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Analysis of students' misconceptions using three-level cognitive diagnostic assessment on the concept of vibration and waves

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Abstract
This research aims to: (1) determine the level of students' misconceptions in science learning using a three-level cognitive diagnostic assessment on the concept of vibrations and waves, (2) determine the profile of students' misconceptions in science learning based on a three-level cognitive diagnostic assessment on the concepts of vibrations and waves. The sampling technique in this study uses the Random Sampling technique. This study uses a quantitative approach with a descriptive type of research and belongs to the category of non-experimental research. Data collection techniques used multilevel multiple choice questions and interviews. Data analysis using descriptive statistical analysis techniques. The results of the research showed that the level of misconceptions experienced by students at SMPN 11 Surakarta and SMPN 27 Surakarta regarding the concept of vibrations and waves using a three-level cognitive diagnostic assessment was divided into three categories, including students with false positive conditions of (18.8%) who were included in the category low, false negatives were (14.4%) which were included in the low category, and pure misconceptions were (39.2%) which were included in the low category. The profile of misconceptions experienced by students in each sub-concept of vibration and waves includes students' misperceptions of physical phenomena, errors in connecting between concept attributes, errors in analyzing object motion, errors in understanding the meaning of concept attributes, errors in analyzing the wave propagation process, and wave propagation medium. This study is expected to be an evaluation of learning for science teachers so that they can create meaningful learning for students.

1. Introduction

21st century learning contains four important competencies that students must have, namely conceptual understanding, critical thinking, creative thinking, and collaboration and communication (Morocco et al., 2008). Conceptual understanding or the ability to understand concepts is an important component in the 21st century learning process that students must have because it acts as an indicator for achieving success in learning. Understanding concepts well is the foundation for students to develop concepts and establish relationships between one concept and another, so that they can overcome various problems in life (Jumadin et al., 2017).

Understanding concepts well becomes the foundation for students to develop concepts and establish relationships between one concept and another, so that they can overcome various problems in life. Good conceptual understanding also provides significant support for students in capturing subsequent learning materials (Jumadin et al., 2017). The ability to understand concepts is very important in the learning process, because apart from just memorizing the material given by the teacher, it also ensures that students really understand the contents of the lesson (Ulfa et al., 2023).

In reality, currently, there is still a lot of learning that is still dominated by the role of teachers as providers of knowledge and the habits of students who only memorize material before exams without paying attention to developing the ability to understand the concept of the material (Mufidah & Budiyanto, 2022). Such learning makes students' reasoning abilities less trained, so that students can only understand a few basic concepts and are not yet able to connect various concepts, let alone understand complex and abstract concepts (Sadiqin et al., 2017). These conditions can trigger misconceptions in students in learning a new concept (Karomah et al., 2018).

Misconceptions or errors in understanding concepts and connecting one concept to another often occur in science subjects (Patil et al., 2019). Many concepts in science subjects are related to other concepts that if students do not have a strong initial understanding of a concept to be developed into an understanding of other concepts will cause misconceptions in science learning (Wulandari et al., 2022). Misconceptions can be caused by various factors, including students' varying intellectual abilities, the habit of memorizing without understanding the relationship between concepts, and difficulty in understanding abstract concepts and complex language (Karomah et al., 2018). The concept of vibrations and waves is one of the concepts that is considered difficult by students in science subjects because it requires a high level of intelligence to understand the abstract concepts in it, so it is very susceptible to misconceptions in this concept (Pratiwi et al., 2022; Susanto, 2022).

One way to identify the level of student misconceptions is to use a cognitive diagnostic assessment. Diagnostic assessment is conducted to find and identify students' learning weaknesses in a subject and its causes (Esomonu & Eleje, 2020). This study used a three-level cognitive diagnostic assessment because it allows educators to see students' misconceptions more specifically. Items in the three-level diagnostic assessment consist of multiple-choice questions, the second level asks students to give reasons for their answers, and the third level measures students' level of confidence in the answers they choose (Gurel et al., 2015). Misconceptions that exist in students are important to identify so that teachers know the forms of misconceptions that occur in students in several concepts of vibrations and waves and teachers can evaluate the learning process in the future to be better, so that misconceptions in students can be minimized.

