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Identification of Students' Misconceptions Using Six Tier Diagnostic Test with CRI (Certainty of Response Index) on Wave

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Abstract: The concept of waves is essential in physics learning. This study aims to obtain a six-level diagnostic test instrument accompanied by a Certainty of Response Index (CRI) and use it to identify students' level of conceptual understanding and misconceptions on wave material. This study used the Research and Development (R&D) method with a sample of 220 students. Misconception data was obtained using a misconception test in the form of multiple-choice questions. There are 32 questions with six stages consisting of multiple choices answer, the level of confidence in choosing answers, the source of answer choices, the choice of reasons in answering questions, the level of confidence in selecting causes, and the source of students' reasons in answering the questions. The results showed that the percentage of students who experienced misconceptions in the whole question was 36%. Students who understood the concept was 30%, and 34% of students did not understand the concept. In addition, 61% of students chose answers and reasons for solutions based on personal opinions. The conclusion is that misconceptions are caused by student errors in applying the concepts received in the given problem, and students tend to choose the correct answers and reasons when the issue presented is equipped with a picture and only requires one step to get the correct answer.

Keywords: Misconception; Six-tier diagnostic; Wave

Introduction

Physics is one of the sciences that plays an essential role in supporting the development of science and technology. The physics learning objectives contained in the 2013 Curriculum framework are to master the concepts and principles of physics and have the skills to develop knowledge and a confident attitude as a provision for continuing education at a higher level (Kemendikbud, 2014). Based on these objectives, physics learning can train students to master physics knowledge, concepts, and principles. In addition to developing students' knowledge, physics learning can develop students' skills. One of the skills that can develop through physics learning is solving problems in everyday life (Sari et al., 2019). Indicators of problem-solving skills consist of focusing, finding reasons, and concluding (Gunawan et al., 2020). To be able to focus on the problem, knowledge is needed; the more knowledge students have, the easier it will be to dig up information, and it will increase students' curiosity. After having curiosity, learners will tend to look for the truth and reasons for the information presented, then, learners can conclude the solution to the problem accompanied by the right reasons and information. Through problem-solving skills, it is hoped that students can develop all their potential into increasing abilities seen from the improvement and balance between attitudes, knowledge, and skills competencies (Mardhiyah et al., 2021). Problem-solving allows the thinker to improve their thinking quality and capability to determine other options beyond their intellectual (B. Utami et al., 2019). High-level thinking is very important for students to have because it is one of the aspects of learning

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(Sulistyowati et al., 2019). Concept learning is one of the learnings that supports problem-solving (Vardakosta et al., 2023).

The essential part that becomes the basis that students must understand in learning physics is called a concept. Conceptual knowledge refers to the understanding, definition, unique characteristics, components, or parts of an object being studied (Ma'rifa et al., 2016). Concepts in a learning material are interrelated with each other. When students understand a concept correctly, they can continue to understand other concepts. However, an error in understanding the concept will affect the understanding of other concepts (Mukhlisa, 2021). Initial concepts or so-called conceptions often need to match actual knowledge and become a misconception.

A misconception is a person's conception of a concept that differs from the concept agreed upon and considered correct by experts (Yuliati, 2017). In physics, misconceptions are defined as incorrect meanings, misuse, misclassification of examples, and false hierarchical relationships between concepts (Maknun et al., 2022). Factors that cause misconceptions by students, among others, are the preconceptions that are owned by themselves, teachers, learning carried out by the teacher or even the teaching materials used (Yuliati, 2017). Learners are the most significant factor in causing misconceptions due to errors in assimilating new concepts obtained during the previous school level.

One of the efforts that can be made to overcome students' misconceptions is to identify students' misconceptions. Identifying and addressing students' misconceptions is a key part of a science teacher's competence (Qian et al., 2017). One of the ways that can be done to identify students' misconceptions is by using a six-tier diagnostic test. The first stage is multiple choice content, the strength of the multiple-choice test has a scoring certainty compared to the essay test for many respondents (Sutiarso et al., 2022). The second stage is students' confidence level in choosing answers, and the third stage is the source of students' answer choices. In the fourth stage, students choose reasons in answering questions, the fifth stage is the level of confidence of students in choosing reasons, and the sixth stage is the source of students' answers in answering level four and five questions accompanied by the level of confidence of students in choosing each distractor.

