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Analyzing Misconceptions Using Four-tier Test on the Topic of Vibration: A Survey of Pre-service Science Teachers

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Abstract

Vibration is one of the essential topics in science education. Pre-service science teachers still often experience difficulties in learning this topic. There are several previous studies related to misconceptions on the topic of vibration. However, research on misconceptions in pre-service science teachers is still limited. This study aimed to analyze pre-service science teachers' misconceptions on the topic of vibration. This research uses a quantitative approach with a survey method. The research instruments include a four-tier test and interviews. The participants in this study consist of 96 pre-service science teachers from a university in Bandung, Indonesia. The results of the analysis showed that pre-service science teachers who had Scientific Knowledge were 31.1%, lack of knowledge 26.9%, misconception 8.0%, false positive 1.8%, and false negative 2.2%. The most common misconception found relates to the relationship between frequency and mass. The perception of pre-service science teachers regarding the four-tier test questions is very easy 0%, easy 6.7%, neutral 36.7%, difficult 53.3%, and very difficult 3.3%. The findings show that many pre-service science teachers still have misconceptions about the topic of vibration so lecturers should strengthen the concepts of Fundamental Physics first before students take advanced Physics courses.

How to Cite

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INTRODUCTION

A deep understanding of concepts is crucial in science learning, especially in physics, as it helps students connect prior knowledge with new concepts (Guerra-Reyes et al., 2024; Solís-Pinilla & Merino-Rubilar, 2024). Science education aims to develop conceptual mastery, analytical thinking, and problem-solving skills (Batlolona et al., 2023; Zou et al., 2024). However, educators often encounter pre-service teachers with misconceptions—alternative or naive concepts that diverge from scientifically accepted knowledge (Lansangan & Caballes, 2023). These misunderstandings, shaped by prior experiences, can hinder accurate scientific comprehension (Jusnar et al., 2020; Milovanovic et al., 2022).

Misconceptions arise when students or pre-service teachers misinterpret or incorrectly link concepts, leading to misunderstandings that deviate from scientific truth (Boshuizen & Marambe, 2020; Habiddin et al. 2022; Panggabean et al., 2023). These errors, often caused by a failure to grasp hierarchical relationships between concepts, hinder further learning as individuals mistakenly believe their misconceptions to be correct. In physics education, misconceptions are flawed understandings that contradict scientific knowledge, often stemming from personal experiences or inaccurate information. These misconceptions create barriers to learning, as students persist in incorrect beliefs, making it difficult to grasp accurate concepts (Çelikkanlı & Kızılcık, 2022; Resbiantoro et al., 2022; Ristanto et al., 2023). Such misunderstandings go beyond minor errors, reflecting deeper misconceptions that systematically oppose scientific principles and hinder future learning (Suprapto, 2020; Vu et al., 2022).

In a constructivist approach to learning, students' prior knowledge is considered a crucial foundation for building further learning, as students are actively involved in linking what they already know to new information (Güne, 2020; Hasanuddin, 2020). However, this prior knowledge is often shaped by misconceptions—incorrect or flawed understandings that can obstruct students from constructing accurate concepts about certain phenomena. Misconceptions are more challenging to address than knowledge gaps, as students may not recognize that their understanding is incorrect and are inclined to maintain it (Manurung et al., 2020; Zhang et al., 2019). In fact, having misconceptions is considered more detrimental than having no knowledge of a topic at all because ingrained misunderstandings tend to be more persistent and restrict the learning process (Resbiantoro, 2022). Therefore, its crucial to identify and address misconceptions early on to ensure effective learning and facilitate students in developing a more accurate understanding consistent with scientific concepts (Ribi et al., 2024).

Physics is fundamental science that studies natural phenomena by analyzing underlying basic concepts. Research shown that students' understanding of various phenomena often contradicts well-established scientific knowledge. Misconceptions in physics present a significant challenge for educators. Various factors, including language barriers, cultural influences, and students' prior understanding, contribute to the emergence of these misconceptions (Kotsis, 2023; Kotsis, 2024). Misconceptions are considered one of the primary causes affecting students' performance in physics education (Chala et al., 2020).