2. Method

The type of research used is quantitative descriptive. Descriptive research is to produce a methodical explanation that highlights the details, characteristics, and relationships of the phenomena being studied (Wahyuni & Aisyaroh, 2018). This research is included in the category of non-experimental research, which is research that is conducted without any treatment or control set for a number of research variables (Hardani et al., 2020:259)

This research was conducted from July 2023 to May 2024. This study describes the level of misconceptions and misconception profiles of class VIII students of SMP N 11 Surakarta and SMP N 27 Surakarta. The population in this study were all class VIII students of the even semester of SMP N 11 Surakarta and SMP N 27 Surakarta in the 2024/2025 academic year totaling 782 students. The technique used by researchers to take samples was random sampling. The samples were selected from the Surakarta area, Pasar kliwon District and Laweyan District and the schools used as research locations were SMP N 11 Surakarta and SMP N 27 Surakarta. The sample in this study amounted to 264 students from 9 classes from both schools whose misconceptions would be analyzed. The data collection technique used was a three-level cognitive diagnostic test instrument and interviews. The diagnostic test consists of three levels: the first level contains multiple-choice questions, the second level contains the reasons for choosing the answer at the first level, and the third level contains the level of confidence in choosing the answer. This form of test can assess the extent to which students can understand the concept, whether they understand the concept, do not understand the concept, positive misconceptions (positive false), negative misconceptions (negative false), and pure misconceptions.

The research procedure consists of several stages, namely the preparation stage which includes the preparation of the instrument and the trial of the instrument. The implementation stage includes data collection by giving three-level cognitive diagnostic test questions and interviews to students. The final stage includes analyzing student answer sheets and categorizing them into the form of student misconceptions on the concept of vibrations and waves. Data analysis uses descriptive statistics, namely data obtained from the three-level cognitive diagnostic test is then analyzed using a table of student answer combination criteria which can be seen in Table 1. and described to produce a profile of student misconception data.

Table 1. Student misconception indicators

First level	Second level	Third level	Category
Correct	Correct	Sure	Have scientific knowledge
Correct	Wrong	Sure	Misconception (positive false)
Wrong	Correct	Sure	Misconception (negative false)

First level	Second level	Third level	Category
Wrong	Wrong	Sure	Misconception
Correct	Correct	Not Sure	Guess, not confident
Correct	Wrong	Not Sure	
Wrong	Correct	Not Sure	Lack of knowledge
Wrong	Wrong	Not Sure	

Then the percentage of misconceptions experienced by students can be calculated using the formula:

$$P = \frac{f}{N} \times 100\% \quad (1)$$

Description:
P = Percentage of each group
f = Frequency being searched
N = Number of individuals

(Widiastutik & Isnawati, 2020)

The results of the percentage of misconceptions in students are interpreted descriptively based on the percentage categories of misconceptions shown in Table 2.

Table 2. Misconception Percentage Category

Percentage	Category
0% - 30%	Low
31% - 60%	Medium
61% - 100%	High

(Irianti, 2021)

The basis for categorization refers to related misconception analysis research which states that an average level of misconception below 30% is said to be low, 31% to 60% is said to be medium, and above 61% is said to be high (Haerunnisa et al., 2022; Irianti, 2021; Wulandari et al., 2022).

3. Results and Discussion

3.1. Level of Student Misconceptions on the Concept of Vibrations and Waves

Based on the results of the diagnostic tests that have been conducted, the level of student misconceptions in each concept is divided into students who experience pure misconceptions, students who experience positive misconceptions (positive false), and students who experience negative misconceptions (negative false). Students who experience pure misconceptions are students who answer incorrectly at the first and second levels but choose to be sure at the third level. Students who are included in positive false are students who answer correctly at the first level, give incorrect reasons, and choose to be sure at the third level. This false positive condition can be interpreted as meaning that students do not understand a concept which indicates a misconception that is very difficult to eliminate or a situation where students have an understanding that is mixed with misconceptions where the reasons given do not show the illogicality of the information when connected to the correct concept (Istiyani et al., 2018; Mubarak et al., 2016). Students who are included in negative false are students who answer incorrectly at the first level, answer correctly at the second level, and choose to be sure at the third level (Mawaddah et al., 2021). The false negative condition can be interpreted as meaning that students have little information or little information obtained by students. Misconceptions in this category are considered not problematic because they are caused by students' carelessness in giving answers or students understand the material presented by the teacher with the wrong concept. Therefore, students provide the right analogy for the material asked using the wrong concept (Istiyani et al., 2018; Mubarak et al., 2016). Based on the results of the study, it was found that 39.2% of students experienced pure misconceptions in the moderate category, 18.8% of students experienced positive false in the low category, and 14.4% of

students experienced negative false in the low category. The category of student misconception levels on the concept of vibration and waves can be seen in Figure 1.

