The analysis of students' ability in solving physics problems using multiple representations

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Abstract. The ability and skills of students in using multiple representations determine the level of students' physics problem solving abilities. Students' thinking ability in solving physics problems tends to vary. Therefore, this study was conducted to analyze the students' ability to solve physics problems by using multiple representations. The type of research was a qualitative research which utilized qualitative descriptive approach. The subjects in this study were 19 students of class XI Science An-Nahl MA Negeri Insan Cendikia Palu City in the 2019/2020 academic year. Respondents in this study were 6 students selected based on the high, medium, and low categories obtained from the results of the respondent selection test. The instruments used in this study were multiple choice tests, problem-solving tests, and interview guides. Based on the results of this study, the students' physics problem solving ability was categorized in the poor category with the acquisition of an average score in percentage of 37.89%, while for the highest average multi-representation ability of each representation, namely pictures, graphics, mathematics, and verbal, students tended to be able to use image representations with a percentage of 38.75%. However, this percentage was still categorized as low.

1. Introduction
Physical phenomena that occur in this universe may happen due to various reasons. The cause of the occurrence of physical phenomena can be studied using physics concepts when applied to these phenomena. However, it is not uncommon for someone to not realize the reason why there is a concept of physics in a physical phenomenon.

Solving a problem in physics can be done in various ways. One way is by physics problem solving. However, in the process, students' ability to solve physics problems is still low [1]. Students tend to use mathematical abilities directly without analyzing the problems beforehand.

Problem solving does not only emphasize on the quantitative aspects such as mathematical equations and procedures, but also emphasizes on the aspects of qualitative analysis in the form of choosing the right concepts and principles in solving problems [2]. Problem solving strategies only are not sufficient for students to successfully solve physics problems. For example, when students are dealing with abstract concepts, they need tools such as representations in visualizing the concepts to create bridges to proper equations to solve problems [3]. A series of physics concepts can be explained using various representations, including symbols, text, pictures, graphs, diagrams, tables, and mathematical equations.
The ability to use various types of representations is an invaluable solving skill in physics and has very interesting benefits [4]. Other studies revealed that problem solving was very commonly used in physics education [5]. The ability to represent is the ability to interpret by explaining a physical concept or problems in physics [6].

The use of various forms of representation can also increase students' knowledge of physics concepts. The student's ability to use more than one representation is referred as multi-representation ability. This can be used as a reference in assessing the ability of students in depth about physics [7]. The use of multiple representations can help students build concepts to make them easier to master the materials, as broad and complex concepts can be presented more simply and holistically [8].

Everyone has different levels of ability in solving problems related to physics concepts. This ability can be seen or reviewed in the physics problem solving process using multiple representations. Other research described problem solving, self-efficacy, and students' perceptions of physics problems by reviewing skills in different representational formats [5]. However, in this study, only two different representation formats were used, namely numeric and symbolic. Therefore, considering the idea that the role of representational skills that must be possessed by students is very important in solving physics problems, the researchers needed to conduct a review of students' abilities in solving physics problems using multi-representation tests. The existence of this study was not only to provide an overview of students' abilities in solving physics problems, but also the tendency of students' abilities to make representations was also found in this study.

### 2. Method

The type of research used in this research was qualitative research with a qualitative descriptive approach. The data collected was in the form of qualitative data. The data obtained was sourced from the given instrument. The instrument was a multiple-choice test of effort and energy which was used for the selection test of respondents. The second test was a problem-solving test given to selected respondents based on previous tests. The last test was an interview test which was conducted after the respondent had completed the problem-solving test. This research was conducted at MA Negeri Insan Cendikia, Palu City. The subjects of this study were 19 students of class XI IPA An-Nahl who had learnt about the physics materials of force and energy. The research subjects were categorized according to their initial knowledge regarding force and energy materials into high, medium, and low categories based on the calculation of the average score (mean) and standard deviation. After being categorized, 6 respondents who fulfilled the predetermined criteria were selected. The six respondents were given a problem-solving test in the form of 3-numbered essay questions, each of which contained three forms of problems that had to be solved using different representations. In the process of solving the problem, students were required to carry out the Thinking Aloud technique. Then, the respondents were interviewed using the interview guidelines prepared by the researcher. The answers and results of the respondents' interviews were then analyzed to identify the respondents' ability to solve force and energy exercises, as well as the respondents' tendencies in making the representations that have been provided. The data obtained from the results of students' problem-solving abilities using the multi-representation test was then analyzed by calculating the scores obtained by the students and the total scores. The percentage of students' problem-solving abilities was calculated using the following formula:

\[ \frac{NN_A}{NN_m} = \frac{N}{Nm} \times 100\% \]