The measurement of students' confidence levels is accompanied by the CRI (Certainty of Response Index) technique. CRI is a technique for measuring the level of confidence or certainty of respondents in answering each question given so that student's level of understanding can be measured accurately (Mattanete et al., 2020). A low CRI indicates the uncertainty of the concept in students, who usually determine the answer based on mere guesses. Conversely, a high CRI reflects high concept confidence and certainty in students, so the element of guesswork in choosing answers is tiny (Fadillah, 2017).

One of the physics materials that can be tested for misconceptions is wave. Which is one of the essential branches of physical science because it is very close to everyday life. Misconceptions in wave material experienced by students, namely: factors affecting the speed of wave propagation 28%, frequency in stationary waves 4.0%, wavelength in stationary waves 28%, period of traveling waves 18.67%, frequency of traveling waves 25.33% (Nawati et al., 2017).

The novelty of this study is to identify misconceptions in high school students using a six-tier test. Therefore, the results obtained are the level of student misconceptions accompanied by the source of the causes of misconceptions and students' confidence level using CRI. Self-confidence is an important factor in enhancing students' learning (Wang et al., 2018). Self-confidence is a student's belief in certain actions or tasks to achieve maximum results (Widodo et al., 2022). Self-confidence affects motivation, can change human behavior, and is considered a factor in students' problem-solving skills (Akbari et al., 2020).

Based on the description, this study aims to identify students' conceptual understanding and misconceptions through the Six-Tier Diagnostic Test along with the Certainty of Response Index (CRI) on Wave.

Method

The method in this research is Research and Development (R&D). Which produce specific products and test the validity and effectiveness of these products in their applications (Sugiyono, 2017). The development procedure in this study uses the 4-D development model design, which consists of four stages: define, design, develop, and disseminate.

The defining stage is carried out through a literature review such as journals, books, and research reports related to research and material analysis related to mechanical wave material. In the planning stage, the instrument design to be tested was carried out as a six-tier test instrument design. The initial instrument consisted of 32 items consisting of six stages, namely multiple-choice, level of confidence in the answer, the source of the answer, the reason for choosing the answer, the level of confidence in the source, and the source of the reason. The development stage is a question instrument divided into four: rope waves, water surface waves, sound waves, and electromagnetic waves; each material consists of 8 questions that can be accessed via

Google Forms. The dissemination stage in the form of product trials in this study was a trial with 220 students as research subjects. The schematic of the research method is shown in Figure 1.

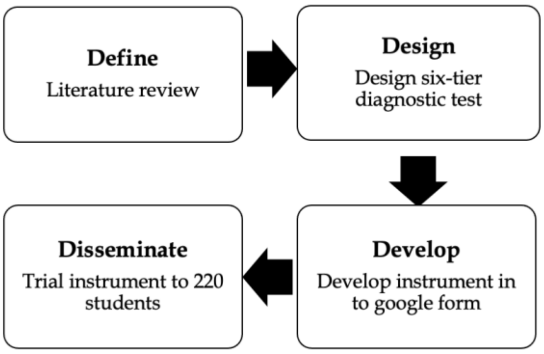


Figure 1. Schematic of the research method

The categories of student answer combinations in the six-tier diagnostic test consist of answers, confident level in answers (CLA), sources of answers, reasons, confident level in the reasons (CLR), and sources of reasons. From the results of the analysis of the combination of answers, students will be grouped into three categories, namely understanding the concept (UC), not understanding the concept (NUC), and misconceptions (MS), as in Figure 2.