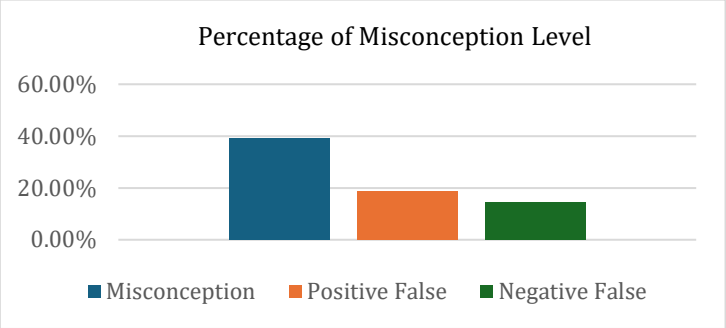

Figure 1. Percentage of Overall Student Misconception Level

Based on Figure 1 shows that the majority of students experience misconceptions with a greater proportion of pure misconceptions compared to the positive false misconception category and the negative false misconception category. The percentage of pure misconceptions that is greater than other categories of misconceptions means that on average students have an initial conceptual understanding that is contrary to the correct concept (Mubarak et al., 2016). This result is similar to previous research by Koriah & Jumini (2024) that the percentage of misconceptions in vibration and wave material is more dominant, but the study did not describe the percentage of misconceptions in other categories. High levels of pure misconceptions indicate that students do not understand the material during the learning process (Istiyani et al., 2018). When students do not understand a concept, they create their own understanding of what they do not understand, resulting in misconceptions or concepts that do not correspond to scientific definitions in related fields (Dwidianti et al., 2017). Misconceptions generally occur because students have difficulty assimilating new concepts that are received so that they are mixed with students' experiences and feelings (Mubarak et al., 2016). Meanwhile, the percentage of students with the positive false category is greater than the percentage of negative false, indicating that more students give correct conceptual answers without knowing the reasons why the concept is correct (Mubarak et al., 2016).

3.2. Profile of Student Misconceptions on the Concept of Vibrations and Waves

The results of students' answers based on the three-level cognitive diagnostic assessment show that the majority of students experience misconceptions in the vibration and wave material which are evenly distributed across all sub-concepts of the vibration and wave material. The percentage of students' misconceptions in each vibration and wave concept can be seen in Table 3.

Table 3. Results of Student Misconception Identification

Question indicator	Percentage of Misconception Categories		
	PF	NF	M
The concept of vibration	7.6	27.3	22
Applications of vibration in life	6.8	5.7	48.9
The relationship between frequency, period, and length of the string on a pendulum	6.1	3.4	35.2
Wave magnitude	20.5	11	25.4
Wave motion	12.9	6.4	48.9
Wave motion	13.6	5.7	50
Wave propagation speed	23.5	1.9	23.9
Speed of sound waves	18.9	7.2	33
Characteristics of sound waves	6.1	19.3	30.7
Sound wave propagation medium	18.9	12.9	32.6

The profile of students' misconceptions on the concept of vibration is the concept of the correct pendulum motion on a pendulum. Students who experience misconceptions are fooled by answering that one pendulum vibration occurs when the pendulum moves from one end to the other. They reason that if the pendulum makes one vibration it will move on the same path without passing through the equilibrium point. In addition, students also assume that the pendulum moves around the equilibrium point and returns to its starting position. In this concept, the percentage of students

with the category of false negatives or negative misconceptions is the largest among the other categories. This indicates that many students still get incomplete information regarding the definition of vibration on a pendulum, which causes carelessness in students in answering (Istiyani et al., 2018; Mubarak et al., 2016). Based on the results of the interview, students who misconceive this question come from a concept built on their personal experience that one vibration occurs when the pendulum moves from end to end. Their initial understanding that is formed based on direct experience in everyday life and forms a concept that is inherent in them causes misconceptions (Karomah et al., 2018; Suparno, 2013). The follow-up that can be done to overcome misconceptions in students is that teachers can demonstrate vibrations in pendulums in real activities or in the form of video animations that make students have a clearer picture of the concept of vibrations in pendulums.

