Berkala Ilmiah Pendidikan Fisika
ISSN : 2337-604X (print)
ISSN : 2549-2764 (online)

Vol 10 No 1 2022
https://ppjp.ulm.ac.id/journal/index.php/bipf
page 56-72

Mechanical Wave Concepts: Composing of Five-Step Conception Diagnostic Test, Validity and Reliability Test, and Student's Profile Conception Level

Aretha P. Andriani and Frida U. Ermawati*
Physics Department, Faculty of Mathematics and Natural Sciences,
Universitas Negeri Surabaya, Surabaya, Indonesia
*frida.ermawati@unesa.ac.id

DOI:10.20527/bipf.v10i1.12364

Received: 30 December 2021 **Accepted: 23 April 2022** **Published: 7 May 2022**

Abstract

A mechanical wave is one of the Physics concepts related to everyday life. When the Authors interviewed some students at one of Gersik's senior high schools, the Authors found that some students didn't understand the concepts yet. Students thought that when a rope was moved up-down, the particles in the rope would be moved horizontally. The truth is that there was no movement of particles in the vibrated rope. Misconceptions must be detected immediately so as not to interfere with students' understanding of the following concepts. One way is by using a conception diagnostic test. The paper aims to report the composition of the five-step conception diagnostic test for Mechanical Wave concepts, its' validity and reliability, and use it to identify students' profile conception level in a Gresik's senior high school. This study used ADDIE (Analysis, Design, Development, Implementation, and Evaluation) model and data collection technique that used was developing of five-step question that passed through the validity and reliability stages. 13 questions were written and tested for their internal validity and 12 only questions declared valid 91.32%. The result of external validity in terms of a true fake (TF) and a wrong fake (WF) was 7.14% and 4.76% (valid as empirical content because of the TF and WF<10%). The conception diagnostic test was also valid as an empirical construct based on the Pearson Product Moment score because rab=0.575>rtable=0.4575 (significance level of 0.05), and 11 questions were finally declared valid and reliable. 40.40% of the 18 students for their profile conception level confirmed as Lack of Knowledge.

Keywords: five-step conception diagnostic test; mechanical wave; reliability; validity test

How to cite: Andriani, A. P, &Ermawati, F. U. (2022) Mechanical wave concepts: Composing of five-step conception diagnostic test, validity and reliability test, and student's profile conception level. *Berkala Ilmiah Pendidikan Fisika*, 10(1), 56-72.

INTRODUCTION

Physics is the study of natural concepts and phenomena relevant to everyday life. Sound waves are a common phenomenon in everyday life, such as when we hear ambulance sirens from a distance. The sound of sirens can be heard because sound waves travel through the medium of air from the sound source in the form of ambulance sirens to the listener's ear. Sound waves are mechanical waves that require a medium to propagate (Young & Freedman, 2012). Waves cannot propagate without a medium. Sound waves can travel through the medium of air, water, or solid objects (Abdullah, 2017).

Many students still do not understand the concepts or have misconceptions about Mechanical Wave concepts. The

authors discovered that after interviewing students at one of Gresik's senior high schools. For example, students had difficulties when asked to determine the motion of particles on a wave of rope tied to a stick (see Figure 1).

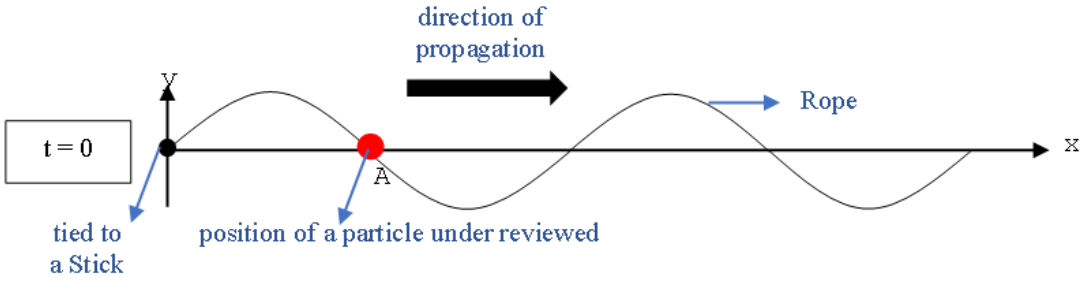


Figure 1 The rope vibrated and forms a transverse wave, where the *x* axis is time taken by wave (*t*) in seconds (*s*), the *y* axis is amplitude intensity (*m*), and point A is the position of the particle to be reviewed when the rope is moved upwards and downwards, thus forming a transverse wave. (Source: Personal Documents)