\( NN_A \): Final problem solving skills test score
\( N \): Score obtained
\( NN_m \): Maximum Score

The results of the calculation were then categorized based on the following Table 1[9].
Table 1. Problem solving skills categories

| Percentage (%) | Category    |
|----------------|-------------|
| 81-100         | Very good   |
| 61-80          | Good        |
| 41-60          | Moderate    |
| 21-40          | Poor        |
| 0-20           | Very poor   |

The percentage of the multiple representation problem solving skills was determined by using the same formula and category on the solved problems.

3. Result and Discussion

Based on the calculation above, the results of students' physics problem solving skill are displayed in the following Table 2.

Table 2. The analysis of students' problem-solving skill

| Respondents | Score |
|-------------|-------|
| RKT-01      | 78.10 |
| RKT-02      | 36.15 |
| RKS-01      | 37.10 |
| RKS-02      | 3.60  |
| RKR-01      | 30.35 |
| RKR-02      | 42.05 |

Total Score 227.35

Average score obtained 37.89

The data is displayed on a graph of Figure 1 which can be observed below.

Figure 1. Students' Physics Problem Solving Skills Graphic

Table 2 and Figure 1 elaborate that the level of problem-solving abilities of the 6 respondents differed. If it is sorted from the highest problem-solving abilities to the lowest, the orders begin from RKT-01, then followed by RKR-02, RKS-01, RKT-02, RKR-01 and ended by RKS-02 who obtained the lowest score. Based on the existing categories, it could be stated that RKT-01 who reached a percentage of 78.10% was categorized in the good category, RKT-02 with 36.15% was included in the poor category, RKS-01 with 37.10% was also categorized in the poor category, RKS-02 with the score of 3.60% was included in the very poor category, RKR-01 who obtained 30.35% was placed in the poor category, and RKR-02 who got 42.05% belonged in the moderate category. Based on the percentage of
scores obtained by all 6 respondents, the average score percentage was 37.89% and it was categorized in the poor category.

The results of problem-solving tests which were carried out by the respondents indicated a variety of different forms of representation according to the problem given. The ability of the respondents to make representations can be seen from the following Table 3.

Table 3. Respondents' representation skills

| Question Item Number (Concepts) | Representation Format | Weight of Each Representative | Score Obtained/Percentage (Category) for Each Respondent |
|---------------------------------|-----------------------|-------------------------------|--------------------------------------------------------|
| 1 (Force)                       | Figure                | 20                            | 20/100% (VG) 18/90% (VG) 3/15% (VP) 3/15% (VP) 3/15% (VP) 6/30% (K) |
| 1 (Force)                       | Mathematic            | 20                            | 10/50% (M) 5/25% (P) 5/25% (P) 0/0% (VP) 5/25% (P) 5/25% (P) |
| 1 (Force)                       | Graphic               | 15                            | 15/100% (VG) 7/46,67% (M) 12/80% (G) 0/0% (VP) 0/0% (VP) 15/100% (VG) |
| 2 (Energy)                      | Verbal                | 15                            | 15/100% (VG) 7/46,67% (m) 1/6,67% (VP) 0/0% (VP) 7/46,67% (M) 9/45% (M) |
| 2 (Energy)                      | Mathematic            | 20                            | 20/100% (VG) 6/30% (P) 6/30% (P) 4/20% (VP) 6/30% (P) 4/20% (VP) |
| 2 (Energy)                      | Graphic               | 20                            | 17/85% (VG) 3/15% (VP) 3/15% (VP) 0/0% (VP) 0/0% (VP) 3/15% (VP) |
| 3 (Relationship between force and kinetic energy) | Figure                | 20                            | 10/50% (M) 5/25% (P) 10/50% (M) 0/0% (VP) 10/50% (M) 5/25% (P) |
| 3 (Relationship between force and kinetic energy) | Verbal                | 15                            | 12/80% (G) 0/0% (VP) 4/26,67% (P) 0/0% (VP) 0/0% (VP) 4/26,67% (P) |
| 3 (Relationship between force and kinetic energy) | Graphic               | 20                            | 8/40% (P) 0/0% (VP) 8/40% (P) 0/0% (VP) 0/0% (VP) 2/10% (P) |