Student misconceptions that occur in the concept of applying vibrations in everyday life are that students consider the swing motion not to be an example of the application of vibrations because they assume that the forward and backward movements are in the swing motion. In addition, some students also argue that moving back and forth on the same path is not an example of vibration. Based on the results of the interview, students who experience misconceptions on this question come from their wrong intuition which assumes that the swing motion is not an example of the application of vibrations. This indicates that students understand something without using rational and intellectual reasoning. This understanding suddenly appears without any previous reasoning process, so that students can answer questions confidently without having to think about it again, which is usually called a spontaneous mindset (Izza et al., 2021). The follow-up that can be done to overcome misconceptions in this concept is that the teacher provides reinforcement of the concept of applying vibrations by providing examples of real applications in everyday life in the learning process that are closest to students' daily activities in general.

Student misconceptions that occur in the concept of the relationship between the length of the pendulum string and the period and frequency are that students assume that a longer pendulum string has the highest vibration frequency and has the smallest period because students assume that when the pendulum string is longer, the frequency will be greater and the period will be smaller. This is in line with the findings of misconceptions in the study (Kurniasih et al., 2023) that students assume that the frequency and period of vibration will increase if the length of the pendulum string is increased. Based on the results of the interview, students who experience misconceptions come from their preconceptions that think that a longer pendulum string causes a higher frequency. This is supported by research (Karomah et al., 2018) their initial understanding which is formed based on direct experience in everyday life and forms a concept that sticks to them causes misconceptions (Karomah et al., 2018). The follow-up that can be done to overcome misconceptions in this concept is that teachers can design learning that is oriented towards experimental activities about the concept of the relationship between the length of the pendulum string and the period and frequency. This is done so that students can have the right concept based on real experiences that are in accordance with scientific explanations.

Student misconceptions that occur in the concept of wave quantities are that students are wrong in defining wavelength. Students who experience misconceptions assume that the X symbol on the graph is a deviation because the deviation separates one wave peak from the next. In addition, some students are correct in mentioning the X symbol on the graph. However, they are wrong in defining wavelength. This indicates that some students do not understand the concept of wave magnitude or show irrationality of information in relation to the intended concept which causes students to know the correct concept without understanding why the concept is correct (Bayrak, 2013; Mubarak et al., 2016). Based on the results of the interview, students who experience misconceptions come from their initial conceptions of waves and their wrong intuition. This is explained in Suparno (2013) that students can experience misconceptions due to wrong intuition by expressing their ideas spontaneously. In addition, students who answer the first level correctly and answer incorrectly at the second level can occur because the students' reasoning or reasoning is incomplete in understanding the definition of wavelength, so that it can cause misconceptions (Suparno, 2013). The follow-up actions that can be taken to overcome misconceptions that occur in students are that teachers can provide conceptual reinforcement for each definition of wave attributes by combining explanations with pictures of each wave attribute.

The misconception of students that occurs in the concept of wave motion is that students assume that leaves when hit by ripples (waves) will move to the right and left and maintain the same distance from the center of the ripples (waves) because students assume that the material will move and the propagation medium will vibrate when there are waves. Some students also assume that waves push matter to move in all directions from the wave source. In other questions that are still in the same concept, students assume that a block when hit by ocean waves will move away from its initial position with the direction of the object's movement in the same direction as the wave's motion because students assume that ocean waves are longitudinal waves that have a vibration direction parallel to the direction of the ocean wave's motion. As Students also reason that waves do not transfer energy but transfer matter. Based on the results of the interview, students who experience misconceptions come from concepts built on students' personal experiences which explain that leaves and blocks will be pushed when hit by waves. This is explained in Suparno (2013) that students who experience misconceptions can occur because of the initial concept that students already have based on their daily experiences which then the concept sticks to them. The follow-up that can be done to overcome misconceptions in this concept is that teachers can provide demonstrations in the form of video animations for each phenomenon in students' daily lives that is related to wave motion.

