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Identification of Students' Misconceptions Using Four-Tier Diagnostic Assessment in Physics Learning Phase F

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ABSTRACT

Physics learning prioritizes understanding concepts, but there is still a misconception about its application. This research aims to identify students' misconceptions about momentum and impulse material using a four-tier diagnostic assessment instrument to implement learning evaluation in the Merdeka curriculum. This type of research is descriptive with a qualitative approach, with data collection techniques carried out through assessments and interviews. Interview data is used to reinforce assessment data. The instrument used in the study is a four-tier diagnostic test on momentum and impulse developed by the researchers. The results showed that 50% of students experienced misconceptions about momentum matter due to the assumption that if two objects move with the same kinetic energy, they should have the same speed so that the momentum of both objects can be determined by ignoring their velocity. Then, as many as 13.9% of students experience misconceptions about the law of conservation of matter momentum because of students' assumptions that ignore direction on velocity vector quantities. In other physics concepts, some students are less careful in calculations. The results of this study are expected to be a reference for teachers in designing more meaningful Merdeka curriculum-based learning plans to help students better understand the concepts of momentum and impulse.

Keywords: diagnostic assessment, merdeka curriculum, misconception, physics learning.

INTRODUCTION

A concept is a general and abstract idea that can be accepted in mind (Mukhlisa, 2021). A proper understanding of concepts can make it easier for students to understand learning at a later stage. Conversely, an improper understanding of concepts can lead to misconceptions about learning at a later stage.

Physics learning prioritizes understanding concepts, but there is still a misunderstanding or a misconception in its application. Misconceptions in physics refer to students' inability to understand and construct good and precise physics concepts (Sandra et al., 2022). Misconceptions usually arise because the students' conception based on everyday experience does not follow the actual conception due to the wrong proposition in the relationship between concepts (Maison et al., 2021). Students' difficulty in understanding physics concepts causes misconceptions in students that can hinder the success of the student learning process.

One of the materials in physics that often experiences misconceptions is momentum and impulse matter. Misconceptions on momentum and impulse matter are shown from students' misconceptions that momentum depends on the type of object, without considering the mass and velocity possessed, and collisions do not bend at all if the masses of both objects are equal (Sani & Aulia, 2018).

Student's difficulties in learning momentum and impulse material, among others, (1) students have not been able to understand the concept of impulses and the law of conservation of momentum, (2) students have not been able to apply the relationship of momentum and impulse in calculations, (3) students have not been able to apply the law of conservation of momentum in solving daily problems, (4) students have not been able to describe the types of collisions, and (5) students have not been able to apply the law of conservation of momentum in solving collision problems (Trinovitasari et al., 2022). The level of understanding of students' concepts on momentum and impulse material is still shallow and can be interpreted as the level of misconceptions experienced by students is very high (Sarifah et al., 2017). For this reason, misconceptions in physics learning cannot be left alone because it will be a big problem.

Teachers must improve their pedagogic abilities by developing meaningful learning strategies to achieve expected learning outcomes (Ekawati & Prastyo, 2022). So, the identification of student misconceptions needs to be done to minimize misconceptions so that learning outcomes are as expected and students are not trapped in the wrong understanding of concepts (Farihah & Wildani, 2018). One identification of misconceptions about understanding physics concepts can be made with a diagnostic assessment. Identifying misconceptions through diagnostic assessment is a form of application of the Merdeka curriculum.

Curriculum changes by the times are expected to overcome the problem of misconceptions in students learning physics. A curriculum is a system of learning plans or designs that can be guided in teaching and learning activities (Laulita et al., 2022). Curriculum development in Indonesia has led to the implementation a new curriculum, namely the Merdeka curriculum. Curriculum Merdeka is a curriculum with learning in a diverse curriculum that optimizes content so that students have enough time to explore concepts and develop their abilities (Laulita et al., 2022). In line with the Merdeka curriculum, there is a "Sekolah Penggerak" to realize the vision of advanced Indonesian education that is sovereign, independent, and personable through creating students with Pancasila (Ibrahim et al., 2022) (Prastyo & Faidi, 2023). "Sekolah Penggerak" is expected to be an example of implementing the Merdeka curriculum for other schools, especially in the learning process.

