Identification of students’ misconceptions using the Certainty of Response Index (CRI) from work and energy material

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Abstract. Research has been conducted at SMAN 1 Pesisir Selatan aimed to determine the level of students' misconceptions on work and energy materials. This research is quantitative descriptive with students from class X MIPA 2 SMAN 1 Pesisir Selatan as objects. The sampling in this study uses purposive sampling method. The data also is analyzed quantitatively. The results shows that the students' misconception level is 13.11% in which the criteria for the level of misconception is low.

1. Introduction

The development of globalization era more advanced makes human needs become more complex. One of the needs which must be fulfilled is education, because it triggers the development of community potential [1]. The purpose of an education is inseparable from the educational process such as teaching and learning activities. School as a formal education is one of the supporting facilities in learning activities [2]. However, one of obstacles in this activity is the concepts conveyed is not received by students well [3], especially in physics which contains scientific concepts that are difficult to understand and make them misconceptions, so the physics subject emphasizes understanding rather than memorizing a concept [4] [5].

Misconception is a condition where there is a mismatch of concepts from students between new concepts and old concepts connected [6]. Several causes of misconceptions can be found in students' personal, teachers' personal, textbooks used, the context and teaching methods. In addition, misconceptions can be caused by initial concepts or preconceptions from students. From some of the causes that have been mentioned, the most dominant aspect that causes misconceptions is students' personal [7], and this is the reason researchers make students as objects in this study. Misconceptions also have an impact on student learning outcomes, but misconceptions cannot be identified directly, so students have to take diagnostic tests to distinguish between students with misconceptions and not because of ignorance about the concept [8].

Based on the results of a preliminary study questionnaire that was conducted and an interview with one of the physics teachers at SMAN 1 Pesisir Selatan, it can be seen that almost every day the teacher finds students with difficulty in understanding physical concepts due to some factors such as inadequate learning literature, in terms of teacher delivery in the learning process that is not good and even the lack of students 'interest in learning physics, and also according to the answers of students'
statements in a questionnaire where most students assume that learning physics subjects are less enjoyable and difficult to understand. All of this is irrespective of whether students experience misconceptions or not in the learning process because teachers cannot distinguish them directly and they have never conducted a misconception diagnostic test before. Misconception diagnostic tests are believed to be more effective in identifying misconceptions [9].

Diagnostic tests are important to identify misconceptions, because if misconceptions are not tested then students who experience misconceptions will always carry wrong concepts [10]. The diagnostic test in this study combines the Certainy of Response Index (CRI) diagnostic test with the Four-Tier Diagnostic Test design. CRI is one way to differentiate between students' misconceptions and not knowing the concept, which is seen from the level of student confidence on the answer sheet [11], and the Four-Tier Diagnostic Test is a diagnostic test that has four levels.

2. Method
The method in this research is descriptive quantitative research. The population are students of class X MIPA SMAN 1 Pesisir Selatan. The sampling is purposive sampling with the sample is Class X MIPA 2 SMAN 1 Pesisir Selatan. The instrument in this study is a four-level objective test combined by a Certainy of Response Index (CRI). To identify the CRI assessment criteria in distinguishing students who understand the concept, misconceptions, do not understand the concept and error, using references from previous research [12]. And to see the percentage category of misconceptions, use references from previous studies [13]. As well as to see the combined category of Four-Tier Diagnostic Test answers also use references from previous research [14].

### Table 1. CRI Assessment criteria.

| CRI | Criteria                              | Confidence Level   |
|-----|---------------------------------------|--------------------|
| 0   | Guessing answer                       | Low / Not Sure     |
| 1   | The answer is almost guessing         | Low / Not Sure     |
| 2   | Answer not sure                       | High / sure        |
| 3   | Sure answer                           | High / sure        |
| 4   | The answer is almost right            | High / sure        |
| 5   | The answer must be correct            | High / sure        |

### Table 2. Percentage category of misconceptions.

| Percentage of P | Criteria |
|-----------------|----------|
| 0% ≥ 30%        | Low      |
| 31% ≥ 60%       | Moderate |
| 61% ≥ 100%      | High     |

### Table 3. Combination of four-tier diagnostic test answer categories.

| No. | Category    | The answer | Confidence Rating | Reason | Confidence Rating Reason |
|-----|-------------|------------|-------------------|--------|--------------------------|
| 1   | Understand  | Right      | Sure              | Right  | Sure                     |
| 2   |             | Right      | Sure              | False  | Sure                     |
| 3   | Misconception | Right   | Not               | False  | Sure                     |
| 4   |             | False      | Sure              | False  | Sure                     |
| 5   |             | False      | Not               | False  | Sure                     |
| 6   | Don't Understand | Right | Sure              | Right  | Not                      |
3. Results and Discussion

