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The Identification of Students' and Teachers' Misconception on Energy in North Central Timor Regency

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Abstract: This study aims to identify the misconception in the students as well as the teachers on the same topic, namely Energy. This study used mixed-method research of sequential exploratory type with the research subjects of the teachers and the students in North Central Timor Regency with a sample size of 163 students and 12 physics teachers. The misconception data was obtained by giving a misconception test in the form of a multiple-choice question. There were 12 questions with 5 answer choices which were equipped with CRI (Certainty of Response Index). The results showed that the percentage of students' misconceptions for the whole question (12 items) was quite large, namely 43.66%, while students who had a good understanding of the concept were 38.80%. Nearly 18% of students did not understand the concept while 4.24% were just guessing and lucky (Lucky Guess) while the remaining 13.29% were the total students who did not understand the concept of the questions at all. Meanwhile, of the teachers, an average of 77.08% have mastered the concept of Energy. However, as many as 22.92% of the teachers had the misconception on several questions, namely (question number 5,6,7,8,9,10, and 12) with the most misconceptions on question number 7, 10, and 5. The conclusion obtained was that the misconception found in physics teachers was 22.92%. For the students, there was still a large portion of them who had misconceptions about the topic of Energy. This was caused by the lack of students' understanding of the topic of Energy.

Keywords: Misconception; Physics; Energy; Teachers; Students.

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Introduction

One of the important goals in learning science is to help students improve their conceptual understanding. According to the constructivism approach, when the learning process occurs, the individual has an active mind and thoughts to make meaning about the world around them (Pines & West, 1986). This means that each individual needs to go through a thinking process that involves brain work to understand and conceptualize a certain knowledge in their minds.

At present, the conceptual understanding of science learning is one of the topics of concern for many researchers in the field of education (Olympiou & Zacharia, 2012; Pines & West, 1986; Venville & Dawson, 2010). How to change students' understanding of science concepts through the learning process in the classroom has become one of the most sought-after topics by many researchers for the last 30 years. The recent research has been also focusing on identifying which science concepts are difficult for students to understand, how teachers can convey these concepts more explicitly, and specific strategies that teachers need to apply to avoid misconceptions in the students (Chiu et al., 2007).

Basically, the definition of Conceptual Understanding has been put forward by several experts according to their respective points of view. Krieger, (2012) defines Conceptual Understanding as a skill owned by individuals to master a certain concept. Meanwhile, Hounsell (1997) defines Conceptual Understanding as an individual's ability to understand a certain concept holistically and thoroughly.

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Meanwhile, if viewed from a psychological study, Conceptual Understanding is the result of a mental process in which an individual can make meaningful connections between facts and ideas that were previously separated or have independent meanings (Johnson-Laird, 1983). A person with a good understanding of concepts can make and understand the relationship of these facts and describe them in words (Perkins, 2006).

In the learning process, the teacher cannot directly provide understanding to the students because this is the result of a mental process. However, teachers can initiate and facilitate the students to gain an understanding of a certain concept. This can be done through a teaching process that involves students' active learning through a constructivist learning process (León & Escudero, 2015).

However, in its journey, the process of learning science is never free from misconceptions that may occur. Several studies have provided different terms for misconceptions such as Alternative Concepts or Student Science Personal Model to define students' scientific concepts that are wrong or deviate from what they should be (Chiu et al., 2007). Misconceptions can occur because when learning a new concept in science, students may already have their prior knowledge of certain concepts without being based on valid scientific explanations. Usually, the initial concepts that have been embedded in their minds are very strong and difficult to be changed even though they have learned the science concepts (Goris & Dyrenfurth, 2010).

Misconceptions will give students a particular disadvantage if they are not identified early by the teacher. Therefore, the process of identifying students' misconceptions needs to be carried out at the elementary level when students begin to recognize science concepts, namely from the junior and senior high school levels. The process of identifying students' misconceptions from an early age at the junior and senior high school level is very important to help teachers get an idea about the factors that make it difficult for students to learn certain topics. Moreover, the teachers could also identify what science concepts that need special attention and what learning strategies need to be applied to teach certain science concepts.

