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Concept understanding profile of high school students on doppler effect and sound intensity levels

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Abstract: The purpose of this study is to map the profile of high school students' conceptual understanding in physics subjects with the Doppler effect and sound intensity levels and to show the causes of misconceptions in high school students from the results of the Certainty of Response Index (CRI) method applied. The research method is descriptive quantitative with data analysis techniques in descriptive statistics. The data collection technique used is an ordinary multiple-choice test instrument equipped with a confidence level scale using the model CRI (Certainty of Response Index). This confidence scale is used to understand students' concepts in answering questions that are analyzed statistically. The research subjects were 66 high school students in class XI who were randomly selected and had received lessons on sound waves. The test results showed misconceptions in each item, with the largest percentage of 45.45% in item number 3 and the smallest 12.12% in item number 2. Other responses in the form of lucky guesses and not knowing the concept were also found with varying percentages. The misconceptions encountered occurred in the use of signs for the observer's speed and the source's speed, the relationship between distance and number of sound sources at the level of sound intensity, and the relationship between sound magnitudes. The results of this concept understanding profile are expected to be information for teachers to be able to overcome students' misconceptions and arrange appropriate learning strategies during the learning process.

Keywords: certainty of response index (CRI); conceptual understanding; sound wave

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Introduction

Physics is one of the sciences containing a collection of systematically arranged knowledge resulting from detailed observations, measurements, and experiments. Physics in its use is generally limited to natural phenomena but possibly produce general laws or basic principles to explain these natural phenomena (Dewi et al., 2019; Ogundeji et al., 2020). One natural phenomenon that needs to be studied in physics is a sound wave. For most people, the sound is certainly felt, heard, and even used almost every time. Sound is also a common phenomenon experienced by students. However, many students still do not understand the concept of the sound wave phenomenon (Gelu et al., 2020; Putra et al., 2019). Sound wave learning in schools mostly only focuses on students' success in solving problems without paying attention to students' understanding of concepts. The tests carried out also only tested students' ability in calculating competence, so there were shortcomings in the test, namely not being able to reveal the causes of student failure in learning (Guido & Dela Cruz, 2015; Negoro & Karina, 2019).

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Physics is also one of the first fields in which learners' pre-instructional conceptions are studied (Aretz et al., 2016). Students' pre-instructional conceptions that have been firmly embedded in daily life experiences can be defined in several ways: alternative conceptions, misunderstandings, naive conceptions, and others. Research shows that students' pre-instructional conceptions are more or less able to damage their conceptual understanding of science topics (Bigozzi et al., 2018; Halim et al., 2014).

Based on literature sources, until now, research related to understanding physics concepts is dominated by mechanical and electric-magnetic materials (Caleon & Subramaniam, 2010), optics (Fariyani et al., 2017), as well as temperature and heat (Leinonen et al., 2013). Physics education research that examines students' conceptual understanding of sound wave material is still quite rare. Thus, research is needed to reveal the distribution of students' conceptual understanding profiles (Kennedy & De Bruyn, 2011). Research related to sound waves that have been generally conducted in the form of developing physics e-book teaching materials based on a scientific approach (Rahayu et al., 2019), developing PBL-based learning modules (Hasanah et al., 2017), and using augmented reality technology (AR) in the learning process (Muliyati et al., 2019). In addition, there are also studies related to the effectiveness of using virtual laboratories on the topic of waves and sound (Maulidah & Prima, 2018). Research on concept understanding that has been carried out is limited to categorizing students' level of understanding based on criteria from very low to very high without identifying opportunities for misconceptions (Nova et al., 2020). Based on this condition, it is necessary to conduct research to map the profile of students' conceptual understanding using the CRI method.

The research was conducted using a test instrument that stated the usual answers and was equipped with a method to analyze the students' conceptual understanding of each question answered. One of these methods is the Certainty of Response Index (CRI). This method was first introduced by Hasan et al. (1999) on Newton's law material, which can explore information on students' level of understanding and confidence in answering each item given (Diani et al., 2019). Research in the field of physics studies with the result of students' misconceptions on the concepts of work and energy has also been conducted (Latif et al., 2021). This is evidenced by the test results accompanied by the Certainty of Response Index analysis for students who experience misconceptions. Students experience the biggest misconceptions about the concept of energy, which is as much as 60% of the number of test-takers, so this method is feasible to be applied to map the profile of students' conceptual understanding in physics education research. The results obtained later can be a guide for teachers in terms of setting appropriate learning strategies.

Based on the explanation above, research was conducted that aimed to (1) map the concept understanding profile of class XI High School students on sound wave material focused on the Doppler effect sub material and sound intensity level using the Certainty of Response Index (CRI) method; (2) show the causes of misconceptions in class XI High School students from the results of the Certainty of Response Index (CRI) method applied.