This study aims to determine the level of students' misconceptions on work and energy subjects in the class X of MIPA at SMAN 1 Pesisir Selatan. Testing the level of misconception is measured by a multiple-tier multiple choice test design combined by a Certainty of response Index (CRI) or confidence level in dealing with the questions. From the students of class X MIPA 2 of SMAN 1 Pesisir Selatan, 30 students, where this study was conducted in May 2019.

3.1. Identification of Students’ Misconceptions

Based on the results of data analysis, the average percentage of students' misconceptions in class X MIPA SMAN 1 Pesisir Selatan is 13.1% with low criteria. The percentage of misconceptions in this study can be seen in Table 4.

Table 4. Results of students' misconceptions.

| No. | Student Code | PK % | M % | TPK % | Error % |
|-----|--------------|------|-----|-------|---------|
| 1   | B-1          | 2    | 6,6 | 4     | 13,3    |
| 2   | B-2          | 1    | 3,3 | 5     | 16,6    |
| 3   | B-3          | 1    | 3,3 | 6     | 20      |
| 4   | B-4          | 1    | 3,3 | 10    | 6       |
| 5   | B-5          | 1    | 3,3 | 5     | 16,6    |
| 6   | B-6          | 1    | 3,3 | 10    | 16,6    |
| 7   | B-7          | 1    | 3,3 | 6     | 20      |
| 8   | B-8          | 1    | 3,3 | 5     | 16,6    |
| 9   | B-9          | 1    | 3,3 | 6     | 13,3    |
| 10  | B-10         | 2    | 6,6 | 4     | 13,3    |
| 11  | B-11         | 1    | 3,3 | 3     | 10      |
| 12  | B-12         | 3    | 10  | 4     | 13,3    |
| 13  | B-13         | 0    | 0   | 6     | 20      |
| 14  | B-14         | 0    | 0   | 3     | 10      |
| 15  | B-15         | 1    | 3,3 | 3     | 10      |
| 16  | B-16         | 0    | 0   | 4     | 13,3    |
| 17  | B-17         | 2    | 6,6 | 3     | 6       |
| 18  | B-18         | 0    | 0   | 4     | 13,3    |
| 19  | B-19         | 1    | 3,3 | 7     | 10      |
| 20  | B-20         | 2    | 6,6 | 4     | 13,3    |
| 21  | B-21         | 1    | 3,3 | 5     | 16,6    |
| 22  | B-22         | 1    | 3,3 | 5     | 16,6    |
3.2. Misconception Identification on each Item

In this study, researchers use a test instrument with 10 items. Each item has four levels that are equipped with reasons and confidence. The test questions used in this study consist of several submaterials, such as the concept of work, kinetic energy and potential energy (gravity and spring), the relationship between work and energy, and the law of conservation of mechanical energy. Categorizing the answers of students who have been identified is divided into 4 categories according to the references used by researchers, among others, Understanding Concepts (PK), Misconceptions (M), Not Understanding Concepts (TPK), and Error. Based on the results of the misconception analysis of each item, the average misconception of 10 items was 39.3% with the moderate criteria of misconception. The results of students' misconception tests for each item are presented in more detail in Table 5.

| Number | PK | M | TPK | Error |
|--------|----|---|-----|-------|
| Questions | Σ | % | Σ | % | Σ | % | Σ | % |
| 1 | 1 | 3,3 | 17 | 56,6 | 11 | 36,6 | 1 | 3,3 |
| 2 | 7 | 23,3 | 12 | 40 | 8 | 26,6 | 3 | 10 |
| 3 | 8 | 26,6 | 8 | 26,6 | 12 | 40 | 2 | 6,6 |
| 4 | 0 | 0 | 11 | 36,6 | 15 | 50 | 4 | 13,3 |
| 5 | 5 | 16,6 | 12 | 40 | 12 | 40 | 1 | 3,3 |
| 6 | 1 | 3,3 | 11 | 36,6 | 15 | 50 | 3 | 10 |
| 7 | 0 | 0 | 14 | 46,6 | 16 | 53,3 | 0 | 0 |
| 8 | 6 | 20 | 11 | 36,6 | 12 | 40 | 1 | 3,3 |
| 9 | 2 | 6,6 | 7 | 23,3 | 17 | 56,6 | 4 | 13,3 |
| 10 | 3 | 10 | 15 | 50 | 11 | 36,6 | 1 | 3,3 |
| Total | 33 | 110 | 118 | 393,3 | 129 | 430 | 20 | 66,6 |
| Average | 3,3 | 11 | 11,8 | 39,3 | 12,9 | 43 | 2 | 6,6 |

