The Implementation of Guided Discovery Learning Using Virtual Lab Simulation To Reduce Students’ Misconception on Mechanical Wave

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Abstract. This study aims to determine the effectiveness of the implementation of guided discovery learning with virtual lab: Physics Education Technology (PhET) simulation in reducing students’ misconceptions in mechanical wave physics. The design of this study was pre-experimental design with One Group Pretest-Posttest Design. This research was conducted in Mojokerto, East Java, Indonesia. Thirty five 11th grade high school students and one teacher participated in this study. This study applied the certainty of response index (CRI) with Two-tier Diagnostic Test to determine students’ misconception. An analysis of differences in the average of misconception between pretest and posttest and also normalized gain analysis had been performed to find out the effectiveness of guided discovery learning implementation towards students’ misconception reduction. The treatment was declared effective if the average of misconception in pretest was greater than the posttest and the normalized gain was negative, which meant there was a decrease in misconception minimum in the moderate category (\(<g> \leq -0.3\)). The results showed that in the initial tests the 3 highest students’ misconceptions occurred on the concepts: wavelength, wave velocity and the nature of the wave. But the implementation of guided discovery learning was able to reduce students’ misconceptions significantly. Based on the statistical analysis of T test, it was found that \(t_{\text{count}} > t_{\text{table}}\) with \(\alpha = 0.05\) with \(1.96 > 1.71\). This meant that there were significant differences in average misconception. Through gain analysis, it is also known that \(<g> = -1.13\) where the average misconception at pretest is 53.33% to 19.55% for posttest. This decrease was included in the high category. According to these analysis results, the application of the Guided Discovery Learning model using Virtual Lab. PhET was able to reduce students’ misconceptions.

1. Introduction

Understanding is to know everything and understand correctly. A person's ability to understand concepts leads to the ability possessed in mastering the signs of objects [1]. Understanding is one type of learning outcome that is much higher when compared to knowledge. But to reach understanding, it is necessary to have a process of knowing a material well before [2]. The lack of understanding certain concepts will influence the formation of scientific concepts in students’ cognitive structures [3].
There are still many students who do not understand and do not master the concept of Physics. One of the difficulties in Physics is the occurrence of errors in concepts. In other words, they have different concepts from scientific knowledge. This is what we call misconception [4, 5, 6]. Misconception can affect students because it can obstruct students to receive new knowledge [7]. There are many ways to identify a misconception. One is using the certainty of response index (CRI) model. CRI is a confidence measurement in the given answer [8]. Using CRI will be quite easy and simple in distinguishing students who experience misconceptions and those who don't. It is a method for the honesty of students in answering a question by filling in the CRI level.

Learning that provides opportunities for active students in studying and do not cause many misconceptions is guided discovery. The findings referred to here are guided discoveries which involve the process of interaction between teacher and student, where students seek for themselves the desired concept through a sequence of questions set by the teacher. This learning gives students the freedom to find a concept [9, 10].

The discovery activities in learning physics cannot be separated from experimental and laboratory activities. From the results of observations at a senior high school in Mojokerto regarding the inadequate state of the Physics laboratory, where there is a lack of tools and materials for students to conduct experiments. Some tools are rusty or not suitable for use. One alternative method so that discovery activities can be carried out in learning is using virtual lab simulation. This method has also never been applied in school. By using virtual simulations it can provide a solution to the state of the laboratory that has equipment problems in the lab [11]. This simulation can provide opportunities for students to learn and apply the concepts they have in real-world skills. Using virtual lab simulation media can increase the effectiveness of understanding student concepts and minimize existing misconceptions [12].

There are a number of Physics concepts which have quite high concept weaknesses including wave propagation, wave superposition and particle movement in a mechanical wave system [13]. This concept allows misconception, it can be seen that many mechanical wave phenomena are found in everyday life. Based on the results of interviews, we find those still students who do not understand the physical meaning of wavelengths, wave velocities, and frequencies. Students only understand mathematically the meaning of wave propagation, which is when given a problem to snap the rope quickly, students will assume that the wave velocity will be large. In this case, the concept of students is different from scientific knowledge. Seeing this problem, the researcher conducted the guided discovery learning using virtual lab simulation in reducing the students’ misconception of mechanical wave material.

2. Research Methods

This research is quantitative research with a pre-experimental design approach. The form of research used was a one-group pretest-posttest design. This research was conducted at a high school in Mojokerto. Thirty five 11th grade high school science students as a research sample. Analysis of student conception was carried out through a diagnostic test in the form of pretest and posttest using CRI as a measure of confidence in the answers given.

| Answer | Low CRI (<2.5) | High CRI (>2.5) |
|--------|----------------|-----------------|
| Correct answer | Correct answer and low CRI (CL) lack of knowledge (lucky guess) | Correct answer and high CRI (CH) knowledge of correct concepts |
| Wrong answer | Wrong answer and low CRI (WL) lack of knowledge | Wrong answer and high CRI (WH) misconception |
Table 1 demonstrates the four potential mixes of the appropriate response (Correct or Wrong) and the CRI (High or Low) with respect to an individual understudy. For a student and for a given question, a correct answer with a low CRI (CL) indicates a lack of knowledge and a correct answer and a high CRI (CH) points to knowledge of correct concepts. A wrong answer with a low CRI (WL) suggests a lack of knowledge, while a wrong answer with a high CRI (WH) indicates the presence of misconceptions.