Talking about students' misconceptions, then of course we cannot escape the misconceptions that teachers may also have. In the research of (Nurulwati et al., 2014), misconceptions can also be caused by the teachers. Until now, the research conducted in Indonesia has mostly reviewed student misconceptions (Faizah, 2016; Karomah et al., 2018; Laksana, 2017; Yuliati, 2017). Meanwhile, it is very rare to find research that identifies misconceptions of the teachers or reviews the misconceptions of students and teachers simultaneously. Therefore, this study aims to identify the misconceptions not only in the students but also in the teachers on the same science content, namely Energy. It is hoped that the result of this research could provide an overview of what science concepts that still misinterpreted by the teachers and the students. The result of this study could be used as a basis for teaching improvement by increasing the teacher's Content Knowledge or Pedagogical Content Knowledge (Shulman, 1987) and at the same time could also increase students' conceptual understanding.

Method

This research was conducted in 9 senior high schools in North Central Timor Regency. The research started from the end of July until October 2021. This research used a mixed-method by combining two existing forms of research, namely qualitative research and quantitative research. According to Creswell, mixed research is a research approach that combines qualitative research with quantitative research (Creswell, 2012).

The research design used in this research was sequential exploratory through collecting and analyzing the qualitative data and then followed by collecting and analyzing the quantitative data. This study gave more emphasis to the qualitative methods. Following what has been said by Creswell, the first stage in this research is the collection and the analysis of qualitative data and then followed by the collection and analysis of the quantitative data (Creswell, 2012). The combination of quantitative data and qualitative data is usually based on the results from the first stage. The main priority at this stage is to give more emphasis to the first stage while the merging process between the two occurs when the researcher connects the qualitative data analysis with quantitative data collection. In this study, quantitative data was used to explain the qualitative data.

The qualitative methods were used to determine the conceptual understanding and the misconceptions of the students and the teachers. In addition, this method was also used to determine the role of the teachers in providing the topic subject for the students. Meanwhile, the quantitative method was used to find out the conceptual understanding and the misconceptions of the students. The population of this study was all students and physics teachers in North Central Timor (TTU) regency. Furthermore, the sampling technique was done by using Simple Random Sampling so that a sample of 163 students and 12 physics teachers were chosen.

The data in this study used the primary data, which means that the researcher takes mixed-method research using both types of data collection (qualitative and quantitative) and both types of data analysis (statistical and qualitative analysis (Tashakkori & Teddlie, 2010). In general, the technique of data collection technique that the author chose was the multiple-choice tests and the documentation. The test instrument in this study is currently under development by the researchers. To identify students' misconceptions, the CRI (Certainty of Response Index) method was also used to measure the respondent's level of confidence/certainty in answering each question given (Novitasari et al., 2019; Rahmah et al., 2020; Safriana & Fatmi, 2018).

The data analysis carried out in this research used two approaches, namely qualitative and quantitative approaches. According to Miles and Huberman, qualitative data are obtained from the data reduction, data display, and conclusion of drawing/verification (Sugiyono, 2015).

The quantitative data were obtained from the result test of students' and teachers' conceptual understanding and misconceptions which were then analyzed by quantitative descriptive analysis using CRI according to the instrument the researchers have developed. The data presentation was described in the form of tables, graphs, and diagrams. The results of qualitative data and quantitative data were then combined and interpreted. Table 1 below shows the CRI criteria and categories of students' understanding.

Table 1. CRI's Criteria

CRI	Criteria
0	Totally guessed answer
1	Almost guess
2	Not Sure
3	Sure
4	Almost certain
5	Certain

(A'yun et al., 2018)a

Table 2. Students' Misconception Categories

Answer	Low CRI (0-2)		High CRI (3-5)	
	Correct Reason	Wrong Reason	Correct Reason	Wrong Reason
Correct	Lucky/Guessing (L)	Not Understanding Concepts (NUC)	Understanding Concepts/Expert (E)	False Positive Misconceptions (M)
Wrong	Not Understanding Concepts (NUC)	Not Understanding Concepts (NUC)	False Negative Misconceptions (M)	Pure Misconceptions (M)

Result and Discussion

This study divided 2 subjects into 2 large groups, namely a group of students (163 students) who were randomly selected from 9 senior high schools out of a total of 19 senior high schools in the North Central Timor regency. Out of the 163 students, 114 were female while 49 were male. In addition, 12 teachers were also sampled from 12 senior high schools in North Central Timor regency where 11 teachers were female and 1 was male (see the attachment).