The concept of vibration and waves is a common source of misconceptions and is crucial for understanding wave mechanics (Wiyoko & Hidayat, 2020). Research has identified misconceptions in various contexts, including vibration, waves, and sound (Ginting & Siregar, 2022; Makhrus et al., 2023; Negoro & Karina, 2019). Addressing these misconceptions is essential, as unresolved misunderstandings can hinder students' overall comprehension of physics (Hamdani, 2024; Munggarani et al., 2019).

Many students still face misconceptions about vibration and waves in physics education (Haerunnisa et al., 2022; Saprudin et al., 2023). Various studies have uncovered misunderstandings among students regarding these concepts, including vibration and waves (Ginting & Siregar, 2022; Makhrus et al., 2023; Rosa & Widiawati, 2022), vibration, waves, and sound (Negoro & Karina, 2019; Sari et al., 2024), as well as specific aspects of the concept of vibration (Hamdani, 2024; Munggarani et al., 2019; Nuriyah et al., 2024). However, research specifically exploring misconceptions among pre-service science teachers on the topic of vibration remains quite limited. This suggests that, although many studies on misconceptions in this area focus on students, little attention has been given to pre-service science teachers' understanding of vibration.

This study analyzes their understanding, as diagnosing misconceptions is crucial in educational research (Maisyaroh et al., 2022; Pulu & Amahoru, 2023). Identifying these misconceptions provides research-based insights into learning difficulties, helping educators design effective strategies for conceptual change (Chen et al., 2020; Adhim et al., 2021; Imaduddin et al., 2023). Early diagnosis prevents the accumulati-

on of incorrect concepts with long-term negative impacts (Grospietsch & Mayer, 2018; Imaduddin et al., 2023). Various methods have been developed, including drawing techniques (Koomson & Owusu-Fordjour, 2018; Nugraha, 2018), concept maps (Respasari et al., 2022), refutation texts (Mufida et al., 2023), conceptual conflict strategies, inquiry-based learning with the Conceptual Change Model (CCM), schema training, and diagnostic tests (Yang et al., 2022). Among these, diagnostic tests are vital for identifying misconceptions, analyzing error patterns, and understanding students' thought processes, enabling targeted interventions for more effective teaching.

This study offers several distinct advantages. First, it specifically concentrates on the topic of vibration, unlike previous research that has covered broader topics such as vibration, waves, and sound. By narrowing its focus to vibration, this study seeks to gain a deeper understanding of the misconceptions held by pre-service science teachers. Second, this study introduces a four-tier diagnostic test, which is an innovative approach compared to the more commonly used three-tier tests in prior studies. Third, the focus of this study is on identifying misconceptions among pre-service science teachers, whereas earlier studies have primarily targeted junior and senior high school students. This study makes a valuable contribution to science education by providing detailed insights into the misconceptions that pre-service science teachers often have about vibration. The findings from this research will play a vital role in developing more effective teaching materials and improving instruction in this area. Consequently, the researcher has opted to use a four-tier test to assess pre-service science teachers' understanding of vibration. This study aims to answer questions:

1. What is the level of understanding of pre-service science teachers regarding the topic of vibration?
2. What are the most common misconceptions found among pre-service science teachers regarding the topic of vibration?

METHOD

Research Design

This research employs a quantitative design with a survey method, where a survey is administered to a sample or population to assess their attitudes, opinions, behaviors, or characteristics without any intervention (Creswell & Creswell, 2018). The primary objective of the study is to evaluate the understanding of pre-service science teachers on the topic of vibration. No interventions are made in the study; instead, the researcher reports the students' concepts as they are. Data is collected using a cross-sectional survey design at a particular moment in time (Creswell & Creswell, 2018).

Participants

The participants in this study were pre-service science teachers who had previously studied the topic of vibration in the Fundamentals of Physics course. The research was conducted at a university in Bandung, Indonesia, with a total of 96 pre-service science teachers involved. Among the participants, 90 were female (93.8%) and 6 were male (6.2%), reflecting a higher proportion of female students in the science education program. The participants, aged between 17 and 22 years, were selected through convenience sampling, based on their availability.

Research Instrument

In this study, data were collected using a four-tier diagnostic test on the concept of vibration and alongside an interview tool. The development of the four-tier diagnostic test was informed by several previous studies. This test is specifically intended to assess the understanding of pre-service science teachers on the topic of vibration and consists of 10 sets of questions. The concepts questions of vibration can be seen in Table 1.