The challenge in implementing the Merdeka curriculum lies in the learning process, including changes in the evaluation or assessment system that prioritizes the diagnostic assessment process in both cognitive and non-cognitive aspects (Supriyadi et al., 2022). A diagnostic assessment is a pre-assessment that provides educators with information about students' knowledge, understanding, and misconceptions before introducing new concepts or activities to identify learning challenges so that students can be given appropriate action (Hodson, 2019). In addition, diagnostic assessment can also be interpreted as a test carried out to determine students' weaknesses so that, based on this, appropriate handling can be carried out according to students' weaknesses (Trinovitasari et al., 2022). Teachers must carry out diagnostic assessments at the beginning of learning to identify whether there are misconceptions about students being given appropriate treatment. The diagnostic assessment in the Merdeka curriculum differs from the previous curriculum, which focuses more on project development (Supriyadi et al., 2022). This is a challenge in making diagnostic assessment instruments.

Based on the existing background, problems can be formulated by identifying the causes of student misconceptions through diagnostic assessment. Therefore, this study aims to identify the causes of student misconceptions about momentum and impulse material through diagnostic assessment.

RESEARCH METHOD

This study used a qualitative approach with a descriptive research type. The research was conducted using the one-shot research method (Sugiyono, 2014). The research techniques used are assessment and interviews. The instrument used was a four-tier diagnostic assessment sheet and a list of questions. This research adopts other research instruments that have been declared valid and can be used. The four-tier diagnostic assessment was chosen in this study by considering its advantages such as 1) being able to distinguish the level of students' confidence in choosing answers and the level of students' confidence in giving reasons so students can explore the understanding of concepts, 2) being able to diagnose more profound misconceptions, 3) able to identify physics concepts that require emphasis, 4) able to help plan better learning (Amin et al., 2016). The assessment instrument was tested on 36 phase F students at SMA Negeri 3 Surakarta. SMA Negeri 3 Surakarta was chosen as the research location because this school is a "Sekolah Penggerak" implementing the Merdeka curriculum in phase F physics learning. The "Sekolah Penggerak" is a pilot school for implementing a new learning paradigm in the Merdeka curriculum (Prastyo et al., 2022). The use of diagnostic assessment in physics learning based on the Merdeka curriculum phase F is the novelty of this study. Interviews were conducted classically after all students completed the assessment. The stages of this research are presented through the chart in Figure 1.

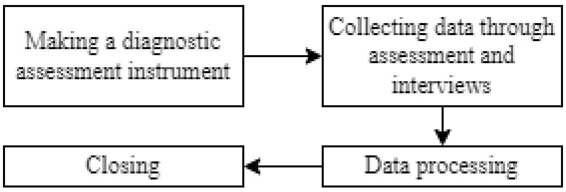

Figure 1. The stage of research

Assessment instruments and interviews have gone through focus group discussions with experts before being used for data collection. Analysis of the written assessment data was carried out descriptively by grouping data into several categories such as misconceptions (M), not understanding concepts (DNUC), understanding concepts (UC), partially understanding (PU), and not being able to be categorized (CBC). At the same time, the analysis of the data obtained from the results of the interviews was carried out in a qualitative descriptive manner to strengthen the information obtained from the assessment results. Pairs of student answers on the four-tier diagnostic assessment are grouped based on the categories presented in Table 1.

Table 1. Conception categories of students

Category	Answer	Level of confidence in the answers	Reason	Level of confidence in the reasons
M	I	S	I	S
DNUC	I	S	I	NS
	I	NS	I	S
	I	NS	I	NS
UC	C	S	C	S
PU	C	S	C	NS
	C	NS	C	S
	C	NS	C	NS
	C	S	I	S
	C	S	I	NS
	C	NS	I	S
	C	NS	I	NS
	I	S	C	S
	I	S	C	NS
	I	NS	C	S
	I	NS	C	NS
CBC	If the student's response cannot be identified			

