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Diagnosing Students' Conception of Wave Propagation Using the Five-Tier Isomorphic Instrument

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Abstract: This research aims to develop and apply a five-tier isomorphic instrument to determine the concept of wave propagation. The research design in this study is a mixed method research design in development and implementation instrument. Quantitative data was collected on 151 students in class XII MIPA SMA Negeri 1 Jambi City using an isomorphic instrument in the form of a five-tier diagnostic test. The test instrument was first tested for validity and reliability. The validity performed includes content and construct validity. Content validity is determined based on the % False Positive (FP) and False Negative (FN), which must be <10%. Construct validity is carried out by calculating factor analysis. Meanwhile, reliability is determined based on Cronbach's Alpha coefficient with r table = 0.413 (significance level 5%). The research results show that the instrument is very valid and reliable. The average understanding of students' concepts in wave propagation material is classified in the low category because the percentage obtained is <30%, namely 16% in all four tiers. Most students' conceptions are in the category of lack of knowledge regarding wave propagation, with a percentage of 23.5%.

Keywords: Five-tier diagnostic test; Reliability; Student conception; Validity; Wave propagation

Introduction

Understanding concepts is the process of truly understanding a design or an abstract idea that allows someone to classify an object or event, and conceptual understanding is obtained through the learning process. Understanding concepts is very important in learning physics because physics is an applied science that is always related to natural phenomena that occur in everyday life or even the environment around us (Azahra & Wasis, 2023). Good conceptual understanding is the basis of good problem-solving abilities. Students with good problem-solving abilities will use their conceptual understanding to solve problems (Liu & Zhi et al., 2017). When students have conceptions that do not follow scientific concepts but are confident in their understanding, it can be said that they have a misconception (Maison et al., 2022; Sandra et al., 2022; Novianti et al., 2023). Therefore, it is necessary to analyze students' conceptual understanding to identify the types of misconceptions they experience. According to Yana et al. (2020), concept understanding analysis needs to be done to show the distribution of students' conceptual understanding, one of which is the concept of wave propagation.

Wave propagation is a natural phenomenon that plays a vital role in various aspects of science and technology. Waves are fundamental concepts in physics that have broad implications, ranging from electromagnetic waves, which include light and radio signals, to mechanical waves, such as water waves and sound. The concept of understanding wave material, which is suitable for wave material, will make it easier for students to learn other physics materials about sound, light, electricity, and magnetism (Ansyah et al., 2021). In addition, understanding waves such as mechanical waves will help students in advanced material on optics and quantum mechanics (Kameo et al., 2020; Warnock, 2019; Wittmann et al., 1999) as well

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as other scientific disciplines such as spectroscopy, seismology, meteorology, engineering and electronics (Kennedy & De Bruyn, 2011; Kryjevskaia et al., 2011; Rusilowati et al., 2022). This shows that students' understanding of wave material is fundamental, especially about wave propagation. This is because understanding concepts about how waves propagate and interact forms the basis of many fields of science, including physics, engineering, medicine, and astronomy.

In the last few decades, much educational research has been carried out that focuses on student conceptions and means to diagnose and improve them (Ansyah et al., 2021). Many research results show that students often have problems regarding conceptual understanding or misconceptions. One of them is research conducted by Widiyanto et al. (2018), which was carried out in class Darul 'Ulum Sumberpenganten Jogoroto Jombang in the Mechanical Waves material is included in the weak category with an average score of 64.6%, and experiencing misconceptions of 26.9%. One way to diagnose students ' understanding of concepts is by carrying out diagnostic tests (Andriani et al., 2021; Maison et al., 2022).

A diagnostic test is a test that can be used to find out precisely and ascertain the weaknesses and strengths of students in certain subjects. In this study, the diagnostic tests used were in the form of five tiers of diagnostics tests. The tiers diagnostics test is a five-tier diagnostic test that presents data about questions regarding understanding of concepts with five test tiers and provides reasons for a concept by providing an overview of the answers that have been selected (Bayuni et al., 2018; Haliza & Hadi, 2022). *Five-tier diagnostics The test* is one of the efforts to assist teachers in exploring deeper student understanding. This is because the first tier of *5 tier diagnostics test* contains the choice of answers to the questions, the second tier contains the level of confidence in the answers to the questions, the third tier contains the reasons for the answers at the first tier, the fourth tier contains the confidence level of the reasons for the answers at the third tier, and the fifth tier contains the sources from which students answered the first tier questions and third.

Based on observations made on high school students in Jambi, it was found that there were still many students who did not understand the concept of wave propagation. Meanwhile, little research still discusses and identifies students' conceptual understanding of the material to determine the level of conceptual understanding that students have, especially those who use the instrument. Five-tier isomorphic. Isomorphic instruments are a form of problem where one indicator or theme contains several questions that solve the same concept but have different forms of representation (Ningsari et al., 2021). Some problems are called isomorphic when the problem-solving uses the same physics concepts with the same problem-solving steps. This isomorphic instrument can also map students' abilities in understanding specific modes of representation and assess students' abilities in transferring what is learned from one context to another. Therefore, researchers researched to diagnose students' conceptual understanding of wave propagation material using a diagnostic test in the form of a five-tier isomorphic instrument.

This research is fundamental because waves are a fundamental concept in physics with broad applications in various aspects of daily life and technology. Understanding students' conceptions of wave propagation is critical to improving their learning in this area. First, by understanding common mistakes students make in understanding these concepts, teachers can develop more effective teaching strategies and design more relevant learning materials. Second, this research will provide valuable insights for developing physics education curricula to ensure students master these basic concepts. Third, this research can contribute to scientific research in physics education by expanding our understanding of how students learn and internalize physics concepts. Thus, this research significantly impacts improving the education system and the development of physical science.

The relevant research that examines the understanding of concepts in the form of a *five-tier* diagnostic test has been carried out by previous researchers with the title "Identification of Misconceptions and Their Causes Using the Five-Tier Fluid Static Test (5TFST) Instrument in Class XI High School Students". This research was conducted in one state school in Bandung City and two in Kuningan Regency, with 217 students participating. Based on the results of data processing, it is known that the Five-Tier Fluid Static Test (5TFST) instrument using the CDQ analysis technique can identify any misconceptions experienced by students and the causes of misconceptions that occur among students in static fluid material (Inggit et al., 2021). Furthermore, research was conducted by Maison et al. (2019) on identifying student misconceptions in business and energy materials. This research aims to discover the misconceptions experienced by 288 students in class. The research results show that, on average, students experience misconceptions about business and energy

materials, which is classified in the low category because the percentage obtained is <30%, namely 24%.