Table 1. Concepts of Questions in Vibration Topic

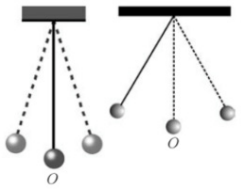
No	Concepts
1	The relationship between frequency and period
2	The relationship between period and string length
3	The relationship between frequency and string length
4	The relationship between period and angle of displacement
5	The relationship between the number of vibrations and string length
6	The relationship between period and mass of the object
7	The relationship between frequency and mass of the object
8	The concept of vibration
9	The concept of vibration
10	The relationship between period, number of vibrations, and time

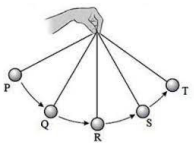
The content validity of the test was evaluated by examining the likelihood of false negatives and false positives, along with expert assessment. According to Kaltakci-Gurel & Eryılmaz (2017) and Weber-Wulff et al. (2023), a false negative occurs when someone has the correct understanding but gives an incorrect answer, while a false positive happens when someone has an incorrect understanding but provides a correct answer. It is advised that the probability of both errors be kept under 10%. In this study, the false negative and false positive rates for the vibration misconception test were 1.8% and 2.2%, respectively.

The reliability of the four-tier instrument was evaluated using two approaches. First, the reliability for correct responses and corresponding confidence levels yielded a Cronbach's Alpha of 0.810, confirming its validity in measuring scientific knowledge of vibrations. Second, reliability for incorrect responses and confidence levels resulted in a Cronbach's Alpha of 0.926, demonstrating its effectiveness in identifying misconceptions.

Expert feedback was sought to ensure the accuracy of the test items in terms of scientific knowledge, the relevance of the misconceptions being assessed, the clarity of the language, and the overall appropriateness of the test for evaluation. Based on this feedback, the test was revised and re-evaluated. An example question from the four-tier diagnostic test on the concept of vibration is shown in Table 2.

Table 2. Sample Questions of Four-Tier Test on Vibration Topic

No	Tier	Question
4	1	 Two pendulums are swung simultaneously, but each with a different displacement or amplitude. If pendulum A has a displacement angle of 5º and pendulum B has a displacement angle of 8º, which of the following statements is correct? A. The period of pendulum A is shorter than that of pendulum B B. The period of pendulum A is longer than that of pendulum B C. The periods of pendulum A and B are equal D. The periods of the two pendulums cannot be compared
	2	Are you sure about your answer? A. Sure B. Not Sure
	3	Reason: A. The larger the angle of displacement of the pendulum, the longer its period of oscillation B. The angle of displacement does not affect the period of the pendulum's oscillation C. The smaller the angle of displacement of the pendulum, the longer its period of oscillation D. The angle of displacement data is insufficient to determine the period of the pendulum
	4	Are you sure about your answer? A.Sure B. Not Sure
Scientific concept		An angle of displacement less than 10° does not affect the period.

9	1	 Which of the following images represents the amplitude? A. R - T C. Q - R B. P - T D. P - R - T - R - P
	2	Are you sure about your answer? A. Sure B. Not Sure
	3	Reason: A. Amplitude is the maximum displacement measured from the equilibrium point, so the amplitude of the pendulum is from R to T. B. Amplitude is the maximum displacement measured from the equilibrium point, so the amplitude of the pendulum is from P to T. C. Amplitude is the distance between the vibrating object's position and its equilibrium position, so the amplitude of the pendulum is from Q to R. D. Amplitude is the back-and-forth motion of an object in a regular pattern across the equilibrium point along the path P – R – T – R – P.
	4	Are you sure about your answer? A. Sure B. Not Sure
Scientific concept		Amplitude is the maximum displacement measured from the equilibrium point.

Data Analysis

The collected data will be analyzed. The combined responses from pre-service science teachers for each question will be categorized into scientific knowledge (SK), lack of knowledge (LK), misconception (M), false negative (FN), and false positive (FP), as shown in Table 3 (Kiray & Simsek, 2021).