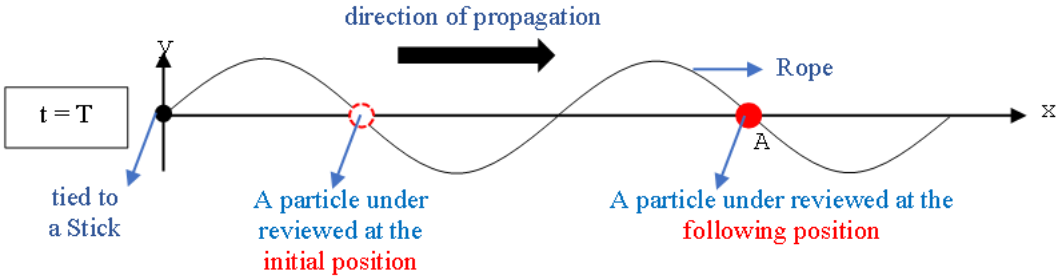


Figure 2 When the wave vibrates during *t=T*, the students chose a rope wave (Source: Personal Document)

The rope wave formed at t = 0 will look like Figure 1. Students assumed that the red particle would move to the right when the wave vibrated at t=T (where T is the wave period). Figure 2 illustrates the wave chosen by students based on this assumption. Meanwhile, according to Young & Freedman (2012), no particles in a rope are transferred when the wave is vibrated. Young & Freedman (2012) mentioned in Chapter 15 of his book University Physics 13th edition, on page 474, that "the medium itself does not travel through space; its particles undergo back-and-forth or up-and-down motions around their equilibrium positions."

Figures 1 and 2 showed the difference in understanding between the student's concepts and the mechanical wave concepts theory. A misconception is defined as a difference in understanding of these concepts. Misconceptions can arise from daily interactions with the environment in which students live or from what is commonly referred to as preconception (Zahra & Suprapto, 2019). Misconceptions can occur when students have what is known as preconception or initial knowledge of students, according to (Aisahsari & Ulfah Ermawati, 2019).

Misconceptions experienced by students can interfere with the following concepts, necessitating the writing of a method for detecting students' conception level. A diagnostic conception test is one way to detect a students' conception level. The conception diagnostic test is the most efficient and practical method for detecting students' conception levels. It is effective because it can detect misconceptions while also identifying the student's profile conception level.

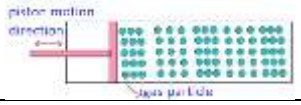
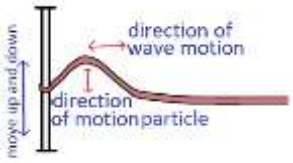
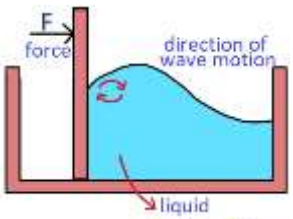
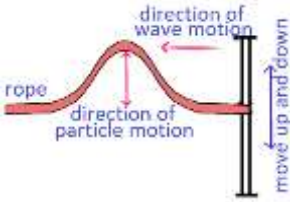
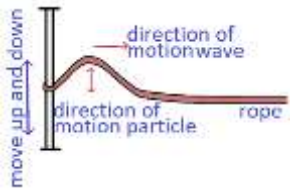
A four-step conception diagnostic test was widely used. Step 1 consists of

questions and answers choices, one of which is the correct answer, and the other is the distractor answer. Step 2 is a student satisfaction level for answering the first step. The student's choice of reason in answering the question in step 1 is then in step 3. One of the answers is correct, while the other is a distractor based on the student's profile conception level, which: (1) preconception, (2) humanistic thinking, (3) incomplete reasoning, (4) associative thinking, and (5) incorrect intuition. Step 4 is a choice of student satisfaction level in answering a question in step 3.

Several four-step conception diagnostic tests were previously composed by Kurniawati & Ermawati (2019) for Dynamic Fluids; Rohmanasari & Ermawati (2019) for Optical Instruments; Jannah & Ermawati (2019) for concepts on Rotational Dynamics and Equilibrium of Rigid Bodies; Aisahsari & Ulfah Ermawati (2019) for Direct Electric Current; Hanifah & Ermawati (2019) for Momentum and Impulse; Anggrayni & Ermawati (2019) for Work and Energy; Isfara & Ermawati (2018) for Static Fluids; and by Utari & Ermawati (2018) for Temperature, Heat and Transfer concepts.

Table 1 shows an example of a five-step conception diagnostic test from steps 1 to 5 that the Authors developed for this work. The four-step conception diagnostic test mentioned above is a question in Table 1 that consists only of step 1 to step 4 questions, excluding step 5.

Table 1 Examples of diagnostic tests of five-step conception of mechanical wave concepts that were previously developed by the authors

Step	Question
1	**Among the following image options that are examples of longitudinal waves are...** a. 
	(√) b.  c.  d.  e.  (Source: Personal Documents)
2	**Satisfaction level choices in choosing answers:** a. Satisfied (√) b. Not satisfied
3	**Reasons for choosing an answer:** a. Longitudinal waves are waves that propagate in a limited space (incomplete reasoning). b. Longitudinal waves propagate only in gaseous substances (Incorrect intuition) c. Longitudinal wave propagation direction perpendicular to particle motion (Preconception) d. The direction of longitudinal wave propagation is in the direction of the motion of the particles. (√) e. Longitudinal waves propagate in all directions (associative thinking) f. The condition of longitudinal waves is the presence of a vibrating source at one point (Humanistic thinking)
4	**Choice of satisfaction level in choosing the reason for the answer:** a. Satisfied (√) b. Not satisfied

Step	Question
5	**What is the direction of motion of the particles and the direction of longitudinal wave propagation?** Gas waves formed when driven by pistons are longitudinal waves where the direction of motion of particles moves horizontally and in the direction of propagation of the waves that are horizontal.

