

Analysis of Students' Physics Misconceptions on Mechanical Materials Using the Multiple Choice of Four Tier Diagnostic Test

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Abstract: *The purpose of this research is to analyze students' physics misconceptions on mechanics material in class XI of State Senior High School (SSHS) of Medan. This type of research is descriptive qualitative. The subjects of this study were 377 students from 6 schools in Medan. This study used a four tier multiple choice diagnostic test instrument consisting of 25 items and questionnaire sheets. The results showed 9.1% students could understand concepts, 19.2% students did not understand concepts, 26.2% students understood partially, 41.4% students overcame misconceptions, and 4.1% students could not be coded. Thus, the level of students' physics misconceptions on mechanics material in Class XI of State Senior High School (SSHS) of Medan carried out in the 2018/2019 academic year belongs to the medium category.*

Keywords: *Misconception, Four Tier Multiple Choice Diagnostic Test, Mechanics*

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I. Introduction

In The Act of the Republic of Indonesia on National Education System article 3 explained that the National Education functions to develop the capability, character, and civilization of the nation for enhancing its intellectual capacity, and is aimed at developing learners' potentials so that they become persons imbued with human values who are faithful and pious to one and only God; who possess morals and noble character; who are healthy, knowledgeable, competent, creative, independent; and as citizens, are democratic and responsible [1].

The process teaching is an activity to implement the curriculum of an educational institution so that can influence the students to achieve predetermined educational goals [2]. To achieve educational goals that a teacher has a very important role and influence in building student character in school [3]. Teachers must be able to create an active, fun teaching and learning environment and impressing students in learning activities in order to absorb and receive the knowledge that has been conveyed by the teacher [4]. Likewise in physics subjects, there are learning objectives to deliver students to understand physics concepts and connect these physics concepts with everyday life or life skill [5].

The problem that arises in learning today is that generally the learning approach is still oriented towards the teacher as a learning resource or teacher centered learning [6], this causes the students not always be able to absorb the information conveyed by educators clearly, even though in physics subjects contain many scientific concepts that require student-oriented learning approach. This problem causes the differences in concepts understood by students not in accordance with the concepts put forward by experts were often happened. The mismatch of conceptual understanding experienced by students is called a misconception or alternative concept. Misconceptions become obstacles for students to understand learning material. Therefore, misconceptions can be said to be an error in the learning process.

Misconception or wrong concept refers to a concept that is not accordance with the scientific understanding or understanding that is accepted by expert. For example, the student argue that when someone pushes the car and the car hasn't moved, there is no force acting on the car. The concept is wrong because even though the car is not moving, there is a force caused by the push but the resultant is zero due to the friction force [7].

One way to detect misconceptions on students is to do a diagnostic test. Diagnostic tests are tests that can be used to pinpoint and determine the weaknesses and strengths of students in a particular subject [8]. In teaching and learning activities, there is a need for a test that can diagnose student success after going through a learning process. A study examining scientific articles on diagnostic tests that was conducted in united kingdom (UK) revealed that a total of 273 articles published (from the year 1980 to 2014) in main journals were investigated thoroughly through document analysis method. The study reveals interviews (53%), open-ended tests (34%), multiple-choice tests (32%) and multiple tier tests (13%) as the most commonly used diagnostic tools [9].

Multiple choice questions to identify student misconceptions have been developed from one-tier to

two-tier, three-tier and four-tier. The four tier diagnostic test is development form three tier diagnostic test which consists of multiple choice questions with 3 distractors and 1 answer key that must be chosen by students, the student's confidence level in choosing answers, the students' reasons for answering questions with 3 reasons for the students answering the questions and 1 open reason and students' level of confidence in choosing reasons [10]. It can be said that multiple choice tests have the advantages of being versatile, efficient, objective, easy to use, and less affected by person's tendency to answer multiple choice in a particular way. Multiple choice is easier to use than other methods, especially if you want to be tested on a population [11].

Based on the description above, the researcher is interested in conducting research with the title "Analysis of Students' Physics Misconceptions on Mechanical Materials Using The Multiple Choice of Four Tier Diagnostic Test in Class XI of State Senior High School of Medan"

II. Review of Literatures

2.1. *The essence of Concept*

The concepts are categories that classify objects, events, and characteristics based on common properties. Some defined the concept as an element of cognition that helps simplify and summarize information [12], a way of grouping and mentally categorizing various objects or events that are similar in certain ways [13]. The others said that the concept was a tool used to organize various knowledge and experiences into various forms of categories [14], and an abstract idea that was generalized from specific examples [15], another opinion that is more specific suggests that concepts were objects, events, situations, or characteristics that have a characteristic and are represented in every culture by a sign and symbol [16]. Thus, a concept can be considered as an unit of thought or idea that cannot stand alone but are related to one another in a dynamic system called the conceptual system.