Table 3. Combination Answer and Decision of Four-Tier Test

1st Tier	2nd Tier	3rd Tier	4th Tier	Decision of Four-Tier Test
True	Sure	True	Sure	SK
True	Sure	False	Sure	FP
False	Sure	True	Sure	FN
False	Sure	False	Sure	M
True	Sure	True	Not Sure	LK
True	Not Sure	True	Sure	LK
True	Not Sure	True	Not Sure	LK
True	Sure	False	Not Sure	LK
True	Not Sure	False	Sure	LK
True	Not Sure	False	Not Sure	LK
False	Sure	True	Not Sure	LK
False	Not Sure	True	Sure	LK
False	Not Sure	True	Not Sure	LK
False	Sure	False	Not Sure	LK
False	Not Sure	False	Sure	LK
False	Not Sure	False	Not Sure	LK

Data analysis will be performed using Microsoft Excel, focusing on the probabilities specified in Table 3. To categorize scientific knowledge, pre-service science teachers' responses must be correct on both the first and third levels, and show confidence on the second and fourth levels (1-1-1-1). A score of "1" will be given for sequences that are all ones, while other sequences will receive a score of "0," determining the scientific knowledge score. False positives will be marked as "1" if the response is correct on the first level, incorrect on the third level, and confident on the second and fourth levels (1-1-0-1). False negatives will be marked as "1" if the response is incorrect on the first level, correct on the third level, and confident on the second and fourth levels (0-1-1-1). Misconceptions will be coded as "1" if the response is incorrect on the first level, confident on the second level, incorrect on the third level, and confident on the fourth level (0-1-0-1). For the lack of knowledge category, responses coded as SK, FN, FP, and M will be assigned a "0," while all other responses will be classified as lack of knowledge and coded as "1."

Research Procedure

The research procedure consists of three main phases. The first phase is preparation, which involves identifying the research problem and setting the research objectives. The researcher conducts a review of relevant literature and examines the curriculum. Based on this analysis, a four-tier diagnostic test instrument is created, and its validity and reliability are assessed. The second phase is the implementation stage, where pre-service science teachers are asked to complete the test in class within a 40-minute timeframe. Data is gathered from their responses to the instrument. The final phase is data processing and analysis, where the researcher organizes the results and discussion, ultimately drawing conclusions based on the data analysis outcomes.

RESULT AND DISCUSSION

Level of Pre-service Science Teachers Conception on Vibration Topic

The results and discussion are presented together based on the data analysis. Findings related to pre-service science teachers' understanding of the topic of vibrations are categorized into Scientific Knowledge (SK), False Positive (FP), False Negative (FN), Misconception (M), and Lack of Knowledge (LK), as illustrated in Figure 1.

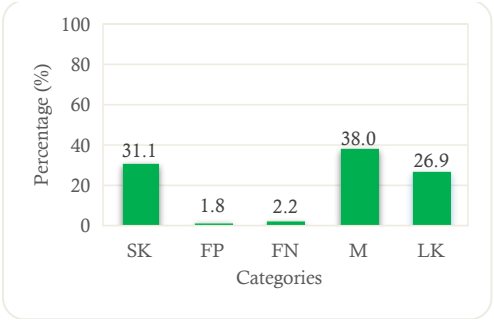


Figure 1. Percentages of Pre-service Science Teachers Conception on Vibration Topic

The findings of this study reveal that 26.9% of pre-service science teachers demonstrated a lack of knowledge, 38.0% exhibited misconceptions, 31.1% showed scientific knowledge, 1.8% were classified as false positives, and 2.2% as false negatives. These data indicate a significant gap in knowledge and misconceptions among pre-service science teachers. Various factors may contribute to these misconceptions. One primary factor is language, particularly the differences between scientific terminology and everyday language, as well as the language used in college textbooks, which can complicate the learning process for pre-service science teachers. Misunderstandings can arise when scientific terms are misinterpreted due to their similarity to everyday expressions, leading to confusion in understanding fundamental concepts. Additionally, contradictory explanations regarding the concept of vibration presented in academic sources or during lectures can further hinder pre-service science teachers' understanding of this topic. Such inconsistencies may make it difficult for pre-service science teachers to reconcile conflicting information, thereby reinforcing existing misconceptions or even creating new ones. Therefore, clarity and consistency in teaching materials and language are crucial for effectively addressing the challenges of misconceptions in learning (Ijuddin et al., 2022; Makhrus et al., 2023).