It is hoped that the results of this research will benefit teachers and students. For teachers, diagnostic tests are information that can be used to update the learning process, while for students, they can be used to improve the learning process. This research will focus on understanding students' wave propagation conceptions using the Five-Tier Isomorphic tool. Therefore, it is essential to carry out this research using the focus to diagnose students' conception of wave propagation using the five-tier isomorphic instrument, with the problem formulation how is the validity and reliability of the instrument on wave propagation material using a five-tier isomorphic instrument?; and how does the student conceive wave propagation material using an isomorphic five-tier instrument?

Method

The research design used is a mixed method research design in developing and implementing the instrument—subjects used as the population were students of SMA Negeri 1 Jambi City. Researchers used a *purposive sampling technique* in selecting the sample. *Purposive sampling* is a sampling technique with criteria determined by researchers based on specific considerations (Denieffe, 2020; Sugiyono, 2015). Sampling considerations depend on the needs of researchers regarding the research being conducted (Maharani & Bernard, 2018). The researcher took samples using a *purposive sampling* technique, considering that the samples used were students who had studied wave propagation material at SMA Negeri 1 Jambi City. Therefore, the samples were class XII IPA students at SMA Negeri 1 Jambi City, with a total sample of 151 students.

The flow in this research consists of several stages. (1) Preliminary stage, research begins by conducting literature studies and preliminary studies; (2) Instrument adaptation stage; (3) Data collection stage; (4) Quantitative data analysis stage; (5) Interpretation and conclusion drawing stage. The flow chart of the research carried out by researchers can be seen in Figure 1.

Data collection techniques in this research used tests, interviews, and documentation. The test used is an isomorphic diagnostic test instrument in a five-tier format. Interviews were conducted with several students who experienced low conception. Research data was obtained using documentation techniques, namely in the form of a list of names of students at SMA Negeri 1 Jambi City respondents to the research, test results, photo documentation at the time of implementation, and other supporting documents.

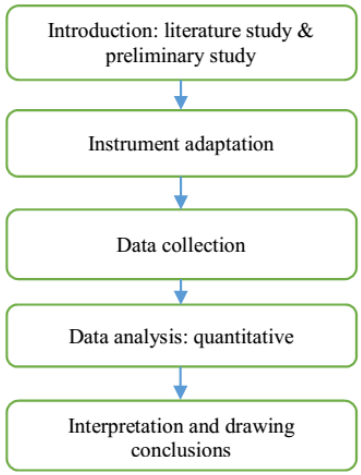

Figure 1. Flow chart of research conducted by researchers

This research uses an isomorphic instrument as a five-tier diagnostic test. The instrument in this research is a conceptual question about wave propagation, which consists of 8 multiple-choice questions with five tiers of answers. The first tier contains the content of the question-answer choices, the second tier contains the tier of confidence in the answer to the question, the third tier contains the reasons for the answer at the first tier, the fourth tier contains the level of confidence in the reasons for the answer at the third tier, and the fifth tier contains the sources from which students answer the tier questions. First and third. The question grid in this isomorphic instrument is presented in Table 1.

Table 1. Diagnostic Test Question Grid

Aspects that are measured	Number of Items	Question number
The propagation time of the two waves	4	1,2,7,8
Velocity of both waves	2	3,4
The distance between the two waves	2	5,6

Table 1 shows that the isomorphic wave instrument consists of 8 questions, divided into three aspects to be measured, namely in the first isomorphic measure of the propagation time of the two waves. The second isomorphic measures the speed of propagation of the two waves, and the third isomorphic measures the distance between the two waves.

The two requirements for a good instrument or measuring tool are to meet the validity and reliability values. An invalid or unreliable instrument will produce biased conclusions and provide inaccurate information about the subject's condition undergoing the test (Siyoto & Sodik, 2015). The instrument was validated first by 2 Physics lecturers at Jambi University. An instrument is

valid when it can reveal data from variables accurately without deviating from the actual situation. According to Gurel (2017), the validity of an instrument can be seen based on content and construct validity.

To determine the content validity of an instrument can be determined quantitatively by calculating the % of false positives (FP) and false negatives (FN) answers with Pers (Kirbulut & Geban, 2014). The FP answer is if the student answers the tier 1 question correctly and is sure of the answer but the reason is wrong. Meanwhile, the FN answer is if the student answers the wrong tier 1 question and is sure of the wrong answer but the reason is correct. Content validity is said to be fulfilled if the percentage of FP and FN is less than 10% (Hesthenes & Halloun, 1995). The percentage can be found using the following equation.

$$\%X = \frac{\sum x}{\sum item\ x\ \sum n}\ x\ 100\% \qquad (1)$$

With:
$\%X$ = Percentage of FP or FN, or LK
$\sum x$ = Number of FP or FB or LK categories
$\sum item$ = Number of question items developed
$\sum n$ = Number of students who were respondents

The students' conception level categories will be grouped based on the answers to the five-tier diagnostic test, namely those containing the first tier in the form of question-answer choices, the second tier is the confidence in answer to the first tier, the third tier is in the form of a choice of reasons for the selected answers in the first tier, the fourth tier is the level of confidence in the third tier of reasons is chosen, and the fifth tier contains the source of information obtained. Next, students' answers are grouped based on the description of the misconceptions that have been determined.

Apart from content validity, researchers also carried out construct validity. Construct validity is carried out by calculating factor analysis with the help of SPSS. In analyzing construct validity, it displays a scree plot and Rotated Component Matrix values. In the Rotate Component Matrix section, the construct validity value of an instrument is obtained. As for the categorization of instrument validity, it can be seen in Table 2.

Table 2. Validity Categories (Arikunto, 2015)

The value of r	Interpretation of validity
$0.80 < r_{xy} \leq 1.00$	Very high
$0.60 < r_{xy} \leq 0.80$	High
$0.40 < r_{xy} \leq 0.60$	Enough
$0.20 < r_{xy} \leq 0.40$	Low
$0.00 < r_{xy} \leq 0.20$	Very low

Furthermore, a reliability test was also carried out. Reliability is the level of constancy (consistency) of a test. A test is reliable if the test results show a determination. The analysis used to test the reliability in this study is using Cronbach Alpha contained in the SPSS application. The following table presents the interpretation of the reliability value.