Description: (M) misconceptions, (DNUC) do not understand concepts, (UC) understand concepts, (PU) partially understand, and (CBC) cannot be categorized, (I) incorrect, (C) correct, (S) sure, (NS) not sure.
(Source: Amin et al., 2016 & Sholihat et al., 2017)

RESULTS AND DISCUSSION

This research produces data in the form of information on misconceptions and their causes. Data was obtained through assessment and strengthened by interviews. The assessment sheet identifies misconceptions through students' responses in the second and fourth tiers. At the same time, the causes of misconceptions are identified through students' responses in the third tier. An example of a question item from a four-tier diagnostic assessment instrument is presented in Figure 2.

Objects p and q are moving with the same kinetic energy. If the mass of object q is $4kg$ and the mass of object p is 4 times the mass of object q, the value of the ratio of the magnitude of the momentum of object p and object q is...
a. 1 : 2
b. 1 : 4
c. 2 : 1
d. 2 : 8
e. 4 : 1

Level of confidence in the answer choices
a. sure
b. not sure

Reason
....
....
....

Level of confidence in reasons
a. sure
b. not sure

Figure 2. An example of a question item from a four-tier diagnostic assessment instrument

Figure 2 shows the four tiers of students answering one question item. Students are given choices to answer in the first, second, and fourth tiers. Meanwhile, students are asked to describe their reasons in the third tier. Data on the results of the diagnostic assessment are presented in Table 2.

Table 2. Grouping of diagnostic assessment data based on students' conception categories.

Concept	Percentage of Students (%)				
	M	DNUC	PU	UC	CBC
Momentum	50	36.1	2.8	11.1	0
Impulse	0	11.1	41.7	47.2	0
The law of conservation of momentum	13.9	5.6	36.1	44.4	0
Elastic collision	0	0	38.9	61.1	0
Inelastic collision	0	11.1	27.8	61.1	0

Based on Table 2, it can be understood that students carry out a complete diagnostic assessment. The highest misconception was experienced by students on the concept of momentum, namely as much as 50%. At the same time, the lowest misconceptions occur as much as 0% on the concept of impulse, elastic collisions, and inelastic collisions. So that students do not experience misconceptions about these three concepts. Most students fall into the concept understanding category in the concept of impulse, the law of conservation of momentum, elastic collisions, and inelastic collisions.

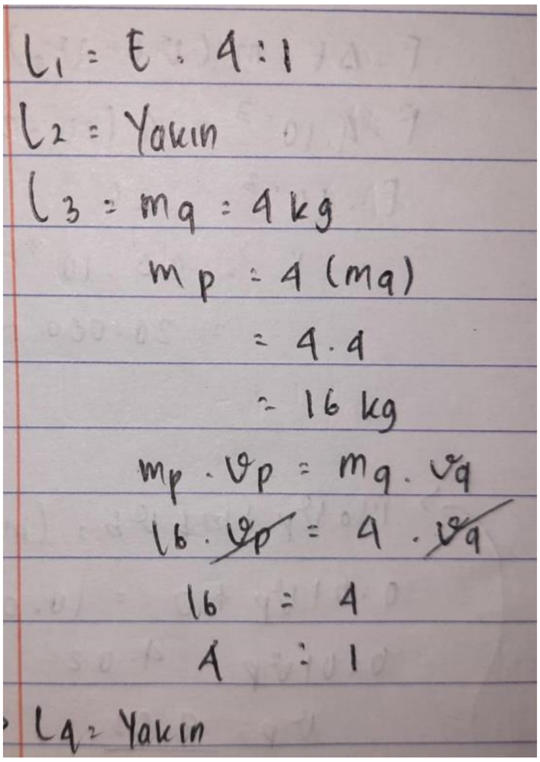

Figure 3. Student's Answer about the Application of the Momentum Concept

In applying the momentum concept, 50% of students experience misconception. Figure 3 shows that students claim that when two objects move with the same kinetic energy, they must also have the same velocity. This assumption shows students' misconceptions in analyzing speed in the concept of momentum. The result of interviews after the assessment process reinforces these results. Students said they have the same velocity when two objects move with the same kinetic energy. Based on this, the velocity of two objects can be omitted so that the momentum of the two objects is only affected by their masses. The correct concept of momentum can be understood through equation 1 (Giancoli, 2009).