Although the majority of pre-service science teachers demonstrated strong scientific understanding, some still faced misconceptions related to vibrations. This may occur when pre-service science teachers are more likely to provide correct answers at the answer level (A) than at the reasoning level (R). Those who provide correct answers at the answer level may not have a deep understanding of the scientific concepts involved. The correct answers may be incidental or based on partial understanding, leading to mere speculation (Zhao et al., 2021).

These misconceptions indicate that although pre-service science teachers may provide correct answers on tests or quizzes, they may still lack a comprehensive understanding of the vibration concepts. This is important to note because shallow understanding can result in the delivery of inaccurate information to students, ultimately affecting students' understanding of the material. Therefore, it is crucial to ensure that pre-service science teachers not only provide correct answers but also genuinely understand the reasoning behind those answers.

A more detailed analysis was carried out to deepen the understanding of pre-service science teachers' conceptions, focusing on their views of vibration-related concepts. These concepts include the connections between frequency and period, period and string length, frequency and string length, the correlation between period and angle of incidence, the relationship between the number of oscillations and string length, period and mass, frequency and mass, the concept of vibration, and the interaction between period, number of oscillations, and time. The results of

Table 4. Percentages of Pre-service Science Teachers Conception on Each Concept of Vibration Topic

Topics	Concepts	Categories				
		SK (%)	FP (%)	FN (%)	M (%)	LK (%)
Vibration	The relationship between frequency and period	58.3	3.1	7.3	11.5	19.8
	The relationship between period and string length	44.8	3.1	4.2	22.9	25.0
	The relationship between frequency and string length	34.4	1.0	1.0	42.7	20.8
	The relationship between period and angle of displacement	0.0	1.0	6.3	53.1	39.6
	The relationship between the number of vibrations and string length	40.6	4.2	1.0	25.0	29.2
	The relationship between period and mass of the object	5.2	2.1	1.0	59.4	32.3
	The relationship between frequency and mass of the object	3.1	1.0	0.0	71.9	24.0
	The concept of vibration	43.8	0.0	0.0	24.0	32.3
	The concept of vibration	26.0	2.1	0.0	50.0	22.9
	The relationship between period, number of vibrations, and time	55.2	1.0	0.0	19.8	22.9
	Mean	31.1	1.8	2.2	38.0	26.9

As presented in Table 4, the topic of vibrations encompasses ten different concepts. This table provides an in-depth evaluation of pre-service science teachers' understanding of various vibration-related concepts. Five key metrics are measured: Scientific Knowledge (SK), False Positive (FP), False Negative (FN), Misconception (M), and Lack of Knowledge (LK), with all metrics expressed as percentages.

The data reveals significant variation in pre-service science teachers' understanding levels. For instance, concept "The relationship between period, number of vibrations, and time" has a moderate level of Scientific Knowledge (SK), at 55.2%, indicating a good understanding among most pre-service science teachers. In contrast, another concept, such as "The relationship between period and angle displacement," has a very low or zero SK score of 0.0%, indicating a major challenge in understanding this relationship.

Additionally, instances of false positives (FP) and false negatives (FN) were found, where pre-service science teachers mistakenly believe they understand a concept, or conversely, feel they do not understand a concept when they actually do. For example, the concept "The relationship between the number of vibrations and string length" shows an FP rate of 4.2%, indicating slight overconfidence among some pre-service science teachers. On the other hand, the concept "The relationship between frequency and period" has an FN rate of 7.3%, suggesting a lack of confidence despite actual understanding.

Misconceptions (M) were also relatively common, especially in the concept "The relationship between period and mass of the object,"

where 59.4% of pre-service science teachers held incorrect understandings. Furthermore, areas where lack of knowledge (LK) was observed include a 39.6% LK rate in understanding "The relationship between period and angle of displacement." Overall, while there are areas with good understanding, this data emphasizes the need for targeted interventions and further learning to address misconceptions and enhance understanding of all vibration-related concepts.

Scientific Knowledge (SK) achieved the highest ranking among vibration-related concepts. The analysis indicates that pre-service science teachers are generally confident in their responses and can provide accurate explanations when selecting the correct answer. A similar trend is evident in the misconception analysis. For example, the concept of "The relationship between frequency and period" shows a substantial SK percentage of 58.3%, reflecting that most pre-service science teachers possess a solid understanding of this concept. This high SK percentage highlights that pre-service science teachers not only comprehend the material effectively but also exhibit confidence in their understanding.