Table 3. Interpretation of Reliability Value (Arikunto, 2014)

The magnitude of the reliability value	Interpretation
$0.80 < r_{11} \leq 1.00$	very high reliability
$0.60 < r_{11} \leq 0.80$	high reliability
$0.40 < r_{11} \leq 0.60$	moderate reliability
$0.20 < r_{11} \leq 0.40$	Low reliability
$-1.00 < r_{11} \leq 0.20$	Not reliable

After obtaining the results of the validity and reliability tests, the test instruments were ready to be tested on 151 students at SMAN 1 Jambi City. Next, quantitative data analysis was done by categorizing the percentage level of student understanding of concepts in wave propagation material. The category of students' conceptual understanding was adopted from research by Sari et al. (2017), presented in Table 4.

Table 4. Concept Understanding Category

Description	Category
$0 \leq x \leq 30\%$	Low
$30\% < x \leq 60\%$	Currently
$60\% < x \leq 100\%$	Tall

Result and Discussion

Validity criteria are obtained from 2 things: content validity and construct validity. The results of the validation of this instrument are shown in Table 4 and Table 5. The content validity of an instrument can be determined quantitatively by categorizing student answers into false positive (FP) and false negative (FN) categories. The content validity results are shown in Table 5, namely as follows.

Table 5. Number of FP and FN in Trial Results Data

Item	False positive (FP)	False negative (FN)
Item 1	3	4
Item 2	2	18
Item 3	6	5
Item 4	5	5
Item 5	3	2
Item 6	32	4
Item 7	11	9
Item 8	4	24
Amount	66	71
Percentage (%)	5.5	5.9

Based on Table 5, % FP and % FN from the isomorphic wave instrument data results obtained percentages of 5.5 and 5.9, respectively. Thus, the isomorphic wave instrument in a five-tier format has met the empirical content validity criteria because of % FP and % FN <10% (Yuanita & Suprapto, 2019). Next, the empirical validity of the construct is reviewed from the question items. Validity is determined using Product moment correlation. A question item is valid if r calculated (r calculated) is greater than r table (Arikunto, 2005). Based on the calculations that have been carried out, the calculated r-value is obtained for each question item as in Table 6.

Table 6. Construct Validity Test Results

Item	Components		
	1	2	3
Item 1	0.72		
Item 2	0.63		
Item 4	0.76		
Item 6	0.69		
Item 3		0.55	
Item 7		0.87	
Item 5			0.74
Item 8			0.74

Table 6 shows that the question items in group one are item 1, item 2, item 4, and item 6. The question items in group 2 are items 3 and 7. Meanwhile, the question items in group 3 are items 5 and 8. Because the grouping of loading values is based on absolute values, each is > 0.3, so it is declared valid. Next, the reliability test was carried out. Considering that the number of test students involved was 151, with a significance level of 5%, the value of r_{table} = 0.16 was obtained. The reliability results of the waveform isomorphic instrument with a five-tier format are presented in Table 7.

Table 7. Reliability Test Results

r_{hitung}	r_{table}	Criteria
0.55	0.159	Very high

Based on Table 7, it was found that the value of r_{count} > r_{table} so that the wave isomorphic instrument is very reliable (Arikunto, 2016). Given that the instrument is very valid and reliable, the results of the average percentage of students' correct scores will be obtained from this study. The following are the results of data analysis for the correct score, which are presented in Table 8.

Table 8. Results of the Average Percentage of Correct Scores for XII IPA Students at SMAN 1 Jambi City

	Item 1	Item 2	Item 3	Item 4	Item 5	Item 6	Item 7	Item 8	Mean
Only first tiers	14%	10%	29%	24%	3%	36%	39%	41%	24.5%
First third tiers	12%	9%	25%	21%	1%	15%	32%	38%	19%
All four tiers	10%	7%	20%	17%	1%	13%	26%	33%	16%

Based on the data in Table 8, it can be seen that class XII Science students at SMAN 1 Jambi City have different average percentages of correct answers for various levels of understanding. The percentage is 24.5% at the first tier, while at the first and third tiers, the percentage is 19%. Overall, the average correct score for all levels of understanding of the wave propagation concept was 16%. These results are further classified in the low concept understanding category because the percentage of concept understanding obtained is below 30%. If the data in Table 8 is presented in graphical form depicting the percentage of correct student answers at the first, first, and third tiers, and all tiers, then the results look like Figure 2.

As seen in Figure 2, the correct score sequence based on the highest percentage is at the first tier, followed by the first and third tiers, and lastly, the correct score for all tiers. The average correct score for the first tier of all item items is about 24.5%. The percentage of correct scores at the first tier is always higher because the instrument questions used are ordinary multiple-choice questions, and the level of student confidence in choosing an answer is not considered. Therefore, if a student answers correctly at the first tier, it does not necessarily indicate a strong understanding of the concept. The correct answer could have arisen from chance or the student's guess.

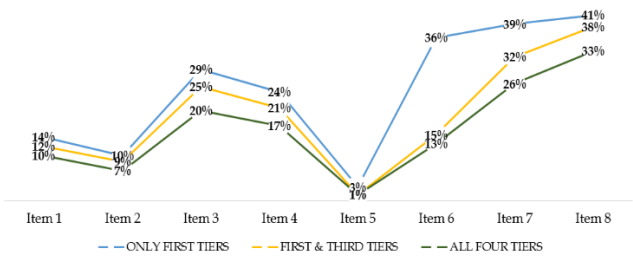

Figure 2. Graph of the average percentage of correct scores for XII IPA students

Furthermore, the percentage of correct scores for the first and third tiers is 19%, lower than that for the first. This happens because assessments are carried out at the first and third tiers by considering the answers and reasons students give. If the answer and reason are correct, the score given is 1. However, if there is a

combination of correct answers and wrong reasons, or vice versa, the score is 0. Furthermore, the percentage of correct scores for all tiers is 16%, lower than the previous tiers - first and third. This is because assessments at all tiers consider students' answers, reasons, and confidence levels in choosing answers and reasons. If the answer and reason are correct, and the student's confidence level is sure, then the score given is 1. However, if uncertainty or one of the four aspects is incorrect, the score is 0. The results of the percentage of false positives, false negatives, and LK are also presented in Table 9.