$$\boldsymbol{p} = m\boldsymbol{v} \qquad (1)$$

Where $\boldsymbol{p}$ is the object's momentum, v is its mass, and v is its velocity. A comparison of the momentum of two objects that move with the same kinetic energy can be expressed in Equation 2.

$$\frac{\boldsymbol{p_1}}{\boldsymbol{p_2}} = \frac{m_1\boldsymbol{v_1}}{m_2\boldsymbol{v_2}} \qquad (2)$$

The comparison of objects' velocity can be changed to another form of equation based on the kinetic energy equation in equation 3 (Giancoli, 2009).

$$\boldsymbol{KE} = \frac{1}{2}m\boldsymbol{v}^2 \qquad (3)$$

KE is the object's kinetic energy, mass, and object velocity. Using equation 3, the comparison of the object velocity $\left(\frac{v_1}{v_2}\right)$ can be substituted into equation 4 so that the concept of momentum in physics obtains the momentum comparison results.

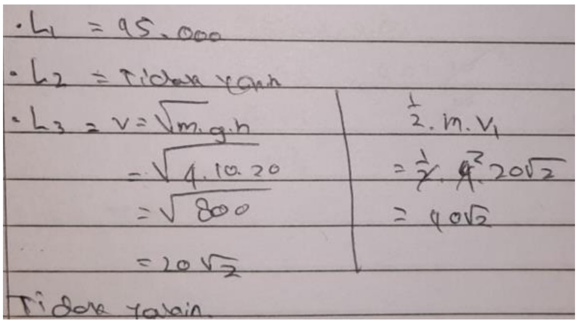

Figure 4. Student's Answer about the Application of the Impuls Concept

In the application of the impulse concept, there were no students who experienced misconception. However, there was some mathematical calculation error in the mathematical process, and the result showed uncertainty in the answer given. For this question, students were given an event of free fall at a certain height and experiencing an elastic collision, and students needed to analyze the average force acting on the object.

The answer given by students in Figure 4 shows that students have difficulty deciding the formula. Students use the wrong formula, so 11.1% of students still do not understand the concept of impulse. The correct concept can be understood through equation 4 (Giancoli, 2009).

$$\boldsymbol{I} = \boldsymbol{F}\Delta t \qquad (4)$$

Where $\boldsymbol{I}$ is impulse, $\boldsymbol{F}$ is force, and Δt is a time interval. Impuls can also be defined by the momentum change in equation 6 (Giancoli, 2009).

$$\boldsymbol{I} = \boldsymbol{\Delta p} \qquad (5)$$

$$\boldsymbol{I} = m\boldsymbol{v_t} - m\boldsymbol{v_0} \qquad (6)$$

Where $\boldsymbol{I}$ is impulse, m is mass, $\boldsymbol{v_t}$ is final velocity, and $\boldsymbol{v_0}$ is the initial velocity. Using the combination of equations 4 and 6, the average force can be found with the concept of impulse.

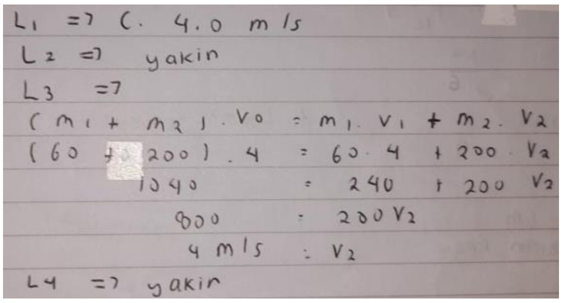

Figure 5. Student's Answer about the Application of the Law of Conservation of Momentum

In applying the law of conservation of momentum, 13.9% of students experienced misconception. The results of the student's answers in Figure 5 show a misconception in understanding the concept of velocity. A quantity such as a velocity with magnitude and direction is a vector quantity (Giancoli, 2009). However, students ignore the direction of the velocity or do not add a positive or negative sign when declaring a velocity quantity. This action shows that students have a misconception of the concept of velocity when using the formula of the law of conservation of momentum.