The questions given to the 2 groups (teachers and students) were the same to review the misconceptions of teachers and students on the same topic, namely Energy. The number of questions tested was 12 numbers with the different levels of difficulty covering C1 (cognitive 1) to C4 (cognitive 4) (see the attachment). The instrument measured focused on the cognitive domain and was developed by the researchers with the main objective to measure the conceptual understanding and the misconception of the students and the teachers. The collected data was then processed descriptively to see the level of students' understanding of the topic of Energy. The following are the results of the data analysis in this study.

Students' Conceptual Understanding and the Misconceptions

Table 3. Students' Conceptual Understanding and the Misconceptions

Understand the Concept (UC)	Not Understand the Concept/Lucky Guess (NUC/LG)	Not Understand the Concept (NUC)	Miscon ception (MC)
81	7	9	66
122	7	10	24
77	10	13	63
67	6	26	64
61	6	30	66
58	8	20	77
56	8	23	76
56	7	32	68
18	4	24	117
25	5	24	109
77	9	22	55
61	6	27	69
759	83	260	854
Understand the Concept (UC)	Remark: Not Understand the Concept/Lucky Guess (LG)	Not Understand the Concept (NUC)	Miscon ception (MC)
38.80%	4.24%	13.29%	43.66%

Remark:
UC: Understand the Concept
NUC/LG: Not Understand the Concept/Lucky Guess
NUC: Not Understand the Concept
MC: Misconception

From table 3, it can be seen that the presentation of students' misconceptions for the whole question (12 questions) was quite large, namely 43.66%. Meanwhile, students who understand the concept for the 12 items were 38.80%. Nearly 18% of the students did not understand the concept while 4.24% were just guessing (Lucky Guess) while the remaining 13.29% were the total students who did not understand the concept at all. The percentage of students' conceptual understanding and misconceptions in detail per item can be seen in Table 4 below.

Table 4. The percentage of Students' Conceptual Understanding and Misconception per Item

Understand the Concept (UC)	Not Understand the Concept/Lucky Guess (NUC/LG)	Not Understand the Concept (NUC)	Misconception (MC)
49.69	4.29	5.52	40.49
74.85	4.29	6.13	14.72
47.24	6.13	7.98	38.65
41.10	3.68	15.95	39.26
37.42	3.68	18.40	40.49
35.58	4.91	12.27	47.24
34.36	4.91	14.11	46.63
34.36	4.29	19.63	41.72
11.04	2.45	14.72	71.78
15.34	3.07	14.72	66.87
47.24	5.52	13.50	33.74
37.42	3.68	16.56	42.33

From Table 4, it can be seen that the biggest misconception was in questions number 9 (71.78%) and question number 10 (66.87%). Basically, question number 9 aimed to test students' understanding of the Conservation Law of Mechanical Energy with the following question and answer choices:

"Which of the following choice is the example of the conservation law of mechanical energy?"
a. A child pushes a table so that its place is changed
b. A child pushes against a wall but does not move
c. The mango falling from the tree
d. The mango that is still hanging on the tree
e. The car at a certain speed when goes through the end of the road"

From the question, it can be seen that this type of question was designed to measure the cognitive domain at the C3 level (application) where students are required to apply the concept of the Conservation Law of Mechanical Energy in everyday life. Students' misconceptions about Energy may occur because students have the difficulty in connecting physics concepts with the experiences they find in everyday life (Nabila & Rachmasari, 2021; Ulya & Utami, 2021). The concept of Mechanical Energy is a new term that students have just learned, and it needs to be associated with the everyday events that they encounter. For example, how the changes in mechanical energy (Potential Energy and Kinetic Energy) are explained when a mango is still hung on a tree until it falls to the ground. Psychologically, Jerome S. Bruner's theory of human cognitive development when learning new things can be used to explain students' mental processes (Ozdem-Yilmaz & Bilican, 2020). Bruner argues that there are 3 special stages when students learn new things, namely the Information Stage (new students learn new information/concepts), the Transformation Stage (understanding and digesting the new concept), and the Evaluation Stage (providing an assessment of whether the concept just learned is correct or not) (Sundari and Fauziati, 2021; Unaenah et al., 2020).