Note:
VG : Very Good
G : Good
M : Moderate
P : Poor
VP : Very Poor

Table 3 shows the representative ability of each respondent in solving physics problems regarding the three different concepts using different representations. Based on the table, between one respondent to another, different values for each representation were obtained. This concludes that each respondent had their respective expertise in making representations. There were those who were experts at making graphic representations, but there were also those who were not mathematical experts. In percentages, the figure representation has the highest position among other representations, in which the 6 respondents were able to provide an average percentage of 38.75%.
The low level of students' ability to solve this problem was triggered by several reasons the respondents expressed during the Thinking Aloud problem-solving process and during the interview which were also capable of creating diversity in the respondents' abilities in solving this problem. Some of these factors include: 1) lack of memory, 2) not in accordance with the indicators of the problem solving stage, 3) lack of student motivation, 4) anxiety, doubts and carelessness, 5) lack of student ability to make representations, 6) low ability students in terms of understanding the concept, 7) inappropriate strategy used.

Lack of memory is a common problem faced by students in solving physics problems. Most of the students only memorize the material. This causes students' understanding to be very lacking. The following is part of the interview which was disclosed by RKS-04 on the excerpt below regarding the answer to the question about the force in physics materials.

Researcher: Nothing. Now, for the B section... okay, in your answer sheet, you did not answer section B and C. Can you explain why you did not answer?
RKS-02 : I forgot.

Similarly, RKS-04 also mentioned it in the question regarding energy within the interview, which can be observed in the excerpt below.

Researcher : Then, for the question number 2, in the point of A, you did not answer that? Why so?
RKS-02 : Because I don't know
Researcher : But, you've been taught this in Grade 10 before, right?
RKS-02 : Yes
Researcher : Does that mean you forgot?
RKS-04 : Yes

The process of solving physics problems requires structured stages. This research used the problem-solving stage which was developed by Polya. The problem-solving stage includes 4 stages, namely understanding the problem, designing a solution plan, implementing the planned solution, and re-checking. Each stage has its own indicator. However, the 6 respondents carried out a problem-solving process which was not in accordance with the stages of the pattern. Many of the respondents' answers missed the first stage, namely recognizing the problem, and so, it can be stated that the low category student test results were influenced by the process of students' work which did not follow the problem solving stages and the multi-representation indicators correctly [10]. This can be reviewed in the answer sheet RKT-02 in Figure 2 below regarding the exercise on force materials.

![Figure 2. Answer Sheet of RKT-02 on Question Number 1 on Section A](image)

In addition to the inappropriate answers to the problem-solving stages, lack of motivation was one of the causes of the respondents' low ability to solve these problems. This can be seen directly from the answers given by RKS-02 for questions about force, as shown in Figure 3 below.
The answer in Figure 3 shows that RKS-02 was less motivated to solve the problem [11]. This can be seen from the results of the answers which did not match the answer key. The format of solving the questions was also limited to providing information obtained from the questions.

Moreover, lack of research was also a common reason which students often face in solving problems. This inaccuracy was influenced by the anxiety they had during the problem-solving process, and this certainly made respondents feel doubtful. This statement was based on the results of the interview shown in the following excerpt.

*Researcher:* This is only the picture of C. Where are the parts for these? Please read the C section again.
*RKS-01:* ...
*Researcher:* How many are there?
*RKS-01:* Two
*Researcher:* And this picture is for which part?
*RKS-01:* A斯塔ghfirullah, I only drew one, Miss, I did not read until the end, too.
*Researcher:* Okay, so, Mayang forgot, right? Or maybe, you did not pay attention beforehand?
*RKS-01:* Nervous, Miss, I was nervous (while laughing)

The excerpt above discussed the mistakes made by RKS-01 when describing a bar chart of potential, kinetic, and mechanical energy. RKS-01's error in solving these problems was caused by several things, such as not understanding the concept, forgetting, not being careful and not focused [12]. This resulted in unsuccessful problem-solving solution.