The results of the pretest and posttest were analyzed statistically. An analysis of differences in the average of misconception between pretest and posttest use paired t-test and also normalized gain analysis had been performed to find out the effectiveness of guided discovery learning implementation towards students’ misconception reduction. The treatment was declared effective if the average of misconception in pretest was greater than the postest and the normalized gain was negative, which meant there was a decrease in misconception minimum in the moderate category ($<g> \leq -0.3$).

3. Results and Discussion

The profile of the initial concept understanding is based on the value of the pretest.

| Absent Numbers | Lucky Guess | Lack of Knowledge | Correct Concept | Misconception | Category of Misconception |
|----------------|-------------|-------------------|-----------------|---------------|--------------------------|
| 28             | 0,00        | 0,00              | 11,11           | 88,89         | High                     |
| 7              | 0,00        | 11,11             | 11,11           | 77,78         | High                     |
| 34             | 0,00        | 0,00              | 22,22           | 77,78         | High                     |
| 5              | 0,00        | 0,00              | 33,33           | 66,67         | Medium                   |
| 6              | 0,00        | 0,00              | 33,33           | 66,67         | Medium                   |
| 11             | 0,00        | 0,00              | 33,33           | 66,67         | Medium                   |
| 15             | 0,00        | 0,00              | 33,33           | 66,67         | Medium                   |
| 16             | 0,00        | 0,00              | 33,33           | 66,67         | Medium                   |
| 19             | 0,00        | 0,00              | 33,33           | 66,67         | Medium                   |
| 27             | 0,00        | 0,00              | 33,33           | 66,67         | Medium                   |
| 30             | 0,00        | 0,00              | 33,33           | 66,67         | Medium                   |
| 3              | 0,00        | 33,33             | 11,11           | 55,56         | Medium                   |
| 14             | 11,11       | 22,22             | 11,11           | 55,56         | Medium                   |
| 17             | 0,00        | 0,00              | 44,44           | 55,56         | Medium                   |
| 22             | 0,00        | 0,00              | 44,44           | 55,56         | Medium                   |
| 24             | 0,00        | 0,00              | 44,44           | 55,56         | Medium                   |
| 29             | 0,00        | 0,00              | 44,44           | 55,56         | Medium                   |
| 21             | 11,11       | 33,33             | 11,11           | 44,44         | Low                      |
| 31             | 0,00        | 0,00              | 55,56           | 44,44         | Low                      |
| 35             | 0,00        | 0,00              | 55,56           | 44,44         | Low                      |
| 12             | 22,22       | 33,33             | 11,11           | 33,33         | Low                      |
| 23             | 0,00        | 22,22             | 44,44           | 33,33         | Low                      |
Based on the profile of conceptual understanding of class: 29% of students understood the concept. Students who had lack knowledge are 12% and those who answered by guessing are 6%. Misconceptions that occurred are still large at 53%. Misconceptions that occurred could be said to be quite large because it exceeded the number of students in the class. Most of the misconceptions that occurred made it possible for most students to be rarely given the problem of deepening the concept which prioritized mathematical elements. Reinforced again with the students' reasoning that was not in accordance with scientific knowledge.

Misconceptions that occur in students are divided into several levels of categories, namely low, medium, and high. This is used to find out how many students experience irregularities. This level is obtained by determining the upper and lower limits of the percentage perception data. Students who are categorized as high in misconceptions are equal to 12% of the total students. Students who experience a high level of misconception are students who get a large percentage of misconceptions $>75.087\%$, moderate levels with a percentage of $75.087\% \leq x \leq 31.579\%$ and low levels with a percentage of $<31.579\%$.

![Figure 1 Profile of Understanding Concept](image)

Understanding the concept of mechanical wave material is obtained from the pretest values that have been mapped into several concept categories that were asked in the CRI model diagnostic test questions. The following is the mapping.

| Concept          | Percentage (%) |
|------------------|----------------|
| Lucky Guess      | Lack of Knowledge | Correct Concept | Misconception |
| wavelength       | 0.00            | 20.00           | 4.00           | 76.00          |
| wave nature      | 4.00            | 13.33           | 28.00           | 54.66          |
| fast propagation factors | 8.00            | 14.67           | 25.33           | 52.00          |
| period           | 4.00            | 8.00            | 44.00           | 44.00          |
| amplitude        | 16.00           | 4.00            | 40.00           | 40.00          |

The concept of mechanical waves that experienced the highest misconception with a percentage of 76% is the wavelength. When students do diagnostic tests, they often experience errors between the concept of period and wavelength. Most students are less careful in understanding the components in the graph such as information located on the x and y axes. Thereof, when shown the closest distance
between two peaks on the graph of the relationship between the size of the deviation and the distance traveled, students equate the graph of the deviation and time relationships frequently. As a result, students often answer with the same answer, namely the period.