The correct concept of conservation momentum law states that the total momentum before the collision is the same as afterwards, whether the collision is head-on or not, as long as no net external force acts. The law of conservation of momentum is stated in equation 7 (Giancoli, 2009).

$$m_A\boldsymbol{v_A} + m_B\boldsymbol{v_B} = m_A\boldsymbol{v_A}' + m_B\boldsymbol{v_B}' \qquad (7)$$

The left side of equation 7 shows the momentum sum before the collision, and the right side shows the sum after the collision. When using equation 7, it should be noted that speed is a vector quantity, so when stating its value, it needs to be accompanied by a positive or negative sign. Generally, the positive and negative signs can be determined based on the cartesian coordinate system. The value is negative if the object is moving on the negative axis and joyous if the object is moving on the positive axis.

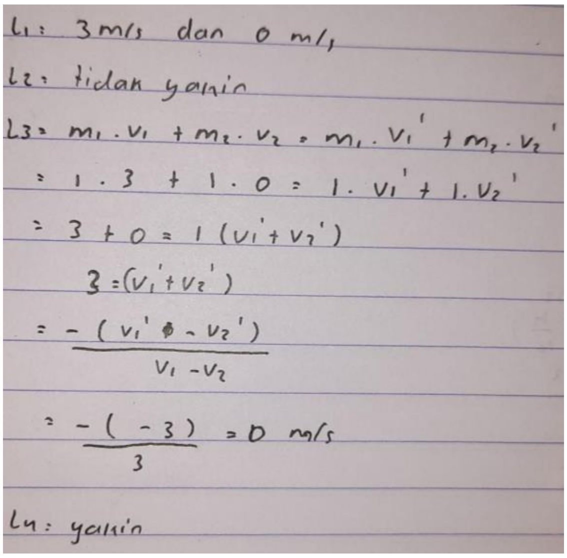

Figure 6. Student's Answer about the Application of the Elastic Collision Concept

In the application of the elastic collision concept, no student experienced misconception. In this question, students need to analyze the velocity of the two marbles after the collision. Figure 6 shows that students make mathematical process mistakes and are uncertain about their answers or reasons. This happens because the calculations are pretty complicated and require accuracy in the mathematical process. Therefore, 38.9% of students still partially understand the elastic collision concept. The correct concept of elastic collisions is that when two objects experience collisions, the relative velocity of the two objects after the collisions have the same magnitude, with opposite velocity directions, as before the collision, no matter what the masses are (Giancoli, 2009). Therefore, it applies the law of conservation momentum in equation 7.

In applying the concept of inelastic collision, no student experienced misconception. This problem discusses a beam on a ballistic swing shot by a bullet. The bullet lodged in the beam. Students need to analyze the initial velocity of the bullet. Based on the student's answers, they make some mathematical mistakes or are uncertain about their answer or reason. This can happen because of complicated calculations and students' inaccuracy. Figure 7 shows that students also have difficulty in deciding the formula that can be used to solve the problem. Therefore, 11,1% of students still do not understand the concept, and 27,8% partially understand the concept of inelastic collisions. The correct concept of inelastic collisions is that when two objects stick together due to the collision, the collision is inelastic (Giancoli, 2009). This incident shows that when two objects experience an inelastic collision, the velocity of the two objects after the collision will be the same. The formula for the inelastic concept can be found in equation 8.

$$m_A \boldsymbol{v_A} + m_B \boldsymbol{v_B} = (m_A + m_B)\boldsymbol{v}' \qquad (8)$$