In addition to seeing problem-solving abilities, this study also discussed representation skills. The representation meant here was verbal, mathematic, figure, and graphic representation. Based on this study, there were several respondents who still did not master the expected form of the representations from the questions, as seen in the following respondents' answers.

The answer written by RKS-01 is shown in Figure 4 above, which shows that the graph made was still wrong. The graph does not show the proper relationship that should be drawn.

Understanding the concept is also a critical aspect in solving problems. However, in this study, some respondents still lacked of understanding concept. The lack of this concept caused a misconception. This
was experienced by RKR-02 when solving the problem of the relationship between effort and energy. The concept which was not suitable is described by RKR-02 in Figure 5 below.

![Figure 5. Answer Sheet written by RKR-02 on Question Number 3 Section B](image)

The capture of the respondent's worksheet described verbally in Figure 5 had not yet described the concept of the relationship between effort and kinetic energy as provided in the equation. This indicates that RKR-02 had not mastered the concept of the relationship between effort and kinetic energy. As a result, RKR-02 was unable to solve this problem with the supposed correct results. This indicates that conceptual mastery plays an important role in the problem-solving process. Mastery of good and correct concepts is the point of success of students in solving problems [13].

In addition to understanding the concepts needed, the suitability of the strategy is also the main foundation for success in solving physics problems. However, in this study, there were still respondents who used incorrect strategies. This strategy error was triggered by the selection of inappropriate strategic planning. There were still many respondents who incorrectly determined the validity of the formula. This error occurred because of the forgetful factor. This was revealed by one of the respondents, namely RKR-02, in the following interview.

Researcher : Now, let's see Anisa's answer here to observe the situations. Which situation? Can you read this below, there are two situations, A and Be, which is the one you drew?
RKR-02 : A
Researcher : Then, where is the B situation?
RKR-02 : aahhh, I forgot.
Researcher : Forgot what? Forgot to write it?
RKR-02 : Yes

Based on the interview above, it can be said that the respondents' low memory at each stage of problem solving provided a great opportunity for errors in the problem-solving process, especially at the stage of implementing the strategies which have been compiled. This statement illustrates that one of the factors of strategy error which is usually done is an error in determining the steps to solve the problem caused by students who forget [14].

In addition to problem-solving abilities, this study also discussed the ability of respondents to make representations. Observed from the point of view of the average score, the respondents' problem-solving ability was still low. Even when observed from its multi-representation ability, the score was still low. However, respondents tended to be able to produce figure representations in the form of drawings compared to other forms of representation. This can be seen from the results of the average percentage of the 6 respondents for each representation. These results indicate that the image representation has the highest position among other representations. The ability of respondents who tended to be able to draw image representations is also in accordance with another research. The results of these studies reveal that the highest percentage of representation ability is focused on image representation [15]. However, in other research it was also stated that the highest representation ability obtained by students tended to be the verbal representation ability [16].

4. Conclusion and Suggestions
4.1. Conclusion
Based on the results of the research data analysis and the discussion obtained from observing students' abilities in solving physics problems, especially regarding force and energy using multi-representation tests, then it is concluded that:

1) The respondents' abilities in physics problem solving skills, based on the results of the analysis, show that students' problem-solving skills were categorized in the "poor" category with a percentage of 37.89%.

2) When observed from the abilities in multi-representation, all 6 respondents tended to be able to solve problems which were in the form of figures with the average percentage of 38.75%, categorized as poor.

3) The low ability of students in solving physics problems using multiple representations was influenced by the following factors: 1) lack of memory, 2) discrepancy of the indicators of problem solving stages, 3) lack of student motivation, 4) anxiety, doubts and carelessness, 5) the lack of student ability in making representations, 6) the low ability of students in terms of understanding concepts, 7) errors in the strategy used.

4.2. Suggestions

Based on the conclusion elaborated above, the researchers wish to deliver suggestions for future research. The researchers suggest that this study becomes a reference in the next research which is closely associated with the theme. In addition, further studies related to students' abilities in solving physics problems using multi-representation is needed. In several schools, the multi-representation is applied.

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