The findings, supported by various studies, demonstrate that four-tier tests are more effective than traditional multiple-choice tests in identifying misconceptions among pre-service science teachers. This test format not only detects incorrect answers stemming from a lack of conceptual understanding but also identifies pre-service science teachers with low confidence levels or those who answer correctly by guessing (Kaltakci-Gurel et al., 2017; Kiray & Simsek, 2021; Zhao et al., 2021).

In higher education, four-tier tests offer substantial potential for enhancing learning quality. They provide a deeper understanding of pre-service science teachers' thought processes, including their grasp of the concepts being taught. By incorporating confidence level assessments, educators can pinpoint pre-service science teachers xhold weak or incorrect understandings. Additionally, these tests can highlight pre-service science teachers who demonstrate high confidence in incorrect answers, revealing the presence of more profound misconceptions.

Most Common Pre-service Science Teachers Misconception on Vibration Topic

The misconception scores of pre-service science teachers were analyzed at different assessment levels: the first level (traditional multiple-choice test), the first and third levels (two-tier test), and all four levels, focusing on ten specific misconceptions. The comparison of average percentages reveals that while one-tier and two-tier tests provide an estimate of misconception levels, the four-tier test offers a more precise and in-depth assessment of actual misconceptions. This is because incorrect answers at the first level may not always indicate misconceptions; they could result from false negatives, guesswork, or a lack of knowledge rather than firmly held misunderstandings.By incorporating confidence levels, the four-tier test minimizes these uncertainties, making it a more reliable tool for diagnosing misconceptions compared to two-tier or three-tier tests. This ensures a more accurate identification of conceptual misunderstandings without being influenced by random errors or knowledge gaps (Kaltakci-Gurel et al., 2017). Table 5 presents a comparison of misconception percentages among pre-service science teachers on the topic of vibrations, highlighting the effectiveness of the four-tier test in distinguishing misconceptions from simple errors.

Table 5. Comparison Percentages Pre-service Science Teachers Misconception on Vibration Topic

Questions	Only First Tier	First & Third Tier	Four Tier	Misconception (>9.6%)
Q1	29.2	26.1	11.5	Misconception
Q2	37.5	36.5	22.9	Misconception
Q3	58.3	57.8	42.7	Misconception
Q4	95.8	92.7	53.1	Misconception
Q5	37.5	41.2	25.0	Misconception
Q6	91.7	91.2	59.4	Misconception
Q7	93.8	94.3	71.9	Misconception
Q8	39.6	40.7	24.0	Misconception
Q9	65.6	65.1	50.0	Misconception
Q10	31.3	31.3	19.8	Misconception
Mean	58.0	57.7	38.0	Misconception

According to Tan (cited in Nuraisyah et al., 2022), a misconception is considered significant if it occurs in at least 10% of the sample population. As outlined in Table 5, a detailed analysis of misconception percentages based on the four-tier test results shows that pre-service science teachers are considered to have misconceptions if the misconception percentage reaches 9.6%. This significant misconception is found across various concepts related to the topic of vibrations. The highest percentage of misconceptions is recorded at 71.9% in Q7, with the questions showing significant levels presented in Table 6.

Table 6. The Most Common Misconception Question in Vibration Topic

No.	Tier	Question
7	1	Please look at the image below!  A father, mother, and child are playing on a swing. The father has the largest mass, while the child has the smallest mass. If they swing at an angle of less than 100 (disregarding friction), who has the highest swinging frequency? A. Father C. Mother B. Brother D. All three are the same
	2	Are you sure about your answer? A. Sure B. Not Sure
	3	Reason: A. The greater the mass, the greater the frequency. B. The greater the mass, the smaller the frequency. C. Mass does not affect the frequency. D. Mass and Earth's gravity do not affect the frequency of vibrations.
	4	Are you sure about your answer? A. Sure B. Not Sure
Concept		The mass of an object does not affect the frequency of vibrations.

The most misconceptions among the pre- service science teachers are presented in Table 7.

