Analysis of students’ difficulties about work and energy

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Abstract. Identification of students’ difficulties is an important part of designing a quality learning. This research used survey method that aims to identify the difficulties experienced by students in understanding the concept of work and energy. The research subjects consisted of 142 undergraduate students in physics education (46 first-year students, 39 second-year students, and 57 third-year students). Data collection was carried out from 2018-2019. There are 10 multiple choices questions that are used to uncover the difficulties experienced by students. Based on the results obtained it can be concluded that many students still have difficulty in understanding the concepts of work and energy. The percentage of students who answered correctly are 20.42% in concept of work as a result of dot product multiplication; 11.26% in the work-energy theorem; 38.03% in the concept of spring potential energy, and 22.54% in the conservation law of mechanical energy.

1. Introduction

Many studies related to physics education find that students have difficulty in learning scientific concepts as a result of some knowledge of pre-existing concepts which are mostly alternative misconceptions or conceptions [1,2]. Understanding a physics concept as understood by physicists is an important goal in the process of learning physics. Proper understanding of a physics concept will make it easier for students to solve problems of physics learning [3,4]. By mastering the concepts of physics, it will have an impact on the way students explain the phenomena around and conclude [5]. Several methods have been attempted to improve problems using multi-representation in work and energy, CPS[6], and the use of modelling instruction that is effective in understanding physical phenomena.

One method of physics learning that is often a misconception by students is work and energy. Between work in physics and work in daily life have different meanings[7]. Energy is one of the basic concepts of physics learning that is abstract [3,8,9]. Almost in all science books, the principle related to conservation energy states that energy cannot be made or destroyed [1]. Work and energy are one of the important concepts in physics learning [10]. Students are expected to learn more about Energy Transfer and Transformation Processes than the definition of work and energy [10]. To learn about the process
of transfer and transformation of energy, it is necessary to understand the students' concepts of work and energy.

Some approaches to introducing energy show some different conceptualizations: energy is an abstract accounting quantity; energy is the ability to do work, to cause change, and to produce heat; energy is a general type of fuel; differences in conceptualism and materialism; energy is a quantity like matter; and form of energy [11]. Although this different approach seems promising, many studies show that students struggle to develop adequate the concept of energy [11,12].

From some of the results of research in the field of physics education, it is known that most students experience misconceptions about work and energy [3]. Students are confused about interpreting the work of certain force components [13]. This is due to the initial concepts and learning received by students in the School [14]. Therefore, it is important to recognize the abilities in the learning process in order to design an effective learning.

2. Methods
This research is a quantitative descriptive study using the survey method. This study aims to identify the difficulties experienced by students in understanding the concepts of work and energy. The survey was conducted on physics education students (46 first-year students, 39 second-year students, and 57 third-year students) of Malang State University. Data collection is carried out from 2018 to 2019.

This research is focused on analyzing the difficulties of learning and understanding the concepts of work and energy. The difficulty for students to solve given test questions. This study uses 10 reasoned multiple choices questions that are used to uncover the difficulties of experienced students in the concepts of work and energy. The question is the elaboration of 4 sub-materials presented in Table 1. The data analysis technique used is descriptive quantitative. The extent to which students understand the sub-material. The sub material that will be discussed in detail is represented by one item.

| Sub-Topic                                   | Question |
|---------------------------------------------|----------|
| Analysis of the Work Concept as a dot product multiplication | 1 & 2    |
| Work theorem and kinetic energy             | 3, 4, & 5|
| Spring Potential Energy                     | 6, 7, & 8|
| The law of conservation of mechanical energy| 9 & 10   |

The test problem used is a question that does not require complicated mathematical calculations. The 10 questions were adapted from questions related to work material and energy contained in international reference books [15–17] national and international journals[3,18–20]. Test questions are structured in such a way as to identify misconceptions and process errors experienced by students when studying work and energy so that the results of the analysis will be known regarding the type and location of difficulties experienced by students during the test.