There are seven dimensions of concept [17] are **Attributes**: each concept has a number of different attributes; **Structure**: regarding how the attributes are related or joined. Judging from its structure, the concept is divided into three types, namely (a) Conjunctive concept or a concept in which it has two or more properties so that it can qualify as an example concept; (b) Disjunctive concept or a concept in which one of two or more characteristics must exist; (c) Relational concepts or relationships between concept attributes. **Abstractness**: the concept is visible and concrete or the concept consists of other concepts. **Inclusiveness**: shown in the examples involved in the concept. **Generality**: the concept may differ in superordinate or subordinate positions if classified. **Accuracy**: a concept concerning whether there is a set of rules to distinguish examples from non-examples of a concept. **Strength**: a concept is determined to what extent people agree that the concept is important.

Concept acquisition can be done in two ways that are concept formation and concepts assimilation [17]. Concept formation is an inductive process which a person who is faced with an environmental stimulus, abstracts certain traits or attributes that are the same from various stimuli. This process is a form of discovery learning. Whereas concept assimilation is the main way to acquire concepts during and after school, referring to the constructivist view that students are responsible for shaping knowledge in their own way in learning situations that provide opportunities for them to learn.

The concept achievement includes four levels that are concrete level, identity level, classification level, formal level. The concept learning approach includes the cognitive approach and adult approach. The concept knowledge including classification and category knowledge, principle and generalization knowledge, knowledge theory, model, and structure.

The Concept understanding is knowledge that students learn in a meaningful and well-integrated manner about a topic including to form many logical relationships between specific concepts and ideas [13]. Understanding a concept means to master the main elements of the concepts that are definition, characteristics, application, and being able to connect and organize what has been learned. It can be ensure that during the learning process not all of student will understand the concepts of physics. The way can be done to help students develop a conceptual understanding of the learning materials are organizing teaching material into several core ideas or themes, exploring each topic in depth, explaining the relationship of new ideas to students' personal experiences and things that have been previously learned, that show students through the words, assignments, and criteria that used to evaluate student achievement, and ask students to teach what they have learned to others.

2.2. *Misconceptions*

Misconception is an inaccurate understanding of a concept, the using of the wrong concept, classification of wrong concept examples, a mess of different concepts and relationship of hierarchical or level of concept is incorrect [18]. Misconceptions are also beliefs that are not in accordance with generally accepted explanations and are proven to be valid about a phenomenon or event [13], as an interpretation of concepts in an unacceptable statement [19]. According to Feldsine, misconception is a mistake and an incorrect relationship between

concepts [20]. Others argue that misconceptions can be in the form of initial concepts, errors, incorrect relationships between concepts, intuitive ideas, or naive views[21].

Based on the explanation that has been described, misconception was defined as an initial concept that students have that is not in accordance with the generally accepted explanation as a result of the experience constructed by students. Misconceptions can also be referred as an alternative concept because the using of alternative concept term was based on the experiences that was constructed by students and often alternative concepts were contextually reasonable and useful in some of the problems faced by students [20].

2.3. How to Resolve Misconceptions

To resolve the misconceptions is not an easy matter because misconceptions tend to be resistant in students. Some misconceptions become student belief systems so that they require a variety of strategies to be applied over a long period of time. According to cognitive psychologists, there are many ways to help students construct their knowledge so that there are no misconceptions that are providing opportunities to conduct experiments, providing expert perspectives, emphasizing conceptual understanding, encouraging dialogue in class, providing activities authentic, designing theoretical constructs, and forming learning communities[13].

2.4. Identify Misconceptions

The duty of teacher is not only to assist students in constructing an accurate understanding of the world around them, but the teacher also encourages students to give up any mistaken beliefs that they have previously constructed [13]. Misconceptions experienced by students need to be detected as early as possible so that teachers can determine remediation lessons for students. Some tools to uncover student misconceptions are concept maps, multiple choice tests with open reasoning, written essay tests, diagnostic interviews, classroom discussions, practicum with questions and answers [18].

2.5. The Causes of Misconceptions

The researchers of misconception founded several things that cause misconceptions on students. Generally, the causes of misconceptions can be summarized in five main groups that are students, teachers, textbooks, context, and teaching methods. [20]. Details of the causes of misconceptions are described as follows[18]: (1) **Students**: Students' preconceptions, associative thinking, humanistic thinking, incomplete/wrong reasons, the wrong intuition, the stage of student cognitive development, students' abilities, and student interest in learning; (2) **Teachers**: Not mastering the material, not competent, teachers are not graduates from the field of science, not allowing students to express ideas, and the relationship between teachers and students is not good; (3) **Text Books**: Misleading explanations, text book is writing wrong especially in formulas, the difficulty level of writing books is too high for students, students do not know how to read text books, science fiction books sometimes divert concepts to attract readers, and cartoons often contain misconceptions; (4) **Contexts**: Student experiences, different colloquial context, the wrong discussion partner, beliefs and religion, other people's misrepresentations, student life context (faulty of TV, radio, and movies), and feelings of being happy, unhappy, free, or depressed; (5) **How to Teach**: Contains only lectures and writing, how to teach directly into mathematics, do not reveal student misconceptions, not correcting wrong homework / assignments, the analogy model, practical model, discussion model, narrow demonstration model, and non-multiple intelligences.