Table 7. Pre-service Science Teachers Misconception on Vibration Topic

Concept	Pre-service Science Teachers Misconception	Correct Concept
The relationship between frequency and period	The period is directly proportional to the frequency. Therefore, the lower the frequency of the vibration, the shorter the period.	The smaller the frequency, the greater the period.
Relationship between period and length of string	The longer the string, the faster the vibration period.	The longer the string, the longer the vibration period.
Relationship between frequency and length of string	The smaller the mass of the object, the higher the frequency produced.	The longer string, the smaller the vibration frequency.
Relationship between period and angle of displacement	The larger angle of displacement of the pendulum, the greater the period of the vibration.	Angle displacement less than 10° doesnt affect period.
The relationship between the number of vibrations and length of the string	The longer the string, the greater the number of vibrations.	The shorter the string, the greater the number of vibrations.
The relationship between period and mass of the object	Mass affects the period of vibration; the larger the mass of the pendulum, the greater the period, meaning it takes longer to complete one vibration.	The mass of the object does not affect the vibration period.
Relationship between frequency and mass of object	The greater the mass, the smaller the frequency.	The mass of object doesnt affect vibration frequency.
Concepts of vibration	Frequency is number of vibrations performed in a unit of time. A frequency of 25 Hz means the object performs of a vibration in 1 second.	Frequency is the number of vibrations performed in a unit of time.
Concepts of vibration	Amplitude is the regular back-and-forth motion of an object through its equilibrium point along the path P – R – T – R – P.	Amplitude refers to greatest distance an object moves from equilibrium position.
Relationship Between Period, Number of Vibrations, and Time	For spring II, the number of vibrations is 6 in 12 seconds, so to determine the period $\frac{n}{t} = \frac{6}{12} =$ 0.5 s	The period is the time required for an object to complete one full vibration.

In addition, to complement the research findings regarding the profile of misconceptions among pre-service science teachers on the topic of vibrations, interviews and an analysis of the difficulty level of the four-tier test items related to vibrations were conducted, as presented in Figure 2.

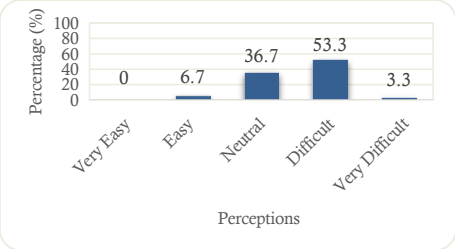


Figure 2. Percentages of Pre-service Science Teachers Perception on Vibration Topic

An analysis of the difficulty level of the four-tier test questions on the topic of vibrations, as illustrated in Figure 2, revealed that most pre-service science teachers found the questions highly challenging. The results show that none of the participants rated the questions as very easy (0%), 6.7% considered them easy, 36.7% rated them neutral, 53.3% found them difficult, and 3.3% rated them very difficult. These findings indicate that over half of the pre-service science teachers (56.6%) perceived the questions as falling into the difficult to very difficult range. The perceived difficulty suggests that the four-tier test is an effective tool for identifying misconceptions, as its structure promotes critical thinking about the concept of vibrations. Interviews conducted revealed that many pre-service science teachers faced difficulties in recalling physics concepts. Further explanations provided insights into the views of several pre-service science teachers:

- **Question:** What is your opinion about the vibration-related questions provided? Do you consider the questions to be very easy, easy, neutral, difficult, or very difficult? Please explain your reasons.
- Pre-service science teachers A: Easy
  Reason: *"I was able to answer the questions easily because I studied Physics from high school to university, but I have forgotten some of the other materials."*
- Pre-service science teachers B: Neutral
  Reason: *"I believe that this question is 50% difficult and 50% easy because I can only remember some of the formulas related to the concept of vibration."*
- Pre-service science teachers C: Difficult
  Reason: *"I had difficulty understanding the physics material because during high school, the lessons were conducted online, so I have forgotten much of the material and formulas."*
- Pre-service science teachers D: Very Difficult
  Reason: *"I believe this question is very difficult and I am unsure about my answer because I have forgotten almost all of the physics material and have not reviewed it."*

The findings indicate that the difficulty perceived by pre-service science teachers is strongly linked to their grasp of fundamental physics concepts, particularly regarding vibrations. Many struggled to recall previously learned material, such as the relationships among period, frequency, restoring force, and oscillations, highlighting weaknesses in their foundational understanding. The significant proportion of pre-service teachers who found the test items challenging or very challenging underscores the need for enhanced teaching strategies. These strategies should focus on bridging the gap between theoretical knowledge and practical application to strengthen their comprehension (Darling-Hammond, 2017; Dzaiy & Abdullah, 2024; Makhambetova et al., 2021).