Table 9. Percentage of FP, FN, and LK in XII IPA Students at SMAN 1 Jambi City

	Item 1	Item 2	Item 3	Item 4	Item 5	Item 6	Item 7	Item 8	Mean
FP	2 %	1 %	4 %	3 %	2 %	21 %	7 %	3 %	5%
FN	3 %	12 %	3 %	3 %	1 %	3 %	6 %	16 %	8%
LK	15 %	32 %	20 %	20 %	21 %	23 %	20 %	21 %	23.5%

Description: FP= False positive; FN= False negative; and LK= Lack of knowledge

The student will be categorized as experiencing a false positive if, in answering the questions given, they answer with true and have confidence in the answer; their reasons are wrong, and they are sure to reason that. On the other hand, the false negative category is the opposite situation, i.e., it happens when student answers wrong and have confidence in the answers; however, their reasons given is correct, and they are sure to reason for that.

From the information in Table 9, it can be identified that the highest percentage of false positives is in question number 6, reaching 21%, while the lowest percentage is in question number 2, namely only 1%. The average percentage of false positives for all question items is 5%. On the other hand, the highest percentage of false negatives was in question number 8, namely 16%, while the lowest percentage of false negatives was in question number 5, namely 1%. The average false negative rate for all question items is 8%. Furthermore, for lack of knowledge, students had the highest percentage in question 2, 32%, and the lowest in question 1, 15%. The average percentage of lack of knowledge for all question items is 23.5%. Based on this analysis, it can be seen that the percentage of students who lack knowledge of wave propagation material is 23.5%.

As for the sources of information (tier 5) used by students in answering the test questions given, they are presented in Figure 3. Figure 3 shows that most students' sources of information in answering questions come from personal thoughts, namely 77%. Meanwhile, the rest comes from books, the internet, teacher explanations, observations, and from friends. Depending on several factors, information sources originating from personal thoughts can produce true or false information. First, limited individual knowledge can result in erroneous thinking if someone has an inaccurate or incomplete understanding of a topic. Additionally, personal biases held by individuals, influenced by their experiences, background, beliefs, and values, can influence how they analyze information, make conclusions, and lead them to errors in interpretation. Invalid sources of information can also be the reason for incorrect personal thinking if individuals refer to untrusted sources or incorrect information. Finally, differences in interpretation may cause different individuals to have different subjective views about the same information. Therefore, it is crucial always to verify, dig deeper, and use various sources of information to ensure the truth and accuracy of the information we receive. For more on wave propagation, the material is explained as follows.

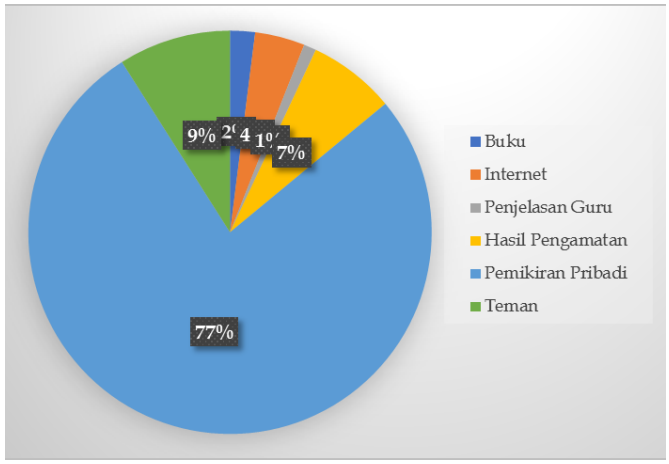

Figure 3. Pie chart of information sources of student answers (Tier 5)

Wave Propagation

The results presented above show that most students still do not understand the concept of wave propagation. One of the causes is students' lack of understanding of the equations or formulas for wave propagation. Many students memorize general equations without knowing their meaning. Memorizing the rules for counting operations without sufficient understanding only makes students unable to understand the concept. Just memorizing formulas for calculation operations will only increase the learning difficulty in wave propagation.

When children get used to memorizing general formulas, it might be easier to do math problems. This is because students are familiar with the exercise. When students are given concept questions, most will have difficulty because their understanding of the concept is low. The concept that students have is different from the actual concept. This is evident from the results obtained in Figure 2, showing that students' understanding of the concept is still low (Bakhri et al., 2023). In the instrument questions given, there are no calculation questions at all. They had difficulty working on concept questions compared to calculation questions.

The following questions measure students' understanding of concepts at SMAN 1 Jambi City, used on the five-tier isomorphic wave instrument.

Question 1

Tier 1.

Large and small stones are dropped at point P from the same height, as shown in Figure 4.

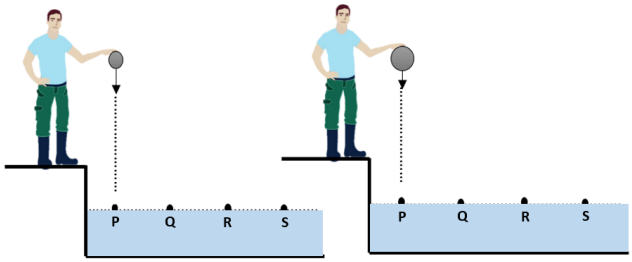

Figure 4

As a result, ripples are formed on the water surface at point P. What is the propagation time for the two types of waves to reach point Q?

a. Water surface waves from small stones take longer to reach Q
b. Water waves produced by larger stones take longer to reach Q.
c. The water waves generated by large and small stones require the same time
d. Another answer…

Tier 2.

Are you sure about your answer?

a. Certain
b. Not sure

Tier 3.

What is the reason for your answer?

a. The bigger or smaller the ripple does not affect the wave propagation time
b. The greater the ripple generated, the longer the wave propagates
c. The smaller the ripple generated, the longer the wave propagates
d. Other reason…

Tier 4.

Are you sure about your reasons?

a. Certain
b. Not sure

Tier 5.

The source of information you use to answer is...

a. Book
b. Internet
c. Teacher explanation
d. Observation result
e. Personal thoughts
f. Friend
g. Other…

In this first question, students' conceptions can vary based on the results of research involving 151 class XII Science students at SMAN 1 Jambi City. Found several conceptions described as follows:

Conception 1. A total of 91 students answered answer choice A) namely, "Water waves produced by small stones take longer." It was found that they answered option A because they thought that the size of the ripples produced by the rock would impact the wave propagation time. In their understanding, the bigger the ripple , the longer the wave will travel. Conception 2. 32 students chose answer B, namely, "Water waves produced by large rocks take longer." They had the conception that if a giant rock fell into the water, it would create larger ripples and, consequently, stronger waves. In their conception, larger waves would take longer to reach their destination. When students were asked about the origin/source of information for the answers and reasons, many answered that they used personal thoughts, friends, and the internet.