Methods

This research is descriptive quantitative research with data analysis techniques in descriptive statistics. Descriptive quantitative research explains the instrument's description or summary of research variable data. The data can be in the form of mean, mode, median, standard deviation, variance, percentage level, and so on (Creswell, 2013). The subjects of this study were 66 high school students in class XI at SMAN 3 Solok for the academic year 2020/2021 who were randomly selected and had received sound wave material learning, especially the Doppler effect and sound intensity level. The data collection technique in this study used an object in the form of an ordinary multiple-choice test instrument as many as ten items equipped with a student confidence level scale for each item with reference to the Certainty of Response Index (CRI) method in which all of the items had been declared valid.

Students can use the modified CRI method from Diani et al. (2019) to identify concept understanding. The criteria for the level of confidence that students can choose are presented in Table 1.

Table 1. CRI Criteria

CRI Scale	Level of Trust
5	Well Understand
4	Quite Understand
3	Certain
2	Uncertain
1	Half Guessing
0	Full Guessing

In addition, four categories which are a combination of student responses for each item, are modified from several previous studies (Ain, 2021; Latif et al., 2021), which is presented in Table 2. The data obtained were analyzed according to the category of student responses. The category of assessment of test results was a combination of true-false answers with a confidence level scale chosen by students as many as four categories.

Table 2. Concept Understanding category based on CRI

Answer Criteria	Low CRI (< 2,5)	High CRI (> 2,5)
Correct Answer	*Lucky Guess* (LG)	Understanding concept (PK)
Wrong Answer	Do not understand the Concept (TPK)	Misconception (MK)

The results of the data obtained in the form of the average and percentage of achievement of each category are calculated statistically, then described to describe the profile of students' conceptual understanding in tabular form and interpreted.

Results and Discussion

In general, the data obtained from the test results using the Certainty of Response Index (CRI) method showed that misconceptions were found for each given item. Data processing found the largest percentage of misconceptions in item number 3 and number 10, namely 45.45%. Meanwhile, the smallest percentage of misconceptions is found in item number 2, which is 12.12%. The concept understanding profile for all items is presented in Table 3. It can be seen from the distribution of data that students experience misconceptions on various questions.

Table 3. Percentage of Student Concept Understanding Profile based on CRI

Item Number	Percentage (%)			
	PK	LG	TPK	MK
1	22,73	6,06	36,36	34,85
2	63,64	9,09	15,15	12,12
3	24,24	4,55	25,76	45,45
4	21,21	9,09	34,85	34,85
5	33,33	16,67	25,76	24,24
6	21,21	9,09	30,3	39,39
7	62,12	10,61	7,68	19,7
8	31,82	12,12	33,33	22,73
9	39,39	9,09	21,21	30,3
10	10,61	6,06	37,88	45,45

Suppose the average value of each category is taken. In that case, the highest order is the PK (Understanding Concept) category of 33.03%, followed by MK (Misconception) of 30.91%, then TPK (Do not Understand concept) of 26.83% and finally the LG (Lucky Guess) category of 9.24%. These results indicate that students' understanding of concepts for the Doppler effect sub-material and the level of sound intensity is still relatively low because the average percentage of concept understanding (PK) for all items is less than 50%. In addition, the percentage of students who experience misconceptions is included in the moderate category, and this requires handling action from educators so that students' misconceptions can be lost. If the misconceptions cannot be identified, then the students' concepts will continue to be wrong, and the impact will be carried to a higher level. This also has the opportunity to spread erroneous concepts from students to others (Fariyani et al., 2017; Tumanggor & Supahar, 2020).

The misconception found in item number 3, as presented in Table 4, is that students are wrong in determining the sign on the speed of the observer and the speed of the sound source, resulting in the wrong interpretation of the sound frequency. As many as 45.45% of students stated that when the observer and the source of the sound move closer to each other, the frequency that arises is at first lower, then higher. This is certainly wrong because the Doppler effect equation says that if the observer and the sound source move closer to each other, the observer's velocity is positive, and the sound source's velocity is negative, resulting in an observer frequency value that is greater than the original sound source frequency. The formulation of the Doppler effect is mathematically given by equation (1).

$$f_P = \frac{v \pm v_P}{v \pm v_S} \times f_S \quad \dots.(1)$$

Where f_P and f_S are the frequencies of the observer and sound source, respectively, v is the speed of sound in air or medium, and v_P v_S are the speed of motion of the observer and sound source, respectively (Giancoli, 2014; Halliday et al., 2011).

Table 4. Item Number 3

Question Number 3

A. Afrizal is riding a motorcycle with Wulan. After driving for a while, they heard the siren of an ambulance coming from the front, then passed each other, as shown in the following picture.

If Afrizal and the ambulance were moving at a constant speed, then the frequency of the sirens that Afrizal heard during the incident would be....