The percentage of misconceptions for each item in detail is presented in Figure 1.
Below is a discussion on the results of students' misconceptions on each item:

3.2.1. Question Number 1 and Participant Answers
According to analysis, students with misconceptions are divided into 4 criteria. The first criterion, students answer the question of tier 1 correctly and the level of confidence of tier 2 is sure and the answer to the reasons of tier 3 is wrong. The second criterion, students answer the questions tier 1 correctly and the level of confidence in tier 2 is unsure and the reasoning answers in tier 3 are wrong. The third criterion, where students answer the question tier 1 is wrong and a tier 2 confidence level is sure and the reasoning answer in tier 3 is wrong. in the fourth criterion, students answering questions tier 1 is wrong and CRI tier 2 is not sure and also the reason tier 3 answers are wrong.

Clearly seen in this case shows the occurrence of misconceptions, where students answer the answers right and also wrong and the reason the answer is wrong. In this case the students are astonished and assume that all objects that move to the left will have a negative value, and also assume that in the application of the game tug of war the work is not negative and also assume that even if the forces acting form a work angle will still not be valuable negative. Not should be examined if all objects moving to the left will be negatively negative. The object will be negative if the applied force forms an angle of 180° with the displacement of the object. In problem number 1 a negative-value work is applied in the tug of war game that is \( \text{the action force} = - \text{reaction force} \), where a group of tug-of-war teams have exerted a force as much as they could but the effort made by the losing tug-of-war team was the opposite, so the effort carried out is in the opposite direction objects then the work done is negative.
3.2.2. Question Number 2 and Participant Answers

After analyzed, students with misconceptions on this question are divided into 4 criteria. The first criterion is students answer tier 1 correctly, the level of confidence in tier 2 is sure, and answers in tier 3 are wrong. The second criterion is that students answer tier 1 correctly, the level of confidence in tier 2 is not sure and answers in tier 3 are wrong. The third criterion is that students answer tier 1 incorrectly, the level of confidence in tier 2 is confident and the reasoning in tier 3 is wrong. In the fourth criterion, students answer tier 1 incorrectly, the level of confidence in tier 2 is unsure and the reasons in tier 3 is wrong.

In this case, students on average give an answer where there is a change in energy i.e kinetic energy (when the bow is drawn) to potential energy (when the arrow is released from the bow toward the target). This is not quite right, where what should happen is the potential energy turned into kinetic energy. Because when you stretch the arrows, the energy in the arrows is the spring potential energy and gravitational potential energy, so that when the arrow is released and slides to the target, the spring potential energy turns into the kinetic of the spring with a horizontal velocity vector that makes the arrow move anterior and its gravitational potential energy changes to the kinetic energy of a spring with its vertical velocity vector that makes the arrow move down.

3.2.3. Question Number 3 and Participant Answers

In question number 3, students with misconceptions are divided into 4 criteria. For the first criterion, students answer level 1 answers correctly, whereas for CRI level 2 is sure and answer level 3 is wrong. The second criterion, students answer tier 1 correctly, but CRI in tier 2 is not sure and tier 3 is also wrong. The third criterion is that students answer tier 1 wrongly, but CRI at tier 2 is sure and tier 3 is wrong. For the fourth criterion, students answer tier 1 wrongly, the CRI level at tier 2 is unsure and tier 3 is wrong.

\[ X \] (The initial position of the ball before being dropped)
\[ Y \] (Ball position when falling)
\[ Z \] (The position of the ball just before it hits the ground)

Picture 2. The position of the ball being dropped.

In this problem, students are fooled by the answer where the potential energy is in position Z and the biggest kinetic energy is in position X. This answer is not true, where the greatest potential energy should be in position X and the biggest kinetic energy is in position Z, because energy potential (EP) is the energy type of energy related to the position of the object (vertical or altitude) to do business, while the kinetic energy (EK) is the energy that the object has due to its motion (its speed), if its speed is doubled, its EK will increase 4-fold.