However, these conceptions are wrong misunderstandings about the propagation of water waves. Answers to options (A) and (B) are incorrect answers based on scientific conception. They may not understand that in the context of surface water waves, as explained in problem 1, the magnitude of the ripples or amplitude does not affect the wave propagation time. Other factors such as water depth, wavelength, and gravitational force influence the wave propagation time.

The correct answer to the question in question 1 is option (C), namely, the water waves produced by large stones and small stones require the same time to arrive at point Q. This is because the waves produced by both stones have a frequency, amplitude, and the same wavelength, so the propagation time is the same (Mufida et al., 2022; Farisi et al., 2023). A wave is a vibration that propagates; in its propagation, it carries energy (Agustho, 2021; Mapau, Helmi, & Haris, 2022). In other words, a wave is a vibration propagating from one place to another. The waves generated by the two stones have the same properties, so the propagation time is the same. Therefore, the correct answer is option (c).

From question number 1, as many as 14% of students were able to answer correctly in tier 1. However, when reviewed based on tier 1 and tier 3 (answers and reasons), the percentage of students who could answer both correctly decreased to 12%. When reviewed based on the entire tier (All four tiers), the percentage of students who answered correctly was only 10%. Therefore, educators need to provide clear and concrete explanations of this concept to students so that they correctly understand the working principles of water waves and avoid misunderstandings like this in the future.

The following is the second question used to measure student understanding using the isomorphic wave instrument in a five-tier format presented in Table 10.

Question 2

Tier 1.

A stone is dropped on the surface of the water (point P) from height A, then the same stone is dropped again from a higher place (height B), as shown in Figure 5.

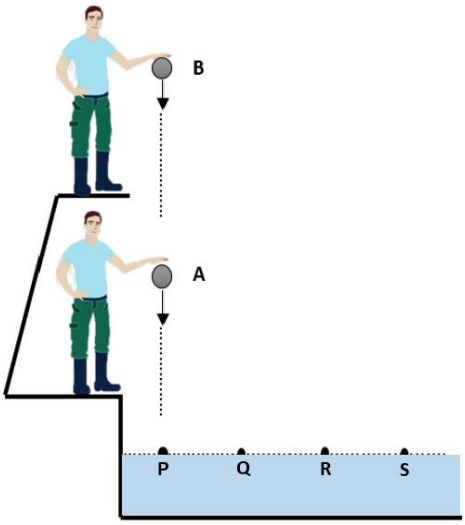

Figure 5

What is the propagation time for the two types of waves from point P to point Q?

a. Water waves caused by stones dropped from a lower place (point A) take more extended
b. Waves of water caused by rocks dropped from a higher place (point B) take longer
c. Water waves from rocks dropped at different heights take the same time to arrive at point Q.
d. Another answer…

Tier 2.

Are you sure about your answer?

a. Certain
b. Not sure

Tier 3.

What is the reason for your answer?

a. Smaller wave ripples have a minor propagation speed
b. . d
c. More giant wave ripples have a minor propagation speed
d. . d
e. The size of the ripples does not affect the speed of the waves, reason …

Tier 4.

Are you sure about your reasons?

a. Certain
b. Not sure

Tier 5.

The source of information you used to answer is…

a. book
b. Internet
c. Teacher explanation
d. Observation result
e. Personal thoughts
f. Friend
g. Other…

In this first question , students' conceptions can vary based on the results of research involving 151 class XII Science students at SMAN 1 Jambi City. Found several conceptions described as follows:

Conception 1. A total of 78 students answered answer choice A), namely "Water waves caused by stones dropped from a lower place (point A) take longer," because many of them thought that smaller wave ripples, such as those produced by stones which fall from a lower place, will have a lower propagation speed. This is due to their conception that smaller ripples will create waves that are weaker or slower in propagation. They also think that the height or low of a falling object will affect the size of the ripples produced, so they think that rocks from a lower height will create smaller ripples.

Conception 1. A total of 58 students chose answer option B, namely "Water waves caused by stones dropped from a higher place (point B) take longer," because most of them thought that more giant wave ripples, such as those produced by A rock that falls from a higher place will have a smaller propagation speed. In this understanding, they think larger waves will take longer to reach point Q because they are bigger or stronger. The conception underlying this answer is that the high or low level of the place where a rock is dropped will directly influence the size of the resulting ripple so that rock from a higher height is thought to create more giant ripples and, therefore, take more time to propagate.

However, this understanding is wrong in the context of wave propagation; the correct answer to the question in problem 2 is option (C), namely, "Water waves from stones dropped at different heights require the same time to arrive at point Q." This is because the size of the ripple does not affect the speed of wave propagation. A wave is a vibration that propagates; in its propagation, waves carry energy. In the context of this question, the propagation time of waves from point P to point Q is the same because the waves produced by both stones have the same frequency, amplitude, and wavelength.

From question number 2, as many as 10% of students could answer correctly at tier 1. However, when reviewed based on tier 1 and tier 3 (answers and reasons), the percentage of students who could answer both correctly decreased to 9%. When reviewed based on all tiers (All four tiers), the percentage of students who answered correctly was only 7%. Therefore, to properly understand the basic principles of waves, educators need to provide clear and concrete explanations to students so that they do not have this kind of misunderstanding in the future.

According to the view of misconception theory, students fail to explain physical phenomena because they have wrong knowledge or do not comply with expert agreement (Taqwa & Pilendia, 2018). The knowledge is continuously used to explain phenomena and solve problems. The only way to reduce or eliminate student misconceptions is to replace existing knowledge with new, correct knowledge. Moreover, this tends to be difficult because students' misconceptions tend to be retained and challenging to eliminate, especially if they provide information verbally. Sometimes, students who experience misconceptions and are given the correct knowledge within a period will return to using their incorrect knowledge.