Description: √= the correct answer.

s shown in Table 1, questions on the first through four steps are multiple-choice, with test students only having the option of selecting one of the correct answer options. According to other authors, the four-step diagnostic test was already capable of detecting students' conceptual levels and identifying the students' profile conception level. However, the examiner does not have the satisfaction of knowing whether the test students' answers from the first to fourth steps are correct or just a guess. As a result, one more question is required to provide satisfaction. In this case, the question is an open question in the fifth step of Table 1. Furthermore, the four-step conception diagnostic test could not explain students' ideas or thoughts when answering questions in writing (Anam, Widodo, Sopandi, & Wu, 2019). To encourage students to express their own thoughts or understanding and avoid guessing answers, one more question in the form of an open-ended question is required, making it a five-step conception diagnostic test (Salsabila & Ermawati, 2020). Step 5 of the diagnostic test contains an open question that can be a request to draw conclusions or sketch/map concept/drawing/flow/graph about the concept asked in the step 1 question. These questions improve the five-step conception diagnostic test's ability to detect students' conception level.

Table 2 contains the five-step conception diagnostic test that some authors already wrote.

Table 2 The five-step conception diagnostic tests that were written by some authors

Physics concepts	Reference
Linear Motion	Sari & Ermawati (2021)
Circular Motion	Ramadhani & Ermawati (2021)
Harmonic Vibration	Putri & Ermawati (2021)
Sound Waves	Lailiyah & Ermawati (2020)
Vector	Qonita & Ermawati (2020)
Elasticity	Salsabila & Ermawati (2020)
Kinetic Theory Of Gases	Fajriyyah & Ermawati (2020)
Heat Transfer	Anam et al. (2019)
Changes of Matters	Bayuni et al. (2018)

The method for assessing the results of the test students' answers when working on the four-step conception diagnostic test is given in Table 3, particularly in columns 2-5. When the test student's answer from the first to the fifth steps is true-satisfied-true-satisfied, the test student is said to be "Concept Understanding", and so on. The true fake (TF) in question is the response of students who detected true but the data was wrong. The combination of answers to TF occurs when the student's answer is true at step 1, satisfied at step 2, wrong in answering step 3 questions, and satisfied at step 4 (true-satisfied-wrong-satisfied).

The wrong fake (WF) is data that appears to be wrong but is in fact true. The coordination of true fake (TF) responses is wrong-satisfied-true-satisfied.

While the assessment of student answer results for the five-step conception diagnostic test is similar to that of the four-step conception diagnostic test, it is enhanced by the students' response to a step five question, as shown in the sixth column of Table 3. Even when the student's answers from steps 1-4 are true and satisfied, students may still experience Concept Understanding (CU), Partial

Understanding (PU), or even Lack of Knowledge (LK). This is where a four-step diagnostic test differs from a five-step diagnostic test. When true and satisfied from steps 1-4, students can be classified as Understanding Concepts and provide answers in the form of true and scientific on fifth step question. While the students' answer is true and satisfied at steps 1-4, when the students' answer to the fifth step question is only partially correct, the student is classified as Partially Understanding (PU) and so on as in Table 3.

Table 3 Student conception levels based on the coordination of answers from step-1 to step-5 (Amin, Wiendartun, & Samsudin, 2016)

No	Combination of answers to step-					Conception Level
	1	2	3	4	5	
1.	T	S	T	S	TS PC MI/UD NA	UC PU LK D
2.	T	S	T	US		
3.	T	US	T	S		
4.	T	US	T	US		
5.	T	S	W	US		
6.	T	T	W	S		
7.	T	US	W	S	PC/UD/NA	LK
8.	T	US	W	US		
9.	W	S	T	S		
10.	W	S	T	US		
11.	W	US	T	S		
12.	W	US	T	US		
13.	W	S	W	US		
14.	W	US	W	S	PC/MI/UD/NA	NU
15.	W	US	W	US		
16.	W	S	W	S	MI/UD/NA	M
17.	There is an unanswered step					D

Note: T = True; W = Wrong; S = Satisfied; US = Unsatisfied; TS = True and Scientific; PC = Partially Correct; MI = Misconception; UD = Undefined; NA = No answer; UC = Understanding Concepts; PU = Partially Understand; LK = Lack of Knowledge; NU = Not Understanding Concepts; M = Misconception and D = Un encode

According to the combination of student responses, the other conception steps are Understanding Concepts (UC), Partial Understanding (PU), Lack of Knowledge (LK), Not Understanding Concept (NU), Misconception (MI), and Cannot Be Encoded (D). The answers mapping results are then evaluated using the categories in Table 4.