Answers	CLA	Answer Source	Reasons	CLR	Reanson Sources	Category
True	High	Teacher/book	True	High	Teacher/book	UC
True	High	Own Opinion	True	Low	Teacher/book	
True	Low	Internet	True	High	Own Opinion	
True	Low	Own Opinion	True	Low	Teacher/book	
True	Low	Teacher/book	False	High	Internet	NUC
True	Low	Teacher/book	False	High	Internet	
True	High	Own Opinion	False	High	Own Opinion	
False	Low	Teacher/book	True	Low	Internet	
False	Low	Own Opinion	True	Low	Teacher/book	
False	Low	Internet	True	High	Own Opinion	
False	High	Internet	True	Low	Internet	
False	High	Own Opinion	True	High	Teacher/book	
False	High	Internet	False	Low	Own Opinion	MS
False	Low	Teacher/book	False	High	Internet	
False	High	Own Opinion	False	High	Own Opinion	

Figure 2. Six-tier diagnostic test answer combination categories

Calculating the percentage of student's level of understanding with the categories of understanding the concept, not understanding the concept, and misconceptions with the equation.

$$P = \frac{S}{N_S} \times 100\% \quad (1)$$

Where,

P = Percentage of students' answers in each category (understand the concept, do not understand the concept, and misconceptions)

S = Number of students in each category group

N_S = The total number of students who are the subject of the research

Result and Discussion

Rope Waves

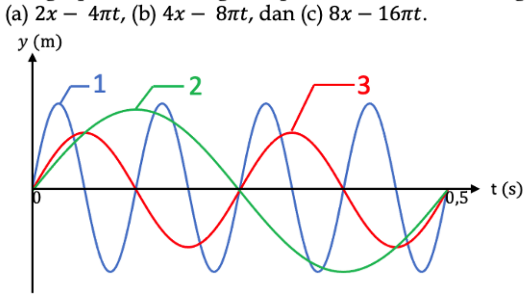
The questions on rope waves consist of the basic concepts of the magnitudes and properties of rope waves. This question was tested on students in class XI MIPA 1, 2, and 3 SMA Negeri 1 Lubuk Sikaping. The misconception levels were grouped into three, as shown in Table 1.

Table 1. Percentage Level of Misconceptions of Ropes Waves

Question Number	UC (%)	NUC (%)	MS (%)
1	51	29	20
2	42	44	15
3	56	29	15
4	38	40	22
5	9	22	69
6	33	42	25
7	18	27	55
8	13	31	56

Based on the table 1, it was identified that students understood the concept in question number 3 as 56% regarding the characteristics of rope waves. Problem number 3 is displayed in Figure 3.

The figure is a composite of three snapshots, each of a wave traveling along a particular string. The phases for the waves are given by (a) $2x - 4\pi t$, (b) $4x - 8\pi t$, dan (c) $8x - 16\pi t$.



Which phase of each wave corresponds to the picture above?

a. 1-(a), 3-(b), and 2-(c)
b. 2-(a), 1-(b), and 3-(c)
c. 3-(a), 2-(b), and 3-(c)
d. 2-(a), 3-(b), and 1-(c)
e. 3-(a), 1-(b), and 2-(c)

Figure 3. Question number 3 (Halliday et al., 2010)

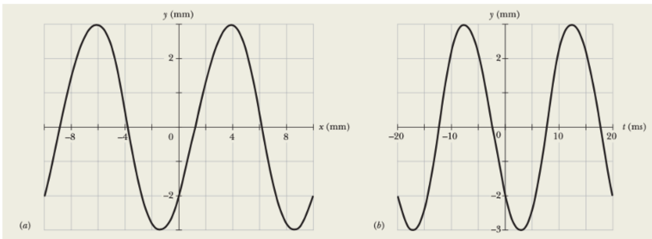
The misconceptions identified in the rope wave material are question number 5 obtaining the largest misconception of 69%, regarding understanding the concept of rope wave magnitudes. Problem number 5 is displayed as shown in Figure 4.