Questions 1 and 2 are forms of isomorphic instrument questions. Isomorphic instruments are a form of problem where one indicator or theme contains several questions that solve the same concept but have different forms of representation (Ningsari et al., 2021). Some problems are called isomorphic when the problem-solving uses the same physics concepts with the same problem-solving steps. The isomorphic concept in the two problems above is that the waves produced by two rocks or from different heights have the same properties, so the propagation time is the same. Some of the sub-concepts studied in this wave isomorphic instrument are:

Wave Propagation Time

Water wave propagation time is required for a wave to propagate from one point to another on the water surface. The concept of wave propagation speed on the water surface is associated with wavelength, frequency, and amplitude (Zhang & Ba, 2021). The speed of wave propagation is the distance traveled by the wave per unit time. The relationship between the propagation time of water waves and wave ripples is that the larger the wave ripples, the faster the waves propagate. Meanwhile, the relationship between the propagation time of water waves and the wave propagation speed is that the greater the wave propagation speed, the faster the wave propagates (Zhang & Ba, 2021).

Several factors, such as water depth, water surface conditions, and wind speed, can influence wave propagation speed on the water surface. At the same water depth, waves propagate faster on a smoother surface than wavy water (Malau, 2018). In addition, wave energy can also affect wave propagation speed. Waves with high energy will travel faster than waves with low energy.

Wave Propagation Speed

The speed of water waves is a physical quantity that measures wave propagation speed in a particular medium, such as water (Basu, 2017). This concept is the same as speed in rectilinear motion kinematics, but there is another quantity called wavelength in propagation speed. The speed of propagation of water waves can be influenced by the physical properties of the medium, such as density, viscosity, and Young's modulus. The relationship between the speed of water waves and wave ripple is that the greater the wave ripple, the faster the wave propagates. Meanwhile, the relationship between the speed of water waves and energy is that the greater the wave energy, the faster the wave propagates.

Wave energy can affect the propagation speed of water waves. Waves with considerable energy will propagate faster than waves with small energy. In addition, the speed of water waves can be found from the distance traveled divided by time or wavelength. Water wave propagation speed is crucial in understanding tsunamis, waves, and water ripples. By understanding this concept, we can predict the speed and arrival time of a water wave somewhere so we can take appropriate action to reduce the impact of the water wave phenomenon.

In addition to the fast propagation of water waves, there is also the fast propagation of sound waves. Sound wave propagation is the speed of sound wave propagation in a particular medium, such as air or water. This concept can be measured using the formula $v = f\lambda$, where v is the propagation speed, f is the frequency, and λ is the wavelength (Desstya et al.,

2020). The relationship between the speed of propagation of sound waves and the loudness of the sound is that the faster the sound wave propagates, the louder the sound produced. Meanwhile, the relationship between the speed of propagation of sound waves and frequency is that the greater the sound frequency, the faster the sound waves propagate. The factors that affect the speed of sound waves are the type of medium, temperature, and pressure. The propagation speed of sound waves will be faster in a denser medium, such as metal, than in a more dilute medium, such as air. Also, temperature and pressure can affect the speed of sound wave propagation. At a higher temperature, the molecules in the medium will move faster, so the speed of sound wave propagation will be faster. Meanwhile, at higher pressure, the molecules in the medium will be denser, so the speed of sound wave propagation will also be faster.

Investigations involving students' conceptions of waves are valuable because wave phenomena are ubiquitous, and wave-related ideas have parallels in physics and other fields (Caleon & Subramaniam, 2010; Kosim et al., 2019). Many students find the concept of waves challenging to understand because waves exhibit various counterintuitive properties. Previous research on students' conceptions of waves shows that students often apply object-based reasoning when dealing with waves, especially regarding sounds (Michael et al., 2002).

Many research results show that students often have problems regarding conceptual understanding or misconceptions. One is research conducted by Maison et al. (2019) regarding identifying student misconceptions in business and energy material. This research uses a four-tier diagnostic test instrument to discover the misconceptions experienced by class XI MIA students at SMAN 8 Jambi City regarding business and energy materials. The research results show that, on average, students experience misconceptions about business and energy materials, which is classified in the low category because the percentage obtained is <30%, namely 24%. Apart from that, there was also research conducted by Widiyanto et al. (2018), which was carried out on class Darul 'Ulum Sumber penganten Jogoroto Jombang in the Mechanical Waves material is included in the weak category with an average score of 64.6%, and experiencing misconceptions of 26.9%.

The novelty of the research is the application of the Five-Tier Isomorphic tool in diagnosing students' understanding of wave propagation material. This tool is an innovative and different method to identify students' conceptual misconceptions in physics, especially wave propagation (Mirza et al., 2022). This novelty is essential because the Five-Tier Isomorphic tool provides a more comprehensive approach and an organized structure for exploring students' understanding, thus helping teachers and researchers better understand where the difficulties lie in understanding physics concepts (Jamaluddin et al., 2018). Using this tool, this research significantly improves the quality of teaching physics. It helps students better understand the concept of waves, which can pave the way toward a deeper understanding of scientific concepts at a higher level.

This study highlights the importance of the Five-Tier Isomorphic tool in diagnosing students' understanding of wave propagation. The first recommendation given by the researcher is to adopt this tool in teaching and further research in identifying students' conceptual misunderstandings. The results of this research also show that there are misunderstandings in students' understanding of wave propagation. Therefore, it is recommended that teaching materials be developed better, emphasizing concepts that may be difficult to understand. Training teachers in using the Five-Tier Isomorphic tool and overcoming student misunderstandings are priorities so teachers can provide effective feedback to students during learning. Additionally, this study encourages further research to explore the potential of this tool in the broader context of education and other scientific concepts to improve teaching and assessment methods in science education as a whole (Bakhri et al., 2023). By implementing these recommendations, students' understanding of wave propagation and other scientific concepts is hoped to be significantly improved.

Conclusion

Based on the research results, it can be concluded that the five-tier format isomorphic wave instrument can be declared valid and reliable with eight questions. This instrument has met content validity with a percentage below 10%, and construct validity obtained with a loading value above 0.3 means all items are valid. The reliability value of the five-tier diagnostic test instrument on wave material is 0.555 in the very high category. Furthermore, the overall understanding of the concepts experienced by students in class is still low.

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Author Contributions
Collecting data, analyzed, and wrote the initial draft of the article, R. F; conceptualization, methodology, designing isomorphic instruments in a five-tier format, validation, writing-review, and editing, M; formal analysis and supervision, A and S. P; supervision and project administration, R. A. All authors have read and agreed to the published version of the manuscript.

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Conflicts of Interest
The authors declare no conflict of interest.