3.2.4. Question Number 4 and Participant Answers

According to analysis, students with misconceptions on this question are divided into 3 criteria. The first criterion is that students answer level 1 correctly, and CRI at level 2 is sure and level 3 is wrong. Whereas the second criterion, students answer tier 1 wrongly, but CRI at tier 2 is sure, and tier 3 answers is wrong. The third criterion is that students answer tier 1 wrongly, the answer in tier 2 is not sure and the answer in tier 3 is also wrong.

In this case, the free fall motion is applied to the coconuts that fall from the tree with the question where the kinetic energy of the fallen coconut after stopping and reaching the ground. most students are fooled and answered that the kinetic energy when a coconut falls and has reached the ground will turn into potential energy or even disappear. the answer is not quite right, where the correct answer is when the falling coconut fruit stops and reaches the kinetic energy and the potential energy remains
the same as in the initial position of the coconut, where the kinetic energy is equal to the potential energy.

3.2.5. Question Number 5 and Participant Answers
In this case, students with misconception are divided into 4 groups. The first group who give the answer in tier 1 is correct, and the level of confidence in tier 2 is sure, but the reason for the answer in tier 3 is wrong. The second group who give the answer in tier 1 is correct, but in the level of confidence tier 2 is not sure and the answer in tier 3 is wrong. The third group who give the answer in tier 1 is wrong, but at the level of confidence tier 2 is confident while the reason for the answer in tier 3 is wrong. The fourth group answering the answers in tier 1 is wrong, the level of confidence in tier 2 is not sure and also the reason for the answer in tier 3 is wrong.

In this question, there are 3 states of objects mentioned first the slingshot rubber is stretched, the second is a distorted pendulum and the third is iron heated with the question, which object has potential energy. Most students choose answers that are stretched slingshots and heated iron. In this case many students are fooled, which should have potential energy is a stretched rubber slingshot that has elastic potential energy and a distorted pendulum that has gravitational potential energy.

3.2.6. Question Number 6 and Participant Answers
In this study, students with misconceptions were divided into 3 categories. In the first category, students answer tier 1 correctly, CRI in tier 2 is not sure and the reason tier 3 is wrong. In the second category, students answer level 1 wrongly, the level in tier 2 is sure but the reason in tier 3 is wrong, and in the third category students answer tier 1 wrongly, the CRI tier 2 is not sure and the reason in tier 3 is wrong.

On item number 6, many students are deceived by choosing answers in a positive direction, while in the problem the instructions have been given namely the amount of effort by the floor friction force on the beam, where the beam moves from the initial position to the end the friction force will be opposite to the direction or negative.

3.2.7. Question Number 7 and Participant Answers
In this study, question number 7 is included in the sub-material of correlation between work and kinetic energy, which is determining the speed of motion of an object from the application of effort with energy changes. After analyzed, there are 3 criteria of students with misconceptions. In the first criterion, students answer tier 1 correctly, the CRI in tier 2 is sure and the reason in tier 3 is wrong. In the second criterion, students answer tier 1 wrongly, the level of confidence in tier 2 is sure, but the reason in tier 3 is wrong and in the third criterion students answer tier 1 wrongly, CRI on tier 2 is unsure and the reason in tier 3 is wrong.

In this discussion students are fooled by the answer that the effort made will make objects move so that the difference between the kinetic energy of objects where according to students the final square velocity of the object will be added to the initial square velocity of the object that is 
\[ F_s = \Delta EK = 1/2 m(v_2^2 - v_0^2), \]
while the correct answer is where the velocity of the final square of the object will be reduced by the initial square velocity of the object that is 
\[ F_s = \Delta EK = 1/2 m(v_2^2 - v_0^2). \]

3.2.8. Question Number 8 and Participant Answers
After analyzed, students with misconceptions are divided into 4 groups. In the first group, students answers the tier 1 correctly, with CRI in tier 2 is sure but the reason in tier 3 is wrong. In the second group, students answers the tier 1 correctly, the level of confidence in tier 2 is not sure and the reason for the tier 3 is wrong. In the third group students answer tier 1 wrongly, the level of confidence tier 2 is sure and the reason tier 3 is wrong and in the fourth group students answer tier 1 wrongly, CRI in tier 2 is not sure, and the reason tier 3 is wrong.