Question number 5 aims to test students' understanding of determining the wave equation from the picture given. The misconceptions experienced by students on wave quantities include determining the phase and amplitude values of waves. Students assume that the wave amplitude can be negative, which affects the value of the wave phase constant. In addition, students also need clarification in determining the phase value. Students assume that as time increases, the wave shifts to the right so that the phase value becomes $(kx + \omega t)$. However, some students who have chosen the correct answer experience errors in choosing the reason. It happens because errors in understanding the concept result in incomplete reasoning (Mata et al., 2017). Reasoning can be caused by teacher learning methods that tend to be monotonous, have not connected with the surrounding environment, and students have not understood the concept (Utami et al., 2020).

A transverse wave traveling along an x axis has the form given by

$$y = y_m \sin(kx \pm \omega t + \phi_0) \ldots \ldots (1)$$

Figure (a) gives the displacements of string elements as a function of x, all at time $t = 0$. Figure b gives the displacements of the element at $x = 0$, as a function of t.



Find the values of the quantities shown in Equation (1), including the correct choice of sign.

a. $y = (3\text{ mm})\sin(200\pi x - 100\pi t - 0{,}73\text{ rad})$
b. $y = (3\text{ mm})\sin(200\pi x + 100\pi t - 0{,}73\text{ rad})$
c. $y = (3\text{ mm})\sin(200\pi x + 100\pi t + 0{,}73\text{ rad})$
d. $y = (3\text{ mm})\sin(25\pi x + 200\pi t + 0{,}73\text{ rad})$
e. $y = (3\text{ mm})\sin(25\pi x - 200\pi t - 0{,}73\text{ rad})$

Figure 4. Question number 5 (Halliday et al., 2010)

Problems number 3 and 5 are problems equipped with pictures and are included in the type of calculation problem. By using pictures, students can understand aspects of problem-solving through information given (Setiana et al., 2021). However, the difference is that problem number 3 requires one step to get the correct answer. Meanwhile, problem number 5 is a problem that requires several steps to get the answer. The misconception in question number 5 occurs because the student is used to multiple choice questions and answering them requires several steps to get the correct answer (Hidayati et al., 2020).

Water Surface Waves

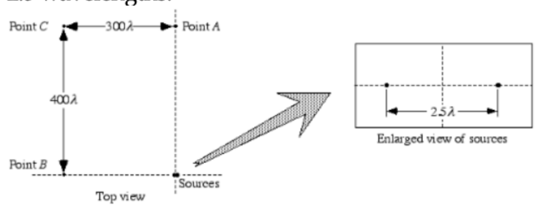
The questions on water surface waves consist of the magnitudes and properties of water surface waves. This question was tested on students in class XI MIPA 1, 2, and 3 SMA Negeri 1 Lubuk Sikaping. The level of misconceptions about water surface waves can be seen in Table 2.

Based on the table 2 it was identified that students understood the concept of the water surface wave material in question number 11 of 67% regarding the understanding of constructive interference in water surface waves. Problem number 11 is displayed in Figure 5.

Table 2. Percentage Level of Misconceptions of Water Surface Waves

Question Number	UC (%)	NUC (%)	MS (%)
9	62	27	11
10	44	42	15
11	67	24	9
12	44	36	20
13	5	25	69
14	16	40	44
15	58	25	16
16	33	42	25

Two sources generate circular water waves in a large tank of water. The sources move up and down regulary and uniform (i.e, the sources have the same frequency and are in phase). The distance beetwen the sources are 2.5 wavelengths.



Based on the picture above, what happened at point C?

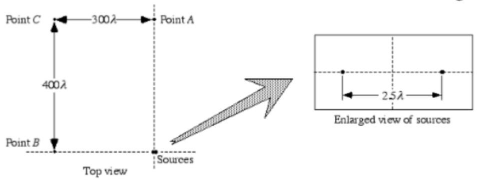
a. Constructive interference
b. destructive interference
c. No interference occurs.
d. Intermediates
e. There is not enough information to explain the interference.