A. higher
B. lower
C. balance
D. higher first, then lower
E. lower first, than higher

B. Choose your confidence level.

CRI	0	1	2	3	4	5

Furthermore, misconceptions were also found in item number 6, as presented in Table 5, namely student errors in interpreting symbols and formula forms (Nova et al., 2020). As many as 39.39% of students answered that the area covered by sound was $\frac{1}{4}\pi r^2$, while it was based on the actual equation $4\pi r^2$ (Halliday et al., 2011). Students tend to directly choose an answer that resembles a shape without understanding the meaning of the symbols contained in an equation.

The biggest misconception at the end is item number 10, as presented in Table 6. As many as 45.45% of students are wrong in determining the main factors that affect the level of sound intensity. Students only consider the distance factor and ignore the fact that several identical sound sources that are turned on simultaneously also have an impact on changes in sound intensity levels. So that the distance and number of sound sources play a role in the level of sound intensity, which is written mathematically in equation (2),

$$TI_{n,r} = TI + 10 \log n - 20 \log r \quad \text{....}(2)$$

Where TI is the initial sound intensity level, n is the ratio of the number of sound sources, r is the ratio of the observer's distance from the sound source, and $TI_{n,r}$ is the final sound intensity level at a certain value of n and r (Giancoli, 2014; Halliday et al., 2011).

Table 5. Item Number 6

Question Number 6							
A. Adit's motor vehicle exhaust has a cylindrical shape, one end of which is connected to the exhaust duct of a vehicle with a diameter of D. If at any time Adit heats up his motorcycle engine so that the exhaust duct makes a sound with power P and the direction is perpendicular to the exhaust, then the intensity of the sound produced is expressed by .... (r stands for radius) A. $I = \frac{P}{\pi D^2}$ B. $I = \frac{4P}{\pi D^2}$ C. $I = \frac{2P}{\pi D^2}$ D. $I = \frac{P}{\pi r^2}$ E. $I = \frac{4P}{\pi r^2}$							
B. Choose your confidence level.							
	CRI	0	1	2	3	4	5

Table 6. Item Number 10

Question Number 10							
One day Larman and his classmates paid a visit to a factory producing industrial goods. Then Larman observed the results of noise measurements in the factory, where the noise data of a machine at a distance of 1 m from the detector was 80 dB. If there are 100 identical machines in a factory and the detector is 100 m away from these machines, then the noise level obtained by Larman becomes .... A. reduced 25% from the initial intensity level B. reduced 75% from the initial intensity level C. reduced 40 dB from the initial intensity level D. increased 20 dB from the initial intensity level E. increased 40 dB from the initial intensity level							
B. Choose your confidence level.							
	CRI	0	1	2	3	4	5

Before taking part in learning, students certainly have an initial conception of natural phenomena that are seen every day, especially in the field of physics. However, not all of these conceptions can be interpreted by students properly and logically. Misconceptions in the field of physics originating from students are classified into several things, namely preconceptions or students' initial concepts, non-scientific beliefs, conceptual misunderstandings, vernacular misconceptions, incorrect or incomplete reasoning and intuition abilities, as well as students' own learning abilities and interests (Bigozzi et al., 2018; Soeharto et al., 2019). Misconceptions often occur in students in physics subjects must be quickly and precisely corrected because this can hinder students from interpreting and understanding scientific concepts (Akarsu, 2012; Maison et al., 2020).

In addition to the occurrence of misconceptions, students' knowledge base is often fragmented. So that if students are asked to solve relatively more complicated problems, they will tend to give up and get confused because of the difficulties they are experiencing. Supposedly, it is expected that students' knowledge is intact so that they are able to solve problems with a relatively more complicated and broad scope (Opitz et al., 2015). Students' misconceptions in working on problems related to the Doppler effect and the level of sound intensity must be identified properly. This is intended to quickly overcome students' mistakes and even difficulties by implementing appropriate and suitable learning strategies. The implementation of appropriate learning strategies can certainly build an understanding of students' concepts and knowledge effectively. Educators obtain good evaluation results from the design of teaching activities that have been prepared (Fariyani et al., 2017; Rahmatina et al., 2018).

Conclusion

In general, students' understanding of concepts in the Doppler effect sub-material and sound intensity level is still in the low group because the percentage of students who understand the concept is less than 50%. This is shown from the average percentage of each category based on the CRI method, where the concept understanding category (PK) is 33.03%, misconception (MK) 30.91%, does not understand the Concept (TPK) 26.83%, and Lucky Guess (LG) 9.24%. Then the causes of misconceptions in students are mostly from themselves in the form of students' preconceptions or initial concepts, non-scientific beliefs, conceptual misunderstandings, vernacular misconceptions, wrong or incomplete reasoning and intuition abilities, and the ability interest in learning of the students themselves. This research may not use a complete approach, but educators can use it to see the description and profile of the understanding of the concepts of students in class XI High School so that in the learning process, special steps or actions can be taken to overcome students who are still experiencing misconceptions and do not understand the concept. These findings can be used as an initial reference in quickly and accurately identifying the level of students' concepts. If possible, for other Physics material, educators can use this method as an initial action to identify students' conceptual understanding.

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