Table 4 shows the score referred to test students at the fifth step based on the answer category. When a test student correctly answers a fifth-step question based on a Physics concept, the answer is classified as a True and Scientific answer (TS) and given a score of 100, as shown in Table 4.

Table 4 Description of conception level and answer score at the fifth step in Table 2 adapted from Sari & Ermawati (2021)

Category	Description	Score (%)
True and Scientific (TS)	When students give the correct answer based on the concept of physics asked on the question, including the description/conclusion.	100
Partially Correct (PC)	When students give a description/conclusion based in part on the concept of physics asked on the question.	99-70
Misconceptions (MI)	When the students' incomprehensible answer or description/conclusion does not correspond to the concept of physics asked about the question.	69-40

Category	Description	Score (%)
Undefined (UD)	When students give the wrong answer and the picture/ conclusion is different from the concept of Physics asked on the question	39-1
No Answer (NA)	When students don't give answers to questions.	0

As far as the author is concerned, and as shown in Table 2, no conception diagnostic test for the Mechanical Wave concepts has been developed, especially for the five-level one. Given that there is no standardized conception diagnostic test, an author of the conception diagnostic test must conduct a feasibility test before using the test.

Based on the above explanation, this paper reported the results of the composing of a five-step conception diagnostic test for Mechanical Wave concepts. The five-step conception diagnostic test developed in this paper is further tested for eligibility and tested on several students.

METHOD

Until now, diagnostic conception tests were not standardized, with each author requiring a feasibility test before using a diagnostic conception test. As a result, the Authors wrote a five-step conception diagnostic test for Mechanical Wave concepts using the ADDIE (Analysis, Design, Development, Implementation, and Evaluation) development research model.

Analysis Stage

The analysis stage is carried out to analyze the needs, concepts, and potential misconceptions in Mechanical Wave concepts (especially in sub-concepts: Wave Type, Medium Wave Propagation, Rapid Propagation of Waves, Particle Movement, Wavefront, Water Waves Properties, and Rope Waves Properties) by reviewing the book University Physics 13th edition in Chapter 15 on pages 472-494 Young & Freedman (2012), as well as the book Basic Physics II in Chapter 9 on pages 602-643 (Abdullah, 2017). Based on the findings of the analysis of needs, concepts, and potential student misconceptions, Table 5 summarizes some potential misconceptions for Mechanical Wave concepts.

Table 5 Some potential misconceptions in mechanical wave concepts

Sub-concepts	The Right Concept	Potential Misconceptions
Medium Wave Propagation	Mechanical waves can propagate through the medium of air, water, or solid objects (Abdullah, 2017).	Students assume that mechanical waves only propagate in the medium of liquids and gases only.
Movement of Particles on Waves	When the rope is targeted, the particles do not move in a horizontal direction and there is no transfer of particles.	Students assume that the transfer of particles from one point to another on a rope wave.
Wavefront	The wavefront is the seat of particles that have the same phase in the wave.	Students assume that the water wave face is all lines that spread away from the source of the shake and visible on the surface of the water wave.

Design Stage

During the design stage, the Authors composed a five-step conception diagnostic test, referred to as Draft 1. Draft 1 consists of five-step questions as detailed in the *Introduction* section. The Authors developed the five-step conception diagnostic test on the Mechanical Wave concepts using some Google Scholar scientific journals and a textbook entitled "University Physics with Modern Physics", 13th Edition written by Young & Freedman (2012) as the references.

Development Stage

Internal Validity

The internal validity of Draft 1 in terms of content, language, and construct is being assessed by two validators, who were appointed as Physics lecturers. Some indicators to assess the internal validity in terms of contents are: (a) whether the details of the problem are following mechanical wave concepts or not; (b) whether the details of the problem are following the indicator of the problem or not; (c) whether the description of the subject matter is following the order of the concepts or not and (d) whether the limits of the question, answer, and explanation of the common reason are following the order of the concepts are clear.

Then the indicators to assess internal validity in terms of constructs are: (a) whether the diagnostic test instructions were expressed clearly or not; (b) whether the criteria of the questions with Bloom Taxonomy and basic competencies are appropriate or not; (c) whether each question in the diagnostic test can identify the conception of the students or not; (d) whether the choice of reasons presented the cause of the misconceptions sourced from within the students or not; (e) whether the distractor options on the choice of reasons were rational and homogeneous with a first-step answer or not and (f) whether the tables, graphs, images and the like have corresponded to the problem presented or not.

While indicators to assess internal validity in terms of language: (a) whether the sentence on the question has used good and correct Indonesian or not; (b) whether the variety of sentences or questions does not give a double interpretation; and (c) whether the question of each test was clearly and communicatively or not. The validator's score on each indicator, ranging from 1 to 4, refers to the assessment rubric shown in Table 6.