Figure 5. Question number 11 (Serway et al., 2012)

In question number 13, it was identified that students' misconception by 69% regarding the understanding of destructive interference. In question number 13, students need clarification in determining the interference at point C. Students assume that there is no interference at point C because the propagation of water waves does not go to point C. In addition, students experience misconceptions in calculating the distance from source 1 (s_{1_C}) and source 2 to point C (s_{2_C}) which affects the value of the difference in the paths of the two sources to point C (Δl). Problem number 13 is displayed in Figure 6.

Problem numbers 11 and 13 are problems equipped with pictures. However, there are differences in the number of steps to get the correct answer in the process. Problem number 13 combines several concepts, namely the physics concept of interference material and the principle of calculating the Pythagorean triangle, so obtaining the results requires understanding concepts and calculations. Meanwhile, problem number 11 in the process only requires one step to get the correct answer and is included in the type of text problem. So that students are facilitated by getting a visualization of the image, and answering the question just requires a little understanding of the concept. Visualization strategy utilizes images to help strengthen students' understanding in interpreting reading; the images created will affect the knowledge that students already have, both in terms of general knowledge of emotions and personal opinions (Sari et al., 2019).

Two sources generate circular water waves in a large tank of water.
The sources move up and down regulary and uniform
(i.e, the sources have the same frequency and are in phase).
The distance beetwen the sources are 2.5 wavelengths.



Based on the picture above, what happened at point C?
a. Constructive interference
b. destructive interference
c. No interference occurs.
d. Intermediates
e. There is not enough information to explain the interference.

Figure 6. Question number 13 (Serway et al., 2012)

Sound Waves

The questions on sound waves of the magnitudes and properties of sound waves. This question was tested on students in class XI MIPA 1, 2, and 3 SMA Negeri 10 Padang. The level of misconceptions about sound waves can be seen in Table 3. The level of misconceptions about sound waves can be seen in Table 3.

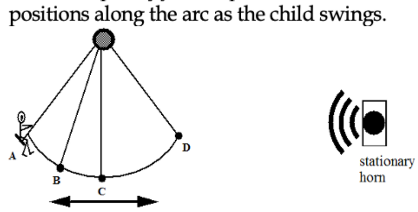
Table 3. Percentage Level of Misconceptions of Sound Waves

Question Number	UC (%)	NUC (%)	MS (%)
17	24	11	65
18	49	84	16
19	55	38	7
20	65	20	15
21	38	42	20
22	35	60	5
23	51	20	29
24	45	51	4

Based on the table 3, the most significant misconception identified in the sound wave material is question number 17 at 65% regarding the Doppler effect material, namely determining the frequency that sounds large at a certain point. Problem number 17 is displayed as shown in Figure 7.

Problem number 17 combines several physics concepts, not only the Doppler effect but also the concept of energy. Students who experience misconceptions assume that at point C, speed is maximum so that when the speed is maximum, the lowest frequency will be heard when approaching the source, namely when the child swings towards point D. In addition, students assume that when at point D, the speed will be minimum so that the frequency heard by the child is the same as the source frequency.

A child is swinging back and forth with a constant period and amplitude. Somewhere in front of the child, a stationary horn is emitting a constant tone of frequency f_S. Five points are labeled in the drawing to indicate positions along the arc as the child swings.



At which positions will the child hear the lowest frequency for the sound from the whistle?
a. at B when moving toward A
b. at B when moving toward C
c. at C when moving toward B
d. at C when moving toward D
e. at D

Figure 7. Question number 17 (Halliday et al., 2010)

In question number 20, it was identified that the students understood the concept of 65% regarding the material understanding of the Doppler effect, namely determining the sequence of frequencies from the largest to the smallest. Question number 20 is displayed as shown in Figure 8.