Therefore, more innovative and interactive learning approaches are needed, such as experiment-based learning, interactive simulations, or active learning strategies (Kamran et al., 2023; Kotsis, 2024; Shloul et al., 2024). Such methods can enable pre-service science teachers to develop a more profound understanding of concepts by connecting them directly to real-world scenarios or related experiments. Furthermore, providing opportunities for pre-service science teachers to practice answering questions in a format like the four-tier test can be a crucial part of the learning process, as this format not only measures the correct answer but also evaluates their confidence level and ability to justify their answers (Istiyono et al., 2023; Nurhafsari & Rismaningsih, 2023).

The four-tier test has demonstrated its effectiveness as a diagnostic tool for identifying misconceptions among pre-service science teachers. Its capacity to explore their conceptual understanding and assess confidence levels in their answers makes it well-suited for application in other physics topics or broader science disciplines (Habbidin & Page, 2019; Kaltakci-Gurel, 2017; Nurhafsari & Rismaningsih, 2023). Expanding the use of this test and incorporating it into more

active and comprehensive learning approaches is expected to enhance the conceptual understanding of pre-service science teachers significantly, equipping them to better navigate future teaching challenges.

The study contributes to understanding the misconceptions of pre-service teachers in science concepts, particularly vibrations, by highlighting key areas of misunderstanding. Despite some participants demonstrating solid scientific knowledge, a substantial portion (38%) exhibited misconceptions, especially regarding the relationships between frequency, period, string length, and mass. For example, misconceptions about how mass influences the vibration period were prevalent, with 59.4% of participants misunderstanding this relationship. The four-tier test proved valuable for revealing these misconceptions, offering more detailed insights than traditional assessments by considering participants' confidence levels in their responses. The results also emphasize the need for improved teaching strategies, as interviews showed that many pre-service teachers struggled with recalling foundational physics concepts. This indicates a knowledge gap that needs to be addressed in teacher preparation programs. The study calls for a more comprehensive approach to teaching, particularly focusing on reinforcing core concepts and addressing misconceptions directly. Overall, the study underscores the importance of diagnosing misconceptions early in teacher education and adopting strategies that promote deeper conceptual understanding.

CONCLUSION

The findings and discussion reveal that the four-tier test effectively evaluates pre-service science teachers' understanding of vibrations, offering accurate insights. The results categorize their understanding into Scientific Knowledge (SK), False Positive (FP), False Negative (FN), Misconception (M), and Lack of Knowledge (LK). Among the participants, 26.9% showed a lack of knowledge, 38.0% exhibited misconceptions, 31.1% demonstrated strong scientific knowledge, while 1.8% and 2.2% fell into the false positive and false negative categories, respectively. Despite a substantial portion showcasing good scientific knowledge, misconceptions persisted, particularly regarding reasoning and conceptual relationships like frequency, period, string length, and mass. For instance, 59.4% of participants misunderstood "The relationship between period and mass of the object," reflecting challenges in grasping how mass influences vibration periods. Question Q7, concerning "The relationship between frequency and mass of the object," recorded the highest misconception rate at 71.9%. These results underscore the critical need to enhance conceptual understanding of vibrations and employ effective teaching strategies to address misconceptions.

The four-tier test outperforms traditional multiple-choice assessments by providing deeper insights into participants' understanding and revealing their confidence levels in incorrect responses. Analyzing the test's difficulty level showed that 56.6% of participants found it challenging or very challenging, highlighting its effectiveness in fostering critical thinking about vibrations. Interviews revealed that pre-service teachers often struggled to recall physics concepts, with some relying on partial formulas or guessing. This indicates the need for a comprehensive teaching strategy to reinforce foundational physics knowledge and minimize misconceptions.

The limitations of this study include a limited sample size, reliance on interviews, and a focus on misconceptions related to the topic of vibrations. Additionally, the study only assesses understanding at a single point in time, without providing information on the long-term development of learning. The study strongly recommends adopting the four-tier test in higher education to identify misconceptions better and enhance learning outcomes. Furthermore, improving the quality of academic explanations and strengthening pre-service teachers' grasp of fundamental physics concepts are essential steps to mitigate misunderstandings. Future research should consider increasing the sample size and extending the study to multiple universities across Indonesia to achieve broader and more representative findings.

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