Table 6 The internal validity suspension instructions along with value interpretation criteria(Sugiyono, 2015)

Assessment Rubric	Value Interpretation Criteria
1	Fulfilled only 0-39%
2	Fulfilled only 40-69%
3	Fulfilled only 70-89%
4	Fulfilled 90-100%

The next step is to compute the percentage of internal validity using Equation (1) and the results of calculations produced and evaluated using Table 7. If the result of computing the percentage of internal validity using Equation 1 is a value between 0 and 20, then classify the internal validity criteria, its criteria are very weak, and so on, as shown in Table 7.

$$V_I = \frac{\Sigma S}{N \times \Sigma Q \times \Sigma V} 100\% \quad (1)$$

V_I = percentage of internal validity (%); ΣS = number of validator scores; N = the highest score; ΣQ = number of questions, ΣV= number of validators.

Table 7 Interpretation of internal validity score results (Riduwan & Akdon, 2013).

Percentage (%)	Score Interpretation Criteria
0 – 20	Very weak
21 – 40	Weak
41 – 80	Enough
61 – 80	Valid
81 - 100	Very valid

The Draft 1 was updated based on the The internal validity test results by two validators, and the question proceeded to the external validity stage.

External Validity

Questions that passed the internal validity stage are used in Trial Phase 1 to assess external validity (empirical content and empirical construct) and reliability of conception diagnostic tests. The empirical validity of content is measured in a developed diagnostic test of

conception by measuring the content or conception. At the same time, the empirical validity of constructs assessed the ability of conception diagnostic tests to be utilized as the test's objective, namely detecting students' level of conception.

Draft 2 is the five-step conception diagnostic exam utilized in the following step of Trial Phase 1. Trial Phase 1 was carried out on 13 students from classes X-7 at Menganti Senior High School. Draft 3 was the legitimate questions derived from the findings of Trial Phase 1. Draft 3 was then tested during Trial stage 2.

The empirical validity of content was tested by determining the proportion (percent) of true fake (TF) and wrong fake (WF) using Equations (2) and (3). The definitions of TF and WF can be found in the section "Introduction."

$$\%TF = \frac{\Sigma TF}{\Sigma_{questions} x \Sigma S} x100\% \quad (2)$$

$$\%WF = \frac{\Sigma WF}{\Sigma_{questions} x \Sigma S} x100\% \quad (3)$$

ΣTF = number of true fake, ΣWF = number of wrong fake, $\Sigma_{questions}$ = number of questions, and ΣS = number of test students (in this work amounted to 13 students).

External validity test empirical construct can be calculated using the Pearson Product Moment correlation (Arikunto, 2013) using Equation (4) and then evaluated using Table 8. If the Pearson product moment correlation coefficient (r_{ab}) is calculated using Equation 4 = 0.000 - 0.199, the empirical external validity of the construct was very low, and so on for the other range of values in Table 8.

$$r_{ab} = \frac{\Sigma ab}{\sqrt{(\Sigma a^2)(\Sigma b^2)}} \quad (4)$$

Where: r_{ab} is the correlation coefficient between variables *a* and *b*; *a* = is the difference between the total answer score 'true' per question in the first and third steps and the average correct answer score on all points of the question; and *b* = is the difference between the number of 'satisfied' answer scores of each question in the second and fourth steps and the average correct answer score on each question. (If $r_{ab} > r_{table}$, the query item will be valid.)

Table 8 Pearson product moment correlation coefficient results criteria (Sugiyono, 2015)

Correlation Coefficient Interval (r_{ab})	Criteria
0,000 – 0,199	Very low
0,200 – 0,399	Low
0,400 – 0,599	Keep
0,600 – 0,799	Strong
0,800 – 1,000	Very strong

The Alpha Cronbach coefficient (r_{11}) was used to computed the reliability value of the conception diagnostic test, as shown in Equation (5). The outcome of Equation (5) is then classified in Table 8. If the calculation (r_{ab}) yields Equation 5= 0.000–0.199, the reliability is categorized as very low, and so on for the remaining value ranges in Table 9.

$$r_{11} = \frac{k}{k-1}\left(1 - \frac{\Sigma \sigma_i^2}{\sigma_t^2}\right) \quad (5)$$

Where: r_{11} = coefficient of reliability of conception diagnostic test; σ_t^2 = total variance; $\Sigma \sigma_t^2$ = number of grain variances and *k* = number of questions.

Table 9 Criteria for the results of the Alpha Cronbach coefficient (Sugiyono, 2015) to determine the reliability of the five-step conception diagnostic test.

Alpha Cronbach coefficient interval (r_{11})	Criteria
0,000 – 0,199	Very low
0,200 – 0,399	Low
0,400 – 0,599	Keep
0,600 – 0,799	Strong
0,800 – 1,000	Very strong

Implementation Stage

Draft 3 was then tested on 18 students to detect the students' conception level of Mechanical Wave concepts in senior high school. Several students at one of Gresik's senior high schools involved in

Trial Phase 2 were different from students in Trial Phase 1.

From Trial Phase 2, the Authors then identified a student's profile conception level. Authors can identify students' profile conception level based on a combination of students' answers to test results according to Table 2.