The second highest misconception (54.67%) is understanding the wave nature. Where students assumed that by increasing the width of the gap that passed through the wave, the wavelength also increased. However, there was an error in understanding that what the students actually observed in the picture was that the diffraction was not the large wavelength produced.

The third highest misconception is the propagation factor with a percentage of 52%. Students assumed that the magnitude of the wave velocity would change in proportion to the change in amplitude. Students assumed that if the amplitude was large then it also had a large thrust so that the resulting wave propagation happened to be relatively large.

After being given the pretest, students conducted a treatment applying guided discovery learning models assisted by virtual lab simulation. To ensure guided discovery learning models assisted by virtual lab simulation is carried out well, the steps in preparation and implementation are as follows: (1) in the preparation process the development of learning tools is carried out consisting of: Syllabus, Learning Implementation Plan, Student Textbooks, Student Worksheet, learning evaluation questions in the form of Two-tier Diagnostic Test and also the observation sheet of the implementation of learning. The worksheets developed in the study are worksheets that provide experimental instructions with the PhET Laboratory as a source of data that students will get. To test the validity of all learning tools and instruments that have been developed, a validation process is carried out by two experts on the learning tools and instruments. The results of the validity of the learning tools and instruments conducted by two experts in the study stated that they were valid and proper to use. (2) to ensure the treatment goes well in the implementation process, an assessment of the implementation of learning is carried out by two observers. The results of the assessment of the delay in learning conducted in three meetings obtained an average value of 90.6%, which means that the learning process was carried out in the excellent category.

To find out the influence of the model applied in reducing misconceptions in students performed paired t-test. That is a test carried out on the subject for the conditions before and after the process. In this study, this test was used to calculate the difference between the pretest misconception score and posttest and to find out if there were differences in it.
From analysis of data on Table 3, we obtained \( t_{\text{count}} > t_{\text{table}} \) with \( \alpha = 0.05 \) which was large with 1.96 > 1.71. Thus, using the guided discovery model assisted by virtual lab simulation can reduce students’ misconceptions in mechanical wave material significantly. Through the gain test, the class was categorized as having a high decrease with value was -1.13 which was 88% of students who experienced a decrease. The increasing understanding of this concept was due to the improvement and strengthening of students’ concepts in construction forming a new concept that had been done in guided discovery learning, namely the data collection phase. There were two students experiencing the greatest decrease in misconceptions, namely students numbers 7 and 34 with a decrease of 77.78%. As seen in the table above, the misconceptions of the two students are completely reduced, as is the case with students absent number 22. This could be seen from the posttest value of misconceptions obtained which was equal to 0%. In this class, only 4% of students did not decrease in misconception. This was because the understanding of the students’ initial concepts in this class was still carried on their initial knowledge, which was called resistance [15]. Misconceptions were resistant or can be said as difficult to change and a tendency to persevere even though a treatment about a concept justification had been given. In addition to originating from resistant misconceptions, it was also caused by observation and reasoning which was considered inaccurate and the level of intelligence possessed by students in the low category.

Besides that, there were two students in the class who experienced an increase in misconceptions, namely students with absent numbers 26 and 33. The increasing misconception was on the concept of wave nature. The learning of wave nature carried out at the second meeting required students to have a high level of precision when understanding the phenomenon of wave nature in water ripples. This was due to the application of the wavelength concept in it, so it could be said that the learning taught was more complex than learning at the first meeting. When viewed from the results of the two students’ pretest, the initial understanding of the concept possessed by the two students belonged to the category of insufficient knowledge. This could lead to difficulties in learning which had a high level of understanding in it. Still, the existence of students who experienced misconceptions showed that the design of the applied learning model needed improvement for the two students in order to reduce the misconceptions that they experienced maximally and thoroughly [16]. This could be one of the factors why in this study there were still students who experienced an increase in misconceptions.

4. Conclusion

Based on data analysis of the pre-test on the mechanical wave, it was found that students’ misconceptions were very high. The students’ biggest misconceptions occur in conceptualization: wavelength, wave properties and factors that influence the velocity of wave propagation. Three of the students’ biggest misconceptions are: (1) in reading the graph, students find it difficult to distinguish
between periods and wavelengths (2) in the diffraction wave process the greater the gap that is passed then the wavelength will change even greater. (3) the greater the amplitude of a wave, the greater the velocity of the wave propagation. Application of Guided Discovery Learning model using Virtual Lab. PhET was conducted to reduce students’ misconceptions on the concepts of mechanical waves. From the analysis of data on the pre-test and post-test shows that: there is a significant difference in student understanding between before and after the application of Guided Discovery learning. Based on the facts obtained in this study it can be concluded that the application of the Guided Discovery Learning model using Virtual Lab. PhET was able to reduce students’ misconceptions on all concepts in mechanical waves.

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