3. Results and Discussion
This research is a quantitative descriptive study using the survey method. This study aims to identify the difficulties experienced by students in understanding the concepts of work and energy. The survey was conducted on physics education students (46th first-year students, 39th second-year students, and 57th third-year students) of Malang State University. Data collection is carried out from 2018 to 2019.

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Table 2. Distribution answers the choice of the correct student option

| Sub Topics                          | Quest. | 1st Year (N = 46) | 2nd year (N = 39) | 3th year (N = 57) | Total N | %      |
|-------------------------------------|--------|-------------------|-------------------|-------------------|---------|--------|
| Work as result of dot prod.         | 1      | 11                | 7                 | 25                | 43      | 30.28% |
| multiplication                      | 2      | 19                | 15                | 20                | 54      | 38.03% |
| work-energy theorem                 | 3      | 12                | 4                 | 13                | 29      | 20.42% |
|                                     | 4      | 7                 | 11                | 28                | 46      | 32.39% |
| spring potential energy             | 5      | 19                | 15                | 13                | 47      | 33.10% |
|                                     | 6      | 13                | 26                | 34                | 73      | 51.41% |
| conservation law of mechanical energy| 7     | 4                 | 7                 | 5                 | 16      | 11.27% |
|                                     | 8      | 31                | 21                | 33                | 85      | 59.86% |
|                                     | 9      | 11                | 19                | 24                | 54      | 38.03% |
|                                     | 10     | 13                | 8                 | 11                | 32      | 22.54% |
| Average(%)                          |        | 30,4348           | 34,10256          | 36,14035          |         |        |

Table 3. The percentage of correct option choices on each sub-material

| Sub-Topic                                      | Percentage |
|-----------------------------------------------|------------|
| Analyse of work as a result of dot product multiplication | 34.16%     |
| work-energy theorem                           | 28.64%     |
| the concept of spring potential energy        | 40.48%     |
| the conservation law of mechanical energy     | 30.28%     |

3.1 The Ability of Students to Understand the Concept of Work as Dot Product Multiplication

The questions used to express students' understanding of the work concept as dot product multiplication between force and displacement magnitudes are represented in items number 1 and 2. Based on Table 3, it can be seen that the percentage of students who answer with the correct choice option is 34.16%. This indicates that the ability of students to understand the basic concepts related to mechanical energy related to work as a result of dot product multiplication between force and displacement is still very low.

One of the questions used to test students' understanding in determining work as a result of dot product multiplication is the number 1 question answered by 43 (30.28%) students. In this question, students are asked to determine the efforts made by the sun in maintaining the planet's orbit to take one revolution. In answering these questions students give various wrong reasons, including (1) students assume that the efforts made by the sun are negative; (2) the sun does not do work because the planet never moves against the sun; (3) the effort carried out is zero because the speed of the planet is always constant. The first mistake that states that the effort carried out by the sun is negative because the direction of force given by the sun on the planet always leads to the centre of the trajectory so that the planet will experience a decrease in potential energy over time. This thinking is wrong because students do not understand that the direction of force (\(F\)) given is always perpendicular to the direction of displacement (\(s\)) of the planet, so the work done by \(F\) is zero. The second mistake, students think that the work is worth zero because students never move. The statement is wrong because it is incomplete. The planet is only said to be immobile if it has never changed its position to the sun. But in reality, the position of the planet changes at any time, except that after taking a revolution the planet returns to its original position so that the statement that the planet 'always' fixed or never moves is wrong. The third mistake, students assume that the planet's speed is always constant. This is wrong because the planet's speed is always in the tangential direction (perpendicular to the radial direction) so that the planet's velocity changes every time.
Based on the answers of students, although students chose the option that the effort carried out by the sun on the planet during the 1 revolution was zero, there were some students who gave wrong reasons. The results of this study correspond to the findings of Mustofa et al. (2016)[2] who found that students’ understanding of the basic concepts of mechanic energy is related to effort as the result of dot product multiplication between force and displacement is still very low. Barniol & Zavala (2014)[13] found that some students had doubts in determining the results of dot product multiplication. In a study conducted by Nugraha et al. (2014)[21] found that 37.1% of students experienced misconceptions about work concepts.