Evaluation Stage

According to Rustandi & Rismayanti (2021), evaluation on the ADDIE model was conducted to process the data and draw conclusions to the results of the work. The results of validity and reliability data and conception diagnostic tests obtained in this work are then concluded whether the conception diagnostic test written is feasible and can be used to detect conception levels or not.

RESULT AND DISCUSSION

Analysis Stage

In the analysis stage, it had successfully The analysis stage had successfully declared 7 sub-concepts for Mechanical Wave concepts, of which 3 were listed in Table 5 in the 'Introduction' section of this paper. Table 5 contains sub-concepts in conception diagnostic tests, right concepts, and potential misconceptions for Mechanical Wave concepts.

Design Stage

As already mentioned, 13 questions in Draft 1 were successfully developed by the Authors where one of the 13 points of the question list in Table 1.

Development Stage

The content's internal validity, external empirical validity, and constructs' empirical validity were successively shown in Tables 10, 11 and 12. The results of internal validity in Table 10 show that the five-step conception diagnostic test for Mechanical Wave concepts as in Draft 1 was a very valid criterion where the average percentage of internal validity is 91.32%, with the number of questions that passed the internal validity stage were 12 questions. The external empirical validity of the contents can be seen in Table 11, which shows the value of %TF was 7.14%, and the value of %WF was 4.76%. Value % TF and WF% WF, less than 10%, indicate that Draft 2 was declared externally valid empirical content. The empirical validity of the construct in Table 12 requires a r_{table} value whose grade depends on the number of students in this work.

Table 10 The Internal validity results by 2 validators

No.	Aspects	Indicators	Validator		Percentage (%)	Criteria
			1	2		
1	Content	(a)	4	4	90.63	Very valid
		(b)	3	4		
		(c)	3	4		
		(d)	3	4		
2	Construct	(a)	3	4	87.50	Very valid
		(b)	3	4		
		(c)	3	4		
		(d)	3	4		
		(e)	3	4		
		(f)	3	4		
3	Language	(a)	4	4	95.83	Very valid
		(b)	3	4		
		(c)	4	4		
Average					91.32	Very valid

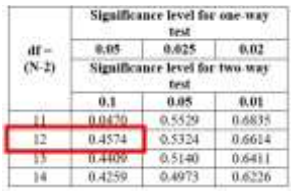
Description: The internal validity indicators 1a-1d, 2a-2f and 3a-3c can be seen in the Methods Development Phase section. The internal validity criteria can be seen in Table 6.

Table 11 Results in the validity of the external empirical content

Question	ΣStudent	ΣFP	ΣFN
1	14	0	0
2		1	1
3		1	2
4		1	0
5		1	1
6		1	1
7		1	0
8		1	1
9		1	0
10		2	1
11		2	1
12		0	0
Sum		12	8
Percentage		7.14	4.76

Table 12 Results of empirical empirical validity of constructs

Question Number	r_{ab}	r_{table}	Criteria
1	0.6460	0,4575	Valid
2	0.6806		Valid
3	0.4659		Valid
4	0.5252		Valid
5	0.6193		Valid
6	0.5385		Valid
7	0.6503		Valid
8	0.6070		Valid
9	0.8870		Valid
10	0.5601		Valid
11	0.4944		Valid
12	0.2286		Invalid



df = (N-2)	Significance level for one-way test		
	0.05	0.025	0.02
	Significance level for two-way test		
	0.1	0.05	0.01
11	0.0470	0.5529	0.6835
12	0.4574	0.5324	0.6614
13	0.4409	0.5140	0.6411
14	0.4259	0.4973	0.6226

Figure 3 Screenshots of significance r_{tabel} values of 0.05 to 0.0005 on degrees of fredoom (df), with *N* being the number of students (at this paper, carry out 14 students) (Sugiyono, 2015)

There were 14 students involved in the external validity test, so the value of r_{table} is 0.4575 (df (degree of freedom) = 12) with a significance level of 0.05 as in Figure 3 given a red box

The requirement of the questions to declared valid at the external validity of the construct is the value $r_{ab}>r_{table.}$ Based on the values of r_{table} in Figure 3 and r_{ab} in Table 12, the question number 12 did not valid at the external validity of the construct so that the question was not used in Draft 3 for Trial Phase 2. Question number 12 was a problem with the sub-concepts of Rope Wave Properties. Although the question number 12 was not used, this work can still detected the students' conception level in the sub-concepts Rope Wave Properties considering that the sub-concepts was also loaded on the question number 11 with a different model. Meanwhile, the questions number 1-11 were valid in terms of empirical constructs.

From the results of Trial Phase 1, the reliability value (r_{11}) was 0.598 which is $r_{11}>r_{table}$ so that the Draft 2 was declared reliable. Based on the results of internal validity, external validity and reliability obtained from Trial 1, Draft 3 with 11 questions were ready to be tested in Trial Phase 2 at the Implementation Stage.

Implementation Stage

The results of Trial Phase 2 were tested on 18 students at one of Gresik's senior high schools and some students' answers were mapped in Table 13 below. For cells marked in red boxes were examples of students' answers in Table 14.