In this study, researchers conducted a study and analysis of the causes of misconceptions from student factors. The causes of misconceptions from student factors are divided into several specific parts that are student preconceptions, associative thinking, humanistic thinking, incomplete or wrong reasons, wrong intuition, student cognitive development stages, student abilities, and student learning interests. From the eight causes above, the study is limited on factors that cause misconceptions based on students' learning interests.

2.6. Four Tier Multiple Choice Diagnostic Test

In terms of usefulness in measuring students, the test is divided into three parts that are diagnostic tests, formative tests, and summative tests. Diagnostic test is used to find out the weaknesses of students. Formative test is used to determine the extent to which students have been formed after attending a particular program, while the summative test is used to evaluate a larger program. Diagnostic test is a test that is used to find out the weaknesses experienced by students so that appropriate handling can be done[22]. Diagnostic assessment is an assessment that aims to see student weaknesses and their causative factors[23]. whereas diagnosis is a complex process in an attempt to draw conclusions from the results of examining symptoms, estimating causes, observing, and properly good categories[24]. So actually the diagnostic test can be done as a prerequisite test, a placement test, student difficulty test (on studying), and final evaluation test (final examination test).

The multiple choice test is an objective test which consists of a description of an incomplete understanding and to complete it must choose one of the possible answers. The possible answer (option) consists of only one answer and the others is a distractor[22]. The multiple choice commonly used is one tier multiple

choice, for each item consisting one part that is option of the answer of question. The four tier diagnostic test is development from the three tier multiple choice diagnostic test. This development is found in increasing the level of student confidence in choosing answers and reasons. The first level is a multiple choice question with four distractors and one answer key that students must choose. The second level is the level of student confidence in choosing answers. The third level is the reason students answer questions in the form of four choices of reasons that have been provided and one open reason. The fourth level is the level of student confidence in choosing reasons [10].

Table1: The Answer Combination of Tier Multiple Choice Diagnostic Test[25]

No.	Category	Option	Confidence Level	Reason	Confidence Level
1.	Misconception (M)	False	Sure	False	Sure
2.	Not Understand Concept (NUC)	False	Sure	False	Unsure
3.		False	Unsure	False	Sure
4.		False	Unsure	False	Unsure
5.	Understand Concept (UC)	True	Sure	True	Sure
6.	Partial Understanding (PU)	True	Sure	True	Unsure
7.		True	Unsure	True	Sure
8.		True	Unsure	True	Unsure
9.		True	Sure	False	Sure
10.		True	Sure	False	Unsure
11.		True	Unsure	False	Sure
12.		True	Unsure	False	Unsure
13.		False	Sure	True	Sure
14.		False	Sure	True	Unsure
15.		False	Unsure	True	Sure
16.		False	Unsure	True	Unsure
17.	Uncodeable (UCD)	If one, two, three or all of them are not filled			

III. Methodology

This research is a descriptive qualitative research, which is intended to determine the state of something about what, how, how much, to what extent, etc. This descriptive study will provide an explanation, description, and analysis of misconceptions of physics students on mechanical materials in SSHS of Medan. This research was conducted in State Senior High School of Medan carried out in the even semester of the 2018/2019 academic year. The population of study was limited to the characteristics of regional similarity, school status, and similarity on having studied mechanic materials. The study population was all of State Senior High School in Medan with a total of 21 schools. In this study, the schools used as the research sample were selected using the proportional stratified random sampling technique, obtained sample consisting of upper, middle, and lower strata respectively obtained by two schools in each stratum that are SSHS 3 of Medan, SSHS 5 of Medan, SSHS 6 of Medan, SSHS 8 of Medan, SSHS 12 of Medan and SSHS 16 of Medan. The research steps began with field observations and continued with the making of research instruments, instrument testing, implementing the Four Tier Multiple Choice Diagnostic Test, data collection and data analysis.