Therefore, the process of students' misconceptions can occur when students fail to reach the Transformation Stage in the cognitive processes in their brains (Dayanti & Nursangaji, 2019; Rehalat, 2016). This causes the students can not able to relate the concept of the Conservation Law of Mechanical Energy to everyday events. If students understand the concept correctly then they should understand that eternal mechanical energy can be seen in the process of falling mangoes. In this example, the mango that falls undergoes a change in the form of energy from potential to mechanical energy but no energy is lost, where the mechanical energy is conserved. Most likely, students still cannot relate the term the Conversation Law of Mechanical Energy (Potential Energy and Kinetic Energy) to everyday events that they encounter.

More or less the same thing also applies to question number 10 "When the catapult is stretched there is potential energy but when the catapult is released there is a change into kinetic energy. From this case, it can be concluded that the transfer of energy is always accompanied by a ...
a. style
b. motion
c. effort/Work
d. displacement
e. mass

This question measures students' ability to connect Energy and Work where many students (66.87%) answered incorrectly because of the misconceptions they had. In this question, many students chose the answer choice of "movement and displacement" where students had not been able to see the concept holistically (Husnah, 2018; Primarni, 2017). If the students have a holistic conceptual understanding, they should be able to make the connection between the concepts of Displacement and Force which are united through the concept of Work. In Bloom's taxonomy (Aziz et al., 2017; Ruwaida, 2019), the activity of connecting the concepts is included in Cognitive 4 (Analysis) where the students are required to connect several concepts that are studied separately (e.g. Displacement and Force) and then able to unite them in the concept of Work (W) and further combine it with the concept of Energy (E).

Based on the analysis result above, it can be seen that students have misconceptions on a medium scale for most of the numbers (1,3,4,5,6,7,8, 11, and 12). In these questions, the cognitive levels tested were still at the levels of C1 and C2 (Ruwaida, 2019) where students were asked about memorization regarding the definition of Energy, its formulas, and several types of descriptive questions (study case questions) with a low level of difficulty. However, the range of students who had the misconceptions on these questions was almost 50% of the total 163 students tested in North Central Timor regency. While in question number 1, the majority of students answered correctly because the question asked about the meaning/definition of Energy which measures the ability of students to memorize or remember (C1).