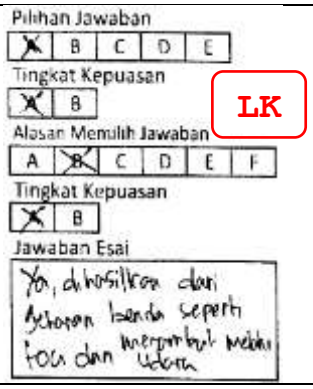
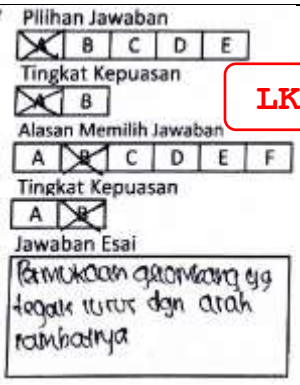
Table 13 Results of trial phase 2 on 18 test students

Students	Sub-Concepts											Conclusion
	A		B		C	D	E	F			G	
	No. Question											
	1	2	3	4	5	6	7	8	9	10	11	
1	UC	LK	PU	LK	PU	LK	LK	LK	LK	LK	C	LK(63.64%)
2	UC	PU	UC	LK	PU	LK	LK	UC	T	LK	LK	LK(45.46%)
3	UC	LK	UC	PU	PU	LK	LK	LK	LK	UC	PU	LK(45.46%)

Students	Sub-Concepts											Conclusion
	A		B		C	D	E	F			G	
	No. Question											
	1	2	3	4	5	6	7	8	9	10	11	
4	UC	PU	PU	UC	LK	LK	M (FI)	M (AT)	LK	LK	PU	LK(36,.37%)
5	UC	LK	UC	UC	UC	LK	LK	PU	LK	UC	PU	UC(45.46%)
6	LK	PU	LK	C	UC	LK	LK	UC	LK	LK	LK	LK(63.64%)
7	PU	LK	LK	LK	LK	UC	M (AT)	UC	UC	LK	PU	LK(45.46%)
8	UC	PU	UC	LK	UC	UC	PU	PU	UC	LK	PU	UC(45.46%)
9	LK	LK	UC	LK	PU	UC	LK	M (AT)	LK	LK	PU	LK(54.55%)
10	UC	PU	UC	LK	LK	UC	PU	UC	LK	LK	PU	LK(36.37%)
11	UC	LK	UC	LK	UC	UC	PU	PU	LK	LK	PU	LK(36.37%)
12	UC	PU	UC	LK	LK	LK	PU	D	LK	D	PU	LK(36.37%)
13	UC	LK	UC	LK	UC	UC	LK	M (AT)	LK	PU	PU	LK(36.37%)
14	LK	M (IR)	UC	LK	LK	LK	PU	UC	LK	LK	PU	LK(54.55%)
15	UC	PU	UC	UC	UC	UC	PU	PU	LK	LK	PU	UC(45.46%)
16	LK	M (IR)	UC	M (HT)	LK	LK	LK	LK	PU	LK	PU	LK(54.55%)
17	UC	PU	UC	UC	LK	UC	PU	LK	UC	LK	PU	UC(45.46%)
18	UC	PU	UC	UC	UC	UC	PU	LK	UC	LK	PU	UC(54.55%)

Description : A = Type of Mechanical Wave based on the direction of propagation, B = Medium wave, C = Velocity of waves, D = Movement of particles on waves, E = Wavefront, F = Water waves properties, G = Rope waves properties, UC = Understanding concepts, PU = Partially Understand, LK = Lack of Knowledge, NU = Not Understanding Concepts, M = Misconception and D = Un encode, PR = preconception, HT = humanistic thinking, IR = incomplete reasoning, AT = associative thinking; FI = faulty intuition.