References

Agustho, A. (2021). Development of Student Worksheet Based on Ttw Learning Model To Improve Student's Communication and Observation. *Jurnal Penelitian Pendidikan IPA*, *9*(8), 6255–6264. https://doi.org/10.29303/jppipa.v9i8.4651

Andriani, D. W., Munawaroh, F., Qomaria, N., & Ahied, M. (2021). Profil Miskonsepsi Peserta Didik Berbasis Taksonomi Bloom Revisi Pada Materi Ipa Konsep Tekanan Zat. *Natural Science Education Research*, *4*(1), 19–27. https://doi.org/10.21107/nser.v4i1.8400

Ansyah, T. A., Kusairi, S., Supriana, E., & Ibad, M. I. (2021). Profil Miskonsepsi Siswa SMA pada Materi Gelombang Mekanik. *Jurnal Pendidikan: Teori, Penelitian, Dan Pengembangan*, *6*(10), 1551–1557. Retrieved from http://journal.um.ac.id/index.php/jptpp/article/view/15049

Azahra, A. P., & Wasis. (2023). Pengembangan , Uji Validitas , Dan Uji Reliabilitas Instrumen Tes. *Jurnal Riset Rumpun Matematika Dan Ilmu Pengetahuan Alam (JURRIMIPA)*, *2*(2), 196–207. https://doi.org/10.55606/jurrimipa.v2i2.1556

Bakhri, S., Tsuroya, N. H., & Pratama, Y. (2023). Development of Learning Media with QuickAppNinja Android-Based (Guess Image & Find Words) to Increase Elementary School Teachers ' Digital Literacy. *Jurnal Penelitian Pendidikan IPA*, *9*(7), 4879–4884. https://doi.org/10.29303/jppipa.v9i7.3574

Basu, B. (2017). On the existence of two-dimensional irrotational water waves over finite depth with uniform current. *Applicable Analysis*, *6811*(10), 1–10. https://doi.org/10.1080/00036811.2017.1376321

Bayuni, T. C., Sopandi, W., & Sujana, A. (2018). Identification misconception of primary school teacher education students in changes of matters using a five-tier diagnostic test. *Journal of Physics: Conference Series*, *1013*(1), 1–7. https://doi.org/10.1088/1742-6596/1013/1/012086

Caleon, I., & Subramaniam, R. (2010). Development and application of a three-tier diagnostic test to assess secondary students' understanding of waves. *International Journal of Science Education*, *32*(7), 939–961. https://doi.org/10.1080/09500690902890130

Denieffe, S. (2020). Commentary: Purposive sampling: complex or simple? Research case examples. *Journal of Research in Nursing*, *25*(8), 662–663. https://doi.org/10.1177/1744987120928156

Desstya, A., Yanti, F. A., & Saputro, A. D. (2020). Miskonsepsi guru sekolah dasar pada konsep bunyi. *AL-ASASIYYA: Journal Of Basic Education*, *4*(2), 13. https://doi.org/10.24269/ajbe.v4i2.2342

Farisi, A., Evendi, E., Halim, A., Syukri, M., & Elisa, E. (2023). Implementing Argumentation-Based Problem-Based Learning Models to Improve Critical Thinking Skills in Vibration and Wave Material. *Jurnal Penelitian Pendidikan IPA*, *9*(2), 609–612. https://doi.org/10.29303/jppipa.v9i2.2716

Haliza, S. N., & Hadi, W. P. (2022). Analisis Miskonsepsi Siswa Pada Materi Getaran, Gelombang, Dan Bunyi. *Science Education National Conference*, 132–139. Retrieved from https://journal.trunojoyo.ac.id/nser/article/view/17821/7512

Hestenes, D., & Halloun, I. (1995). Interpreting the force concept inventory: A response to March 1995 critique by Huffman and Heller. *The Physics Teacher*, *33*(8), 502–502. https://doi.org/10.1119/1.2344278

Inggit, S. M., Liliawati, W., & Suryana, I. (2021). Identifikasi Miskonsepsi dan Penyebabnya Menggunakan Instrumen Five-Tier Fluid Static Test (5TFST) pada Peserta Didik Kelas XI Sekolah Menengah Atas. *Journal of Teaching and Learning Physics*, *6*(1), 49–68. https://doi.org/10.15575/jotalp.v6i1.11016

Jamaluddin, Ramdani, A., & Setiadi, D. (2018). Development of Learning Device of Empowerment Through Thinking Natural Science Learning in Elementary School. *Jurnal Penelitian Pendidikan IPA*, *4*(1), 5–20. https://doi.org/10.29303/jppipa.v4i1.96

Kameo, W., Handayanto, S. K., & Taufiq, A. (2020). Eksplorasi penguasaan konsep gelombang mekanik mahasiswa pendidikan Fisika tahun pertama semester genap Universitas Nusa Cendana Kupang. *Jurnal Riset Pendidikan Fisika*, *5*(1), 46–52. Retrieved from http://journal2.um.ac.id/index.php/jrpf/

Kennedy, E. M., & De Bruyn, J. R. (2011). Understanding

of mechanical waves among second-year physics majors. *Canadian Journal of Physics*, *89*(11), 1155–1161. https://doi.org/10.1139/p11-113

Kirbulut, Z. D., & Geban, O. (2014). Using three-tier diagnostic test to assess students' misconceptions of states of matter. *Eurasia Journal of Mathematics, Science and Technology Education*, *10*(5), 509–521. https://doi.org/10.12973/eurasia.2014.1128a

Kosim, K., Hikmawati, H., & Mahrus, M. (2019). Analisis Kemampuan Kreativitas Mahasiswa Fisika Fkip Unram Dengan Berbantuan Multireprensentasi Design Tes Dalam Penguasaan Materi Gelombang Dan Optik. *Jurnal Penelitian Pendidikan IPA*, *5*(1), 78–82. https://doi.org/10.29303/jppipa.v5i1.203

Kryjevskaia, M., Stetzer, M. R., & Heron, P. R. L. (2011). Student understanding of wave behavior at a boundary: The limiting case of reflection at fixed and free ends. *American Journal of Physics*, *79*(5), 508–516. https://doi.org/10.1119/1.3560430

Liu, Z., Zhi, R., Hicks, A., & Barnes, T. (2017). Understanding problem solving behavior of 6 – 8 graders in a debugging game. *Computer Science Education*, *3408*(April), 1–29. https://doi.org/10.1080/08993408.2017.1308651