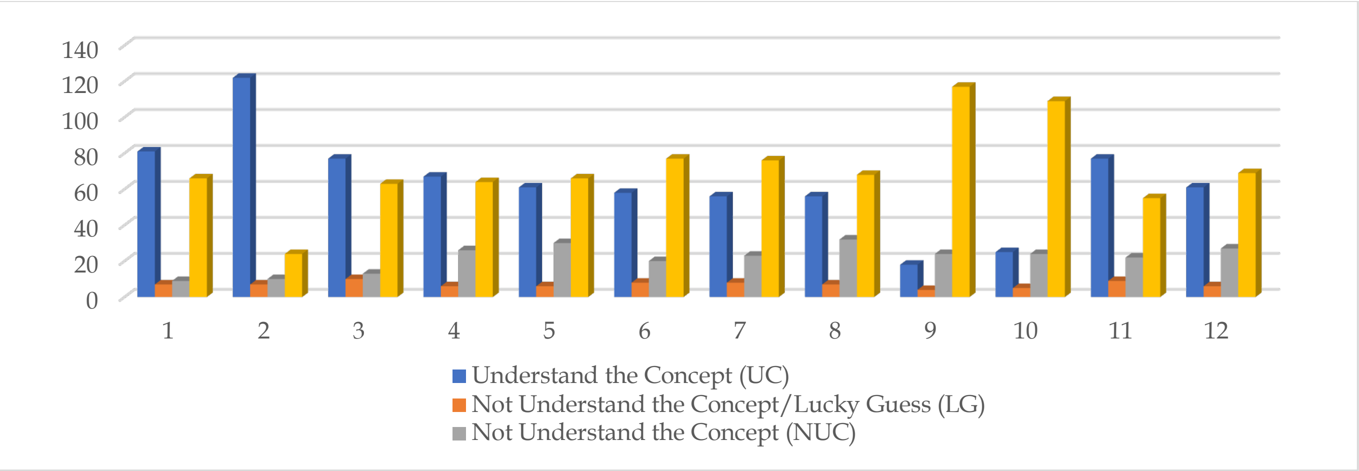


Figure 1. Students' Conceptual Understanding Score per Item of the Question

Meanwhile, in general, the percentage of students' conceptual understanding can be seen in figure 2 below.

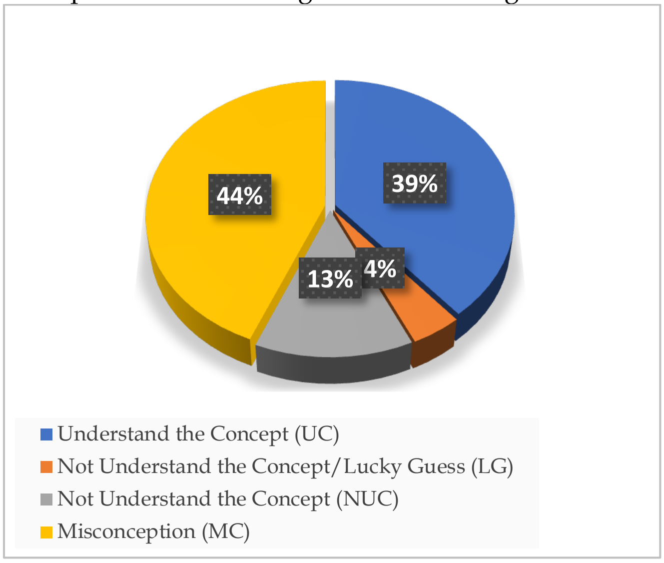


Figure 2. The percentage of Student's Conceptual Understanding

Remark:
UC: Understand the Concept
NUC/LG: Not Understand the Concept/Lucky Guess
NUC: Not Understand the Concept
MC: Misconception

Teachers' Conceptual Understanding and Misconception

In contrast to the data on students' misconceptions, when given the same questions, the teachers showed significantly different results. The following table 5 describes in detail the teachers' conceptual understanding and misconceptions in the 12 questions.

Table 5. Teachers' Understanding and Misconceptions

Understand the Concept (UC)	Not Understand the Concept/Lucky Guess (NUC/LG)	Not Understand the Concept (NUC)	Misconception (MC)
12	0	0	0
12	0	0	0
12	0	0	0
12	0	0	0
6	0	0	6
9	0	0	3
2	0	0	10
10	0	0	2
7	0	0	5
6	0	0	6
12	0	0	0
11	0	0	1
111	0	0	33
Understand the Concept (UC)	Not Understand the Concept/Lucky Guess (NUC/LG)	Not Understand the Concept (NUC)	Misconception (MC)
77.08%	0.00%	0.00%	22.92%

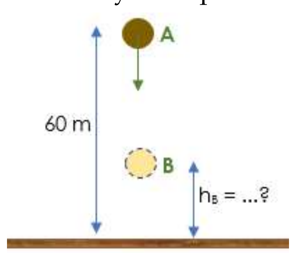
It can be seen in the table above that the average teacher (77.08%) mastered the concept of Energy well. However, as many as 22.92% of the teachers misconceived several question numbers, namely (5,6,7,8,9, 10, and 12) with the most misconceptions on questions 7, 10, and 5. More details can be seen in Table 6 below.