A source of sound vibrates with constant frequency.
If two frequencies are equal, show their equality in your ranking.
Onlyone thing is moving at a time, and all the motions mentioned have the same speed 25 m/s
1. The source and observer are stationary in stationary air.
2. The source is moving toward the observer in still air.
3. The source is moving away from the observer in still air.
4. The observer is moving toward the source in still air.
5. The observer is moving away from the source in still air.
6. The source and observer are stationary, with a steady wind blowing from the source toward the observer.
7. The source and observer are stationary, with a steady wind blowing from the observer toward the source.

If the speed of sound in air is 340 m/s.
Sort the observed sound frequencies in the above case from highest to lowest.
a. (4) = (2) > (1) > (3) > (5) > (6) = (7)
b. (7) > (2) = (4) > (1) > (3) > (5) > (6)
c. (6) > (2) > (4) > (1) > (3) > (5) > (7)
d. (5) > (3) > (1) = (6) = (7) > (2) > (4)
e. (2) > (4) > (1) = (6) = (7) > (3) > (5)

Figure 8. Question number 20 (Halliday et al., 2010)

Problem number 17 is a question that is equipped with pictures. In the process, it combines several physics concepts. However, it only takes one step to get the correct answer and is included in the type of text question. Whereas question number 20 is a question that is not equipped with an image and is included in the type of calculation problem. The process requires several steps to get the correct answer but only requires the Doppler effect formula.

Electromagnetic Waves

The questions on electromagnetic wave material consist of the basic concepts of the magnitudes and properties of electromagnetic waves. This question was tested on students in class XI MIPA 4, 5, and 6 SMA Negeri 10 Padang. The level of misconceptions about sound waves can be seen in Table 4.

Table 4. Percentage Level of Misconceptions of Electromagnetic Wave

Question Number	UC (%)	NUC (%)	MS (%)
25	31	16	53
26	31	5	64
27	4	44	53
28	36	55	9
29	36	29	35
30	33	16	51
31	60	31	9
32	24	38	38

Based on the table above, the misconception identified in electromagnetic wave material in question number 26 obtained the most significant misconception of 64% regarding understanding the concept of electromagnetic wave magnitudes. Problem number 26 is displayed as shown in Figure 9.

Which one of the following types of electromagnetic wave travels through space the fasttest

a. Radio waves
b. Infrared
c. Ultravioled
d. X ray
e. None

Figure 9. Question number 26 (Halliday et al., 2010)

In question number 26, students assume that waves will propagate at a significant speed in a vacuum if they have a large frequency, so many students think that X-rays have a significant speed when propagating in a vacuum. In question number 31, it was identified that students understood concepts 60% regarding the characteristics of microwaves. Problem number 31 is displayed as shown in Figure 10.

Microwaves can be used to cook food quickly by emitting radiation….
a. Microwave
b. Radio Wave
c. Infrared rays
d. Ultraviolet rays
e. Visible light

Figure 10. Question number 31 (Halliday et al., 2010)

Problem numbers 26 and 31 are text problems that require one step to obtain the correct answer. However, what distinguishes it is that question number 31 is a question that is classified as a form of memorization. In contrast, question number 26 requires understanding the speed of electromagnetic waves in a vacuum.

From the analysis of misconceptions about the waves, the percentage of students' understanding of concepts can be described as shown in in Figure 11.