Maharani, S., & Bernard, M. (2018). Analisis Hubungan Resiliensi Matematik Terhadap Kemampuan Pemecahan Masalah Siswa pada Materi Lingkaran. *JPMI (Jurnal Pembelajaran Matematika Inovatif)*, *1*(5), 819–826. https://doi.org/10.22460/jpmi.v1i5.p819-826

Maison, Hidayat, M., Kurniawan, D. A., Sandra, R. O., Yolviansyah, F., & Iqbal, M. (2022). Misconception Tool: Web-Based Assessment of Buoyancy Materials. *Journal of Education Technology*, *6*(2), 237–246. Retrieved from https://dx.doi.org/10.23887/jet.v

Maison, M., Hidayat, M., Kurniawan, D. A., Yolviansyah, F., Sandra, R. O., & Iqbal, M. (2022). How Critical Thinking Skills Influence Misconception in Electric Field. *International Journal of Educational Methodology*, *8*(2), 377–390. https://doi.org/10.12973/ijem.8.2.377

Maison, M., Lestari, N., & Widaningtyas, A. (2019). Identifikasi Miskonsepsi Siswa Pada Materi Usaha Dan Energi. *Jurnal Penelitian Pendidikan IPA*, *6*(1), 32–39. https://doi.org/10.29303/jppipa.v6i1.314

Malau, N. D. (2018). *Modul Fisika Gelombang*. Retrieved from http://repository.uki.ac.id/2645/1/ModulFisgel.pdf

Mapau, O. B., Helmi, H., & Haris, A. (2022). Analisis Penguasaan Konsep Gelombang Peserta Didik Man 2 Kota Makassar Di Masa Pandemi Covid-19. *Jurnal Sains Dan Pendidikan Fisika*, *18*(3), 277. https://doi.org/10.35580/jspf.v18i3.31480

Mirza, M., Irwandi, I., & Safitri, R. (2022). Development of Sound Wave Resonance Props for Understanding the Phenomenon of Stationary Waves Using an ISLE-Based STEM Approach Model in Supporting Transformation Education. *Jurnal Penelitian Pendidikan IPA*, *8*(5), 2341–2349. https://doi.org/10.29303/jppipa.v8i5.1484

Mufida, S. N., Kaniawati, I., Samsudin, A., & Suhendi, E. (2022). Developing MOFI on Transverse Wave to Explore Students' Misconceptions Today: Utilizing Rasch Model Analysis. *Jurnal Penelitian Pendidikan IPA*, *8*(5), 2499–2507. https://doi.org/10.29303/jppipa.v8i5.2229

Ningsari, I. S., Zainuddin, A., & Setyarsih, W. (2021). Kajian Literatur Instrumen Isomorfik Sebagai Asesmen Pembelajaran Fisika. *ORBITA: Jurnal Kajian, Inovasi Dan Aplikasi Pendidikan Fisika*, *7*(1), 54. https://doi.org/10.31764/orbita.v7i1.4407

Novianti, R., Aisyah, W. N., & Sukmawati, W. (2023). Analysis of Student's Answer Error on Understanding of Energy Concept in Conceptual Change Text (CCT)-Based Learning. *Jurnal Penelitian Pendidikan IPA*, *9*(2), 505–508. https://doi.org/10.29303/jppipa.v9i2.2049

Rusilowati, A., Negoro, R. A., Subali, B., & Aji, M. P. (2022). Evaluating ICT literacy: Physics ICT test based on Scratch Programming for high school students. *Research and Evaluation in Education*, *8*(2), 169–180. https://doi.org/10.21831/reid.v8i2.49093

Sandra, R. O., Maison, M., & Kurniawan, D. A. (2022). Pengembangan Instrument Miskonsepsi Menggunakan Dreamweaver Berbasis Web Pada Materi Tekanan Berformat Five-Tier. *Jurnal Fisika: Fisika Sains Dan Aplikasinya*, *7*(1), 22–28. Retrieved from https://ejurnal.undana.ac.id/index.php/FISA/article/view/6575

Sari, W. P., Suyanto, E., & Suana, W. (2017). Analisis Pemahaman Konsep Vektor pada Siswa Sekolah Menengah Atas. *Jurnal Ilmiah Pendidikan Fisika Al-Biruni*, *6*(2), 159–168. https://doi.org/10.24042/jipfalbiruni.v6i2.1743

Sugiyono. (2015). *Metode Penelitian dan Pengembangan*. Bndung: Alfabeta. Retrieved from https://opac.perpusnas.go.id/DetailOpac.aspx?id=996885

Taqwa, M. R. A., & Pilendia, D. (2018). Kekeliruan Memahami Konsep Gaya , Apakah Pasti Miskonsepsi ? *Jurnal Inovasi Pendidikan Fisika Dan Integrasinya*, *1*(2), 1–8. Retrieved from https://www.researchgate.net/publication/327955149

Warnock, R. (2019). On the propagation of electrodynamic waves along a wire by A. Sommerfeld. *Electromagnetics*, *39*(5), 281–324. https://doi.org/10.1080/02726343.2019.1619235

Widiyanto, A., Sujarwanto, E., & Prihaningtiyas, S. (2018). Analisis pemahaman konsep peserta didik dengan instrumen. *Prosiding Seminar Nasional Multidisiplin*, (September), 138–146. https://doi.org/10.35580/jspf.v18i3.31480

Wittmann, M C, Steinberg, R. N., & Redish, E. F. (1999). Making Sense of How Students Make Sense of Mechanical Waves. *The Physics Teacher*, *37*(1), 15–21. https://doi.org/10.1119/1.880142

Wittmann, & Michael C. (2002). The object coordination class applied to wave pulses: Analysing student reasoning in wave physics. *International Journal of Science Education*, *24*(1), 97–118. https://doi.org/10.1080/09500690110066944

Yana, A. U., Antasari, L., & Kurniawan, B. R. (2020). Analisis Pemahaman Konsep Gelombang Mekanik Melalui Aplikasi Online Quizizz. *Jurnal Pendidikan Sains Indonesia*, *7*(2), 143–152. https://doi.org/10.24815/jpsi.v7i2.14284

Zhang, L., & Ba, J. (2021). Wave Propagation in Infinituple-Porosity Media Journal of Geophysical Research : Solid Earth. *Journal of Geophysical Research: Solid Earth*, *126*, 1–19. https://doi.org/10.1029/2020JB021266