Table 6. Teacher's Conceptual Understanding and Misconceptions per Item

Understand the Concept (UC)	Not Understand the Concept/Lucky Guess (NUC/LG)	Not Understand the Concept (NUC)	Misconception (MC)
100.00	0.00	0.00	0.00
100.00	0.00	0.00	0.00
100.00	0.00	0.00	0.00
100.00	0.00	0.00	0.00
50.00	0.00	0.00	50.00
75.00	0.00	0.00	25.00
16.67	0.00	0.00	83.33
83.33	0.00	0.00	16.67
58.33	0.00	0.00	41.67
50.00	0.00	0.00	50.00
100.00	0.00	0.00	0.00
91.67	0.00	0.00	8.33

Based on Table 6, it can be seen that the teacher mastered the concept correctly on questions number 1,2,3,4, and 11. These questions measured the cognitive domains of Cognitive 1 (C1) and Cognitive 2 (C2) where most questions asked about the definitions, the laws in physics, and the application of energy formulas in solving the questions of the study case with a low level of difficulty. However, the presentation of teachers doing many misconceptions was found in number 7 (83.33%).
Question number 7 is displayed below:

"A ball has a mass of 2 kg that falls freely from position A as shown in the figure. When it reaches B, the ball's kinetic energy is twice its potential energy. The height of point B from the ground is...



a. 5 m
b. 10 m
c. 20 m
d. 30 m
e. 40 m"

Based on the problem above, it can be seen that this problem uses the formula of mechanical energy conservation. Energy Mechanic 1 (Em1) and Energy Mechanic 2 (Em2) use an analysis of Potential Energy and Kinetic Energy where Energy Potential 1 and Energy Potential 2 are formulated as Ep1 + Ek1 = Ep2 + Ek2. Based on the researchers' analysis, some teachers who had the misconception basically had mastered the concepts and the formulas that would be used to work on the questions (as evidenced by the zero scores of NUC and Lucky Guess) but made mistakes in the mathematical calculations (Kefi et al., 2021; Putri & Hindrasti, 2020).

In the percentage, a diagram of teachers' conceptual understanding and misconceptions can be seen below.

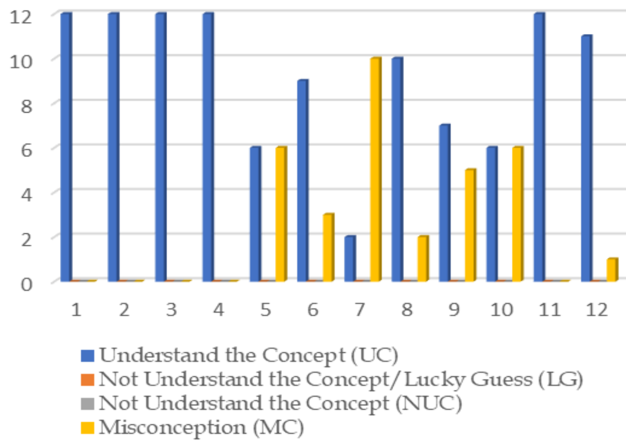


Figure 3. Teachers' conceptual understanding and misconception scores

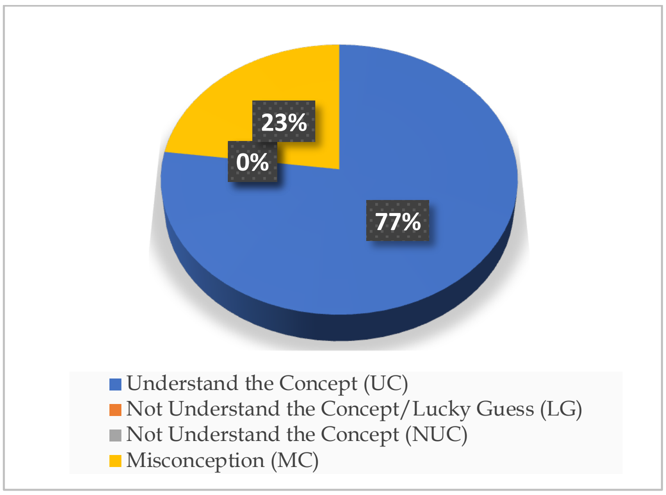


Figure 4. The Percentage of teachers' conceptual understanding and Misconception

Conclusion

The conclusion obtained so far is that the misconceptions found among physics teachers in North Central Timor regency were quite rare (22.92%), and the teachers' conceptual understanding related to energy is in a good category. Meanwhile, for the students, there were still a large number of students who had misconceptions regarding the topic of Energy. This was caused by students' conceptual understanding that was still lacking in the topic of Energy.

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