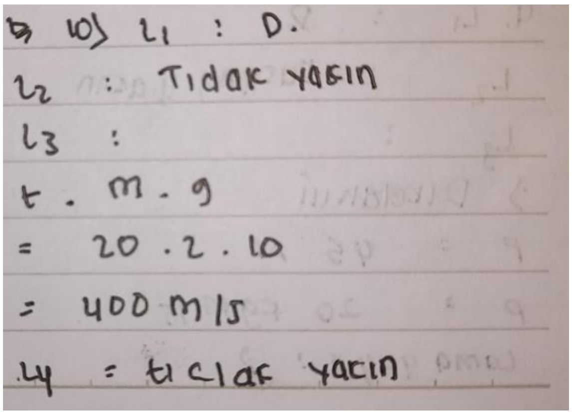

Figure 7. Student's Answer about the Application of the Inelastic Collision Concept

The results of identifying misconceptions in students on momentum and impulse material show that students experience misconceptions in applying the concept of momentum and the law of conservation of momentum. These results are supported by several similar studies on identifying students' misconceptions about momentum and impulse matter. Previous research shows that students still have misconceptions about momentum because they lack an understanding of kinetic energy and analyzing the influence of speed on momentum (Amalia et al., 2019). Many students still do not understand the concept of momentum well (Diyanahesa et al., 2017). Several similar studies also support student misconceptions in applying the law of conservation of momentum. Studies show that students have difficulties regarding the law of conservation of momentum (Afifah et al., 2018). Other studies have also shown that students cannot fully understand the law of conservation of momentum (Semih Dalaklioğlu. et al., 2015).

Analysis of momentum and impulse-matter misconceptions that previous researchers have carried out differs from the results. Studies show misconceptions about impulse and the relationship between impulse and momentum (Amalia et al., 2019). Other studies also show students' misconceptions of momentum and impulse material regarding mathematical and verbal representations of the sub-material concepts of momentum, impulse, momentum and impulse relationships, the law of conservation of momentum, and collision (Mahardika et al., 2020). The difference in results obtained with previous studies is shown by sub-materials that experience misconceptions. The results in Table 2 show that students only experience misconceptions in the sub-material of the concept of momentum and the law of conservation of momentum. This difference in results is influenced by different types of questions and diagnostic assessment models, so it will cause differences in representing results.

Based on the result indicates a lack of mastery of students in momentum and impulse material. The lack of students' concepts can be caused by the ability of students when receiving a lesson in multi-representation and the way teacher material has not yet involved mathematical representations, pictures, graphics, and verbal so that students do not understand the material and experience its misconception (Mahardika et al., 2020). The lack of student conceptualization can be overcome by learning that can lead the student to understand the basic concepts in physics in depth and familiarize students with using the concept to solve relevant problems (Afifah et al., 2018). Therefore, the teacher needs to design appropriate learning strategies to help students understand the concept of momentum and impulse better. In addition, teachers need to improve TPACK abilities by emphasizing their pedagogical abilities (Ekawati & Prastyo, 2022) (Absari et al., 2020). Teachers must improve their pedagogical abilities to develop Merdeka curriculum-based physics learning strategies. So that students can receive knowledge optimally and there are no misconceptions in learning physics.

CONCLUSIONS

Identifying misconceptions through diagnostic assessment is a form of instruction in the Merdeka curriculum. Diagnostic assessment is essential as an indicator of readiness for implementing the Merdeka curriculum and is considered suitable for evaluation. Based on the result, students' conception of momentum and impulse material is divided into five categories such as misconception (M), do not understand the concept (DNUC), understanding the concept (UC), partially understand (PU), and can not be categorized (CBC). The results show that students experienced misconceptions about the concept of momentum and the law of conservation of momentum. In applying the momentum impulse concept, 50% of students experienced misconception because of less understanding of the kinetic energy concept and the effect of velocity on momentum. While applying the law of conservation momentum, 13,9% of students experienced misconception because of less understanding of the vector quantity of velocity. In other physics concepts, some students are less careful in calculations. Some students are not careful in using the formula. Therefore, to overcome the lack of understanding of concepts, the teacher needs to design appropriate learning strategies to help the student understand the concepts of momentum and impulse better. Teachers need to develop learning strategies that are more meaningful and optimize their TPACK abilities. Teachers must be able to develop strategies for learning physics based on a Merdeka curriculum so that students can receive knowledge optimally and not experience misconceptions. So that learning physics in implementing the Merdeka curriculum can run well.

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