Students' misconceptions that occur in the concept of the relationship between the length of the rope which in this question is illustrated as a root with wave propagation speed are that students assume that the wave propagation speed at a longer root will be smaller than a shorter root because students assume that the longer the root, the smaller the wave propagation speed. Some students are correct in answering at the first level but are wrong in explaining their reasons. This indicates that students have a conceptual understanding that is mixed with misconceptions because students give reasons that do not match the correct concept, so students give the correct answer, but they do not understand why the answer is correct (Bayrak, 2013). Based on the results of the interview, students who experience misconceptions come from students' wrong intuition or spontaneous thinking without any correct rational reasoning process, resulting in misconceptions (Izza et al., 2021). The follow-up that can be done to overcome this conceptual problem is that teachers can conduct experimental activities related to the relationship between the length of the rope and the speed of the waves produced. In this way, students will have a clearer picture related to the explanation of the concept.

Students' misconceptions that occur in the concept of the speed of sound waves are that students assume that the speed of sound will increase along with the increase in the tone (frequency of sound) of a person. Based on the results of the interview, students who experience misconceptions come from their wrong intuition and preconceptions brought based on their experiences that assume that sounds with higher pitches will be heard faster. Misconceptions can occur in students because of students' wrong initial understanding, which is based on direct knowledge from everyday life, thus forming a concept that is embedded in students (Suparno, 2013). The follow-up that can be done to overcome misconceptions in this concept is that teachers can provide conceptual reinforcement with the help of learning videos on various platforms regarding the concept of the speed of sound waves and what factors can influence the speed of sound waves.

Misconceptions in students that occur in the concept of sound wave characteristics are that students assume that the man in room B does not hear the voice of the woman singing in room A where the two rooms are isolated. They assume that sound can only be transmitted through the air, because there is a wall that separates the two rooms, the sound is blocked by the wall. Some students answered correctly at the second level but gave the wrong answer at the first level. This indicates that students are careless in giving answers or students understand the material presented by the teacher with the wrong concept. Therefore, students provide the right analogy for the material being asked using the wrong concept (Istiyani et al., 2018; Mubarak et al., 2016). Based on the results of the interview, students who experience misconceptions come from concepts built from experiences they have had. The follow-up that can be done to overcome misconceptions in this concept is that teachers can provide an explanation of the related concept by showing an animation of how sound works in a closed room, so that students have a clearer understanding.

Student misconceptions that occur in the concept of sound propagation medium are that students assume that sound only propagates in the air and then switches to propagating through

trains because they assume that the sound of the train will propagate in the air first and then propagate on the railroad tracks. Based on the results of the interview, students who experience misconceptions come from concepts built from experiences they have experienced themselves which then they make analogies without knowing whether they are right or wrong. The follow-up that can be done is that the teacher can provide reinforcement on the concept of sound propagation medium by showing animations about the differences in the speed of sound waves when passing through various propagation mediums. In that way, students have an idea of how sound waves can propagate through different mediums and can understand the differences in the speed of sound waves in each propagation medium.

Based on the exposure of students' misconceptions on each sub-concept of vibration and waves, it was found that the misconceptions that occurred in students included misconceptions about their perceptions of physical phenomena, the relationship between concept attributes, object movement, definition of concept attributes, wave propagation process, and wave propagation medium. By revealing the misconceptions that exist in students, it can be used as evaluation material for teachers to provide learning that is in accordance with the needs of each student and take appropriate follow-up actions on the misconceptions experienced by students

4. Conclusion

Based on the discussion that has been done, it was concluded from the research results that the level of misconceptions experienced by students at SMPN 11 Surakarta and SMPN 27 Surakarta on the concept of vibration and waves using a three-level cognitive diagnostic assessment is divided into three categories, including students with positive false conditions of (18.8%) which is included in the low category, negative false of (14.4%) which is included in the low category, and pure misconceptions of (39.2%) which is included in the moderate category. The highest percentage of misconceptions in the sub-concept of vibration and waves is in the concept of wave motion of 50% which is included in the moderate misconception category, while the lowest percentage of misconceptions is in the concept of vibration in a pendulum of 22% which is included in the low misconception category. The profile of misconceptions experienced by students in each sub-concept of vibration and waves includes students' misperceptions of physical phenomena, relationships between concept attributes, analysis of object movement, definition of concept attributes, analysis of wave propagation processes, and analysis of wave propagation media.

The results of this study can be used as a reference and study material in similar studies related to the level and profile of misconceptions in the concepts of vibration and waves, and can be used as an evaluation of learning for science teachers as a basis for selecting more varied learning models and methods to visualize abstract concepts.

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