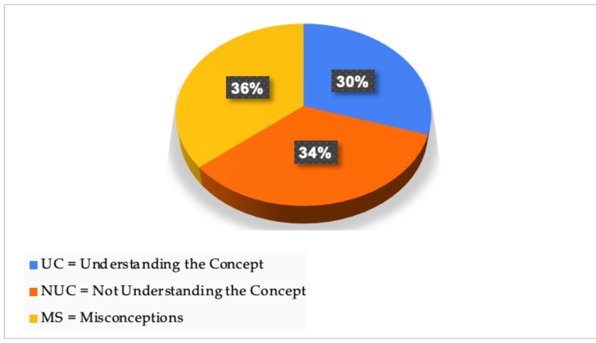


Figure 11. The percentage of students's conceptual understanding

Based on the picture above, of the 32 questions tested with 220 students, it was found that 36% of student's misconception of the material being tested. The results showed no significant difference between students who understood and did not understand the concept and students who needed clarification. Students who need help understanding the concept tend to be corrected in choosing answers or wrong in choosing reasons for answers. Not understanding the concept has the following characteristics a short answer and the reason is wrong, or vice versa, students' answers were inconsistent when meeting different questions, but the concept was the same, and students' answers and reasons with a low confidence level. Meanwhile, misconceptions can occur when students choose the wrong answers and reasons. Misconceptions have the following characteristics: students' answers and reasons, students' wrong answers are consistent when meeting different questions, but the concept is the same, and wrong answers have a high level of confidence.

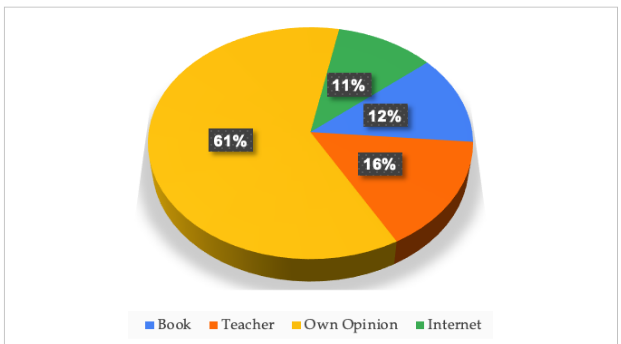


Figure 12. The percentages of the sources of answers

The six-tier diagnostic test instrument is used to analyze student misconceptions and can also find the sources of student answers in answering the questions given, from the results of the trials that have been carried out, the percentage of sources of student answers is obtained as shown in Figure 12.

Besides finding out the sources of student answers, using the six-tier diagnostic test can also help know the sources of student reasons in answering the questions. From the results of the trials that have been carried out, it is obtained the proportion of student sources of reasons, as shown in Figure 13.

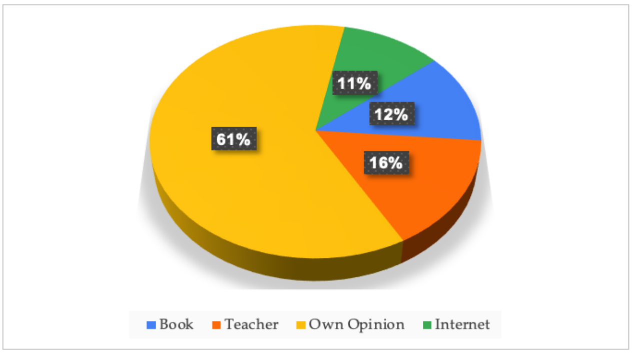


Figure 13. The percentages of the sources of reasons

Based on Figures 12 and 13, the most common source of answers and reasons chosen by students is based on their own opinions. The number of students who choose the source of their own opinion is because, in some questions, it is necessary to combine several physics concepts to get the correct answer. Students assume that when answering the questions, the answer for choices and reasons are based on their opinions. The concepts used for the questions indeed have been explained by the teachers and can be found in textbooks and other sources. However, these sources do not directly display the relationship between one physics concept and another.

Based on the results of this analysis, the most dominant factor causing misconceptions is the intrinsic factor that exists in the students themselves, namely the processing of knowledge that has been received and becomes new knowledge formed, so that mistakes in examining the initial concept will cause misconceptions.

Conclusion

The six-tier test instrument consists of six stages to identify students' misconceptions about wave material. This study found that text-type problems equipped with pictures and only requiring one step to get the correct answer will be more easily digested by students than calculation problems not equipped with pictures and require several steps to get the correct answer. Problems with pictures are preferred by students because they are more visualized compared to text-type problems. In addition, students understanding of concepts needs to be honed by getting students used to solving problems in the form of text problems that require a combination of several concepts to solve a problem so that students can get used to thinking critically about a more complex problem.

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Author Contributions

The authors in this research are divided into executor and advisor.

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Conflicts of Interest

The author declares no conflict of interest in this research.

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