This assumption can be expanded into a more general situation i.e. The achievement scores in numerical problems related to the score of explanation question. Table 1 shows the mean score of the numerical problem is higher than the explanatory question which shows both tests. This observation is different from the assumption.

The fact that the numerical score is higher than the explanation score is similar to the study of Hernández and Tecpan [8]. Aside from giving a multiple choice test, Hernández and Tecpan also asked the participants to explain their answer. Their result showed a contrast between the numbers of correct answers obtained with the test (quantitative result) and the amount of explanation that was considered correct (qualitative results).

This high score on the numerical test is related, among other things, to students' learning tendencies. Students usually prioritize the calculation problem type. Numerical exercise is important to a desirable extent. There is an assumption that teaching problem solving leads to understanding of the subject, however various studies present the side effect. They often are unable to explain the meaning of their own numerical solutions [3]. Students try to reach the solution as soon as possible by manipulating mathematical equations without having a clear conceptual insight into the problem situation [10]. Those researches show that traditionally formulated numerical exercise, which are mostly used in physics teaching, do not develop students' abilities in higher-order thinking.

About a half of the student achieves a score less than 50% of the maximal score for the explanation test. Students encounter difficulties in understanding the concept as well the way to express it. Similar results were qualitative assignments are not easily completed by students had been reported in the literature [11]. One of the questions of this type is regarding the analysis of the photoelectric effect and Compton effect. Students are able to describe both the photoelectric and the Compton Effect, however unable to explain the difference between them. They do not realize that their description contains the difference as well as the similarity between those effects. In order to explain scientific phenomena one needs skill to collect, select and use the data as evidence to support the statement / answer [8]. Furthermore the evidence should be linked with the scientific principles involved. In our case it seems that students possess a low skill in selecting and using the data.

Byun and Lee [12] reported that high school physics teachers in South Korea mostly used traditional lectures and solving or discussing quantitative or mathematical problems in their instruction. Their study showed that students who had solved many physics problems are not always adept at understanding the physics concepts. Adams and Wieman [13] showed various individual sub-skills that correlate to students' overall problem solving ability. Students' current state should be

considered for effective teaching. The teacher can help students to become better problem solver by teaching a problem-solving strategy that can be applied to any situation [11, 14, 15]. Qualitative problem solving strategies can improve students' achievement in explaining and understanding of the underlying physics concepts and principles.

4. Conclusion

Problem solving in physics is closely related to the understanding of its concept. Although the numerical problems seem to be computing problems, it can easily be solved if the concept is understood clearly. The study presented here shows that the students achieved a higher score in the numerical problems rather than those of the explanation questions. Students have difficulties in collecting, selecting and using the data to explain the answer of the problems/questions.

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