3.2 Student Understanding of the Work Theorem and Kinetic Energy

One of the questions (question number 3) that is used to measure students’ understanding of the concept of kinetic energy—theorem is to determine the kinetic energy ratio of 2 different mass objects driven by the same constant force. Both objects are both in the initial state of silence. Both objects are above the slippery plane and are pushed to the same displacement. Students are asked to determine the kinetic energy ratio of the two objects at the end of the track (the starting and ending points of the track are the same).

In answering this question, most students reason that large mass objects will have greater kinetic energy because kinetic energy is proportional to mass. This shows that students have succeeded in calling their knowledge related to kinetic energy equations namely \( K = \frac{1}{2} mv^2 \). But in using these equations students do not think that both objects have different speeds, so kinetic energy is not only affected by the masses. For constant \( F \), it is obtained that, \( v^2 = 2Fs / m \) so that \( K = \frac{1}{2} m (2Fs/m) = Fs \). Based on this equation, for \( F \) and \( s \) which are equal, it can be predicted that both objects have the same kinetic energy.

3.3 Students’ Understanding of Energy in Springs

The ability of students to understand the concept of spring potential energy is tested using the questions in Figure 1.

![Figure 1](image)

**Figure 1.** questions to reveal students' understanding of the concept of poto mamalam energy

To answer the question correctly, students must be able to activate some of the knowledge they have in full, including (1) spring potential energy if the spring is stretched or compressed; (2) the potential spring energy increases because there is a transfer of energy from the beam, so that the beam has a decrease in kinetic energy; (3) The amount of kinetic energy and potential energy is always constant as long as the system is in a conservative force. In answering these questions there are still many students who choose option D, which is as many as 94 (66.20%) students. That means students don’t call on the knowledge that \( V + K \) must always be constant. The diagram in option A should be wrong, because \( V + K \) is not the same as the total energy in the question. Students who justify option A assume that in the case of beating beams will accelerate so that the kinetic energy always increases therefore, \( V + K \) can be greater than the initial state.
3.4 Students’ Understanding of the Law of Mechanical Energy Conservation

One of the questions used to be able to reveal students’ understanding regarding the conservation law of mechanical energy is presented in question number 10. The question is shown in Figure 2.

**Figure 2.** To know Students’ Understanding of the Law of Mechanical Energy Conservation

The correct answer to this problem is the option (A). All three objects have the same mechanical energy when on the ground. This is because objects are thrown from the same height (same initial potential energy) and the same speed (mechanical energy is the same) so that the three objects have the same initial mechanical energy. Because the three objects work conservatively, the three objects do not experience changes in mechanical energy.

In answering the question, 21 (14.79%) students chose option (B). This shows that students think the mechanical energy of the object in figure (1) is large because the object is thrown upwards first. In addition, 34 (23.94%) students chose option (C). Students who choose the option (C) think that the farther the object is, the object will have greater mechanical energy. The results of this study are also in accordance with the findings of Dalaklioglu et al. (2015) [1] where only 32% of students (N = 284) were able to understand the concept of energy deficiency. So it can be concluded that the legal concept of mechanical energy is still a material that is difficult for students to understand. Students’ mistakes in answering this question are not caused because students do not have relevant knowledge about the problem [22,23]. Students fail to answer the problem because they fail to activate their knowledge so the conclusion are also wrong.

4. Conclusion

Students still have difficulty understanding the concepts of work and energy. Such difficulties occur in some topics such as the difficulty in understanding that work is the result of dot product multiplication between force and displacement, difficulty in understanding work relationships and mechanical energy, difficulty understanding the concept of spring potential energy, and difficulties in understanding energy work theorems. These difficulties occur because students' knowledge still tends to be fragmented, not yet forming intact knowledge. This is the triggers of students’ errors in activating relevant concepts when solving problems

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