In this study, question number 8 is included in the sub-material work concept of the moon's gravitational force on the earth. In this question the question is that when the moon rotates around the
earth in circular orbits and the moon is maintained in that orbit by the gravitational force exerted by the earth, in this case whether the gravitational force does positive, negative or even positive and negative work. In answering this question students will be fooled by negative or positive and negative answers regardless of whether they really understand the concept or not. This is not true, where gravity will do positive work because the angle $\Theta$ between the force and momentary moon movement is $90^\circ$, so the work done by gravity is zero ($\cos 90^\circ = 0$).

3.2.9. Question Number 9 and Participant Answers
Based on the analysis conducted, 7 students with misconceptions were divided into 2 groups. In the first group of 6 people, they answer in tier 1 wrongly, the level of confidence in tier 2 is sure while the reason in tier 3 is wrong. on the other group, only 1 student answers in tier 1 wrongly, the CRI in tier 2 is unsure and the reason in tier 3 is wrong.

In answering question number 9, most students answer the question in which the work on the hammerhead is positive. This is not right, where the work on the hammerhead is negative because the total force on the hammer is equal to $-F$, where $F$ is considered constant (working towards the left) and its displacement or $d$ to the right, so that the total work working on the hammer is negative $= (F)(d)(\cos 180^\circ) = -Fd$ is negative.

3.2.10. Question Number 10 and Participant Answers
Problem number 10 in this study is included in the sub-material law of mechanical energy conservation which is about the change of potential energy to kinetic energy in two water slides. 15 students with misconceptions are divided into 4 criteria. In the first criterion, 2 students answer tier 1 correctly, CRI in tier 2 is sure, and the reason in tier 3 is wrong. In the second criterion, only 1 person answers tier 1 correctly, but the CRI in tier 2 is not sure and the reason in tier 3 is wrong. In the third criterion 11 students answer tier 1 wrongly, the CRI in tier 2 is sure and the reason in tier 3 is wrong. In the fourth criterion 1 student answers tier 1 wrongly, the level of confidence in tier 2 is not sure and the reason in tier 3 is wrong.

In answering this problem many students are fooled by the answer that Paul and Kethleen will reach the bottom simultaneously, this is clearly not true, where the one who should reach the bottom is Kethleen because they use different launches where Kethleen converts its potential energy into kinetic energy early, so he glides faster along the track and the distance is more or less the same, so Kethleen will get to the bottom earlier than Paul.

3.3. Overall Identification of Misconceptions
After identifying misconceptions on students or samples, the results of the answers are presented in Figure 1.

![Figure 2. Percentage of Students Misconceptions.](image-url)
From Figure 2. It can be seen that the percentage of misconceptions of students as a whole who experience misconceptions is 13.11%, while the criteria for students to understand the concept as a whole is 3.67%, for the criteria of students who do not understand the concept as a whole amounted to 14.33% and for students included in the overall error criteria was 2.22%. In this study, the sub-concepts of work and energy materials with the highest misconceptions occurred in the work and energy sub-concepts with a percentage of 46.67%. This is consistent with previous research, where the highest misconception also occurs in the sub-concepts of work and energy relations [15]. Based on the results of the analysis on the answers tier 3 and tier 4, the cause of students experiencing the biggest misconception in the sub concept of work and energy relations, namely where the misconceptions that occur are generally caused by students' logic that is not right, namely students assume that the effort made by the force causes objects to move so that the difference between the kinetic energy of the object, \( F.s = \Delta EK = \frac{1}{2} m (v_f^2 + v_0^2) \) where the final velocity is added to the initial velocity, this is clearly wrong because what should happen to the difference in the kinetic energy of the object is the final velocity minus the initial velocity \( F.s = \Delta EK = \frac{1}{2} m (v_f^2 - v_0^2) \).

Generally, in this study the percentage of misconceptions of students in grade X MIPA SMA 1 Pesisir Selatan is 13.11% and misconceptions are in the low category.

4. Conclusions and Recommendations

Based on the results of research on the Identification of Student Misconceptions Using the Certainty of Response Index (CRI) on Work and Energy Material, it can be concluded that there are misconceptions in students of class X MIPA SMAN 1 Pesisir Selatan with a level of misconception as rudimentary as 13.11% where misconceptions are in the low category and the highest misconception occurs in the sub-concepts of work and energy relations.

For further researchers, it is expected to apply the same method using the Four-Tier Diagnostic Test accompanied by Certainty of Response Index (CRI) and find out the cause of students' misconceptions both on the same material or on the different material and provide a way to guarantee the honesty of students in affirming the value of the Certainty of Response Index (CRI).

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