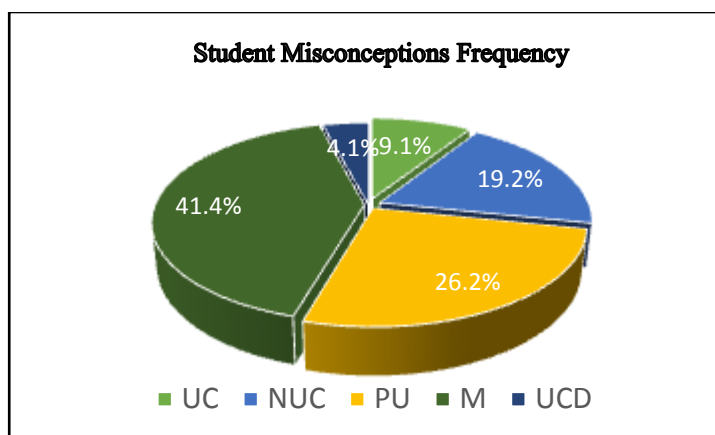
IV. Result and Discussions

Overall, the level of misconception of all students in State Senior High School of Medan on the mechanics material of 377 people is shown in table 2 below.

Table2: Misconception Level All of Student in State Senior High School of Medan on Mechanics Material

Conclusion									
UC		NUC		PU		M		UCD	
Σ	%	Σ	%	Σ	%	Σ	%	Σ	%
855	9,1%	1807	19,2%	2472	26,2%	3903	41,4%	388	4,1%

The percentage of data in Table 2 is in pie graphic form was shown in figure below:



The results of data analysis in the table above, it can be concluded that the level of misconception (M) of students in SSHS of Medan is 41.4% is in the moderate category. Meanwhile, the level of conceptual understanding (UC) of students in SSHS of Medan is classified as low at 9.1% with a low category. While the percentage of students in SSHS of Medan who do not understand the concept of all (NUC) on mechanics material is 19.2%, then the percentage of students in SSHS of Medan who partially understand (PU) the concept of mechanics is 26.2%, and the percentage of students in SSHS of Medan that are Uncodeable field (UCD) because they did not fill in one, two, three, or all answers on the answer sheet is 4.1%.

From the questionnaire data, it was obtained that several factors caused the occurrence of student misconceptions which were analyzed from each statement item as follows: Lack of student interest in learning the subject matter of mechanics (63.7%), especially learning physics concepts (53.6%); Mechanics material in physics lessons is considered too boring (58.6%); Difficulty to understand (56.5%) and remember (53.3%) physics subject matter; The low of students' interest in working on physics problems, especially on mechanics (58.9%); Students are less interested in learning physics because of the many formulas that must be learned (53.6%); The low participation of students in asking questions (56.0%) and expressing opinions (58.4%) is caused by the laziness of students (69.8%) and the lack of students courage is in working physics problems in front of the class (51.7%); Lack of student interest in reading physics books (65.8%); Most of the students studied physics when they were going to face tests or exams (56.8%); Students rarely did physics questions or assignments at home (61.3%); Students often feel bored when studying physics (61.3%).

The results of data analysis of research conducted toward students of SSHS of Medan on mechanics material showed a result of understanding concept that very low. The results of the data analysis was showed that the students' understanding of the concept to mechanics questions were only 9.1% , and 19.2% was not understand the concept, 26.2% was partially understand; 41.4% was experienced misconceptions and 4.1% was uncodeable field. From the results of each student's misconception analysis, most of students (65.3%) were in the moderate misconception level.

V. Conclusions

Based on the processing and analysis of research data, the following conclusions are obtained:

1. From the results of the analysis of students' misconceptions of physics on mechanics material using the four tier multiple choice diagnostic test for class XI in SSHS of Medan of the 2018/2019 academic year showed that students' conceptual understanding on mechanics material of 9.1%, not understand the concept of 19.2%, partially understand of 26.2%, experiencing misconceptions of 41.4% and uncodeable of 4.1%. Generally, all schools that were used as research samples experienced moderate category misconceptions.
2. The category of student misconceptions for each sub-concept on mechanics that are the sub-concept of kinematics of 2-dimensional motion (bullet motion) with percentage of 59.5%; the sub-concept of kinematics of 1-dimensional motion with percentage of 52.4%; work and energy with percentage of 44.4%; rotational motion with percentage of 41.4% and motion and force (dynamics) with percentage of 37.2%; momentum and impulse with percentage of 29.4%; and regular circular motion and gravity with percentage of 28.3%.
3. The causing factors of student misconceptions of physics based on the results of percentage analysis of student questionnaire scores were lack of student interest in learning the subject matter of mechanics, especially learning physics concepts, mechanics material in physics lessons was considered too boring, difficulty to understand and remember physics subject matter; the low of students' interest in working on

physics problems especially on mechanics, students are less interested in learning physics because of the many formulas that must be learned, the low participation of students in asking questions and expressing opinions is caused by the laziness of students and the lack of students courage is in working physics problems in front of the class, lack of student interest in reading physics books, most of the students studied physics when they were going to face tests or exams, students rarely did physics questions or assignments at home and students often feel bored when studying physics.

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