Table 14 Some students' answers at their answer sheet

Students	Students' answer	No. Question
1		4
3		7

Students	Students' answer	No. Question
4	Pilihan Jawaban: ~~A~~ B C D E Tingkat Kepuasan: A ~~B~~ — LK Alasan Memilih Jawaban: A B C D ~~E~~ F Tingkat Kepuasan: ~~A~~ B Jawaban Esai: massa jenis tali mem Pengaruhi cepat rambat gelombang.	5
5	Pilihan Jawaban: ~~A~~ B C D E Tingkat Kepuasan: ~~A~~ B — UC Alasan Memilih Jawaban: A B C D ~~E~~ F Tingkat Kepuasan: ~~A~~ B Jawaban Esai: Arah gerak partikel nya tegak - turun sedangkan rambat gelombang nya Horizontal.	1
6	Pilihan Jawaban: A B C ~~D~~ E Tingkat Kepuasan: A ~~B~~ — LK Alasan Memilih Jawaban: A B C D ~~E~~ F Tingkat Kepuasan: ~~A~~ B Jawaban Esai: Tidak. Karena gelombang tali tidak memiliki sifat difraksi	11
7	Pilihan Jawaban: A B C D ~~E~~ Tingkat Kepuasan: ~~A~~ B — LK Alasan Memilih Jawaban: A B C D E ~~F~~ Tingkat Kepuasan: A ~~B~~ Jawaban Esai: Dua anak yang berbicara melalui kaleng dengan perantara benang akan dengan jarak yang cukup jauh	3
12	Pilihan Jawaban: ~~A~~ B C D E Tingkat Kepuasan: ~~A~~ B — LK Alasan Memilih Jawaban: A B C D ~~E~~ F Tingkat Kepuasan: ~~A~~ B Jawaban Esai: hubungannya yaitu dapat mempengaruhi cepat rambatnya	5
14	Pilihan Jawaban: ~~A~~ B C D E Tingkat Kepuasan: ~~A~~ B — LK Alasan Memilih Jawaban: A B C ~~D~~ E F Tingkat Kepuasan: A ~~B~~ Jawaban Esai: Gerak partikel naik turun searah gerak rambatan.	6
15	Pilihan Jawaban: ~~A~~ B C D E Tingkat Kepuasan: ~~A~~ B — UC Alasan Memilih Jawaban: A B C D ~~E~~ Tingkat Kepuasan: ~~A~~ B Jawaban Esai: zat padat dpt menjadi medium perambatan gelombang	3
17	Pilihan Jawaban: ~~A~~ B C D E Tingkat Kepuasan: ~~A~~ B — UC Alasan Memilih Jawaban: A B C ~~D~~ E F Tingkat Kepuasan: ~~A~~ B Jawaban Esai: ketika gelombang merambat cepat sampai dan terjadi perambatan	9

Description: UC = Understanding Concepts and LK = Lack of Knowledge

Based on Table 13, Student-1 and Student-3 predominantly experienced a Lack of Knowledge (LK) on sub-concepts A, B and D-F for 63.64% for Students-1 and 45.46% for Students-2. While in other concepts, students experienced Partially Understand (PU) and Un encoded (D). Student-2 also experienced a Lack of Knowledge at 45.46% in sub-concepts B, D, E and G. While Students-5 only experienced a Lack of Knowledge at 36.37% in sub-concepts C, D and F and the experienced other conception levels in sub-concepts P, S and M. Misconceptions occurred in sub-concepts E and F caused by Faulty Intuition (FI) and Associative Thinking (AT).

The dominant Student-5's conception level was Concept Understanding (CU) at 45.46% and occurred in sub-concepts A-D and F. In other sub-concepts, the conception level of Student-5 was LK and PU. Students-6 and 7 predominantly experienced a Lack of Knowledge at 63.64% and 54.46%. Student-6 experienced LK in sub-concepts A, B and D-G while sub-concepts A-C and F for Students-7. Student-7 also experienced misconception in sub-concepts E, namely the Wavefront caused by Faulty Intuition. Meanwhile, same as Student-5, Student-8 predominantly experienced Concept Understanding at 45.46% on the same sub-concepts.

Student-9 experienced misconception in sub-concepts F caused by Associative Thinking (AT). Meanwhile, the dominant conception level was Lack of Knowledge with 54.55%. Students 10-13 also predominantly experienced a Lack of Knowledge at 36.37%. Students-10 predominantly experienced LK in sub-concepts B, C, and F. Students experienced UC and PU in other sub-concepts. Students-11 experienced LK in sub-concepts A, B and F. Furthermore, Students-12 also predominantly experienced LK, while in other sub-concepts, students experienced UC, PU and Not Understand Concepts (NU) for sub-concepts of Water Waves Properties (F). Unlike the case with Student-12, who predominantly experienced a Lack of Knowledge, Student-13 experienced misconceptions in sub-concepts F caused by Associative Thinking.

The next students who predominantly experienced a Lack of Knowledge (LK) were Students-14 and 16. Students-14 and 16 experienced LK at 54.55% in sub-concepts A and B-F for Students-14 and A and C-F for Students-16. Meanwhile, Students-14 and 16 also experienced misconception at 54.55% in sub-concepts A caused by Incomplete Reasoning (IR). Besides that, Student-16 also experienced misconceptions in sub-concepts B caused by Humanistic Thinking.

Meanwhile, Students-15 17 and 18 predominantly experienced Concept Understanding (CU) with consecutive percentages of 45.46%, 45.46% and 54.55%. The student experienced Concept Understanding in sub-concepts A, B-E for Students-15; A, B, D and F for Students-17 and A, B-D and F for Students-18. While in other sub-concepts, the student experienced Partially Understand (PU) and Lack of Knowledge (LK).

Of the total answers given by 18 students tested on 11 questions, the most dominant conception level was 'Lack of Knowledge (LK)' with 40.40%. The conception level of Understanding Concept (CU) experienced with percentages of 29.29%; Partially Understand (PU) at 23.23%; Not Understanding Concept (NU) at 1.52%; Misconception (M) at 4.04% and Un encoded (D) at 1.52%.

One of the Water Wave Properties sub-concepts questions was question number 8, with some combination of students' answers shown in Figure 4. That figure shows that the conception levels in question number 8 were: Understanding Concept (CU), Partially Understand (PU),

Lack of Knowledge (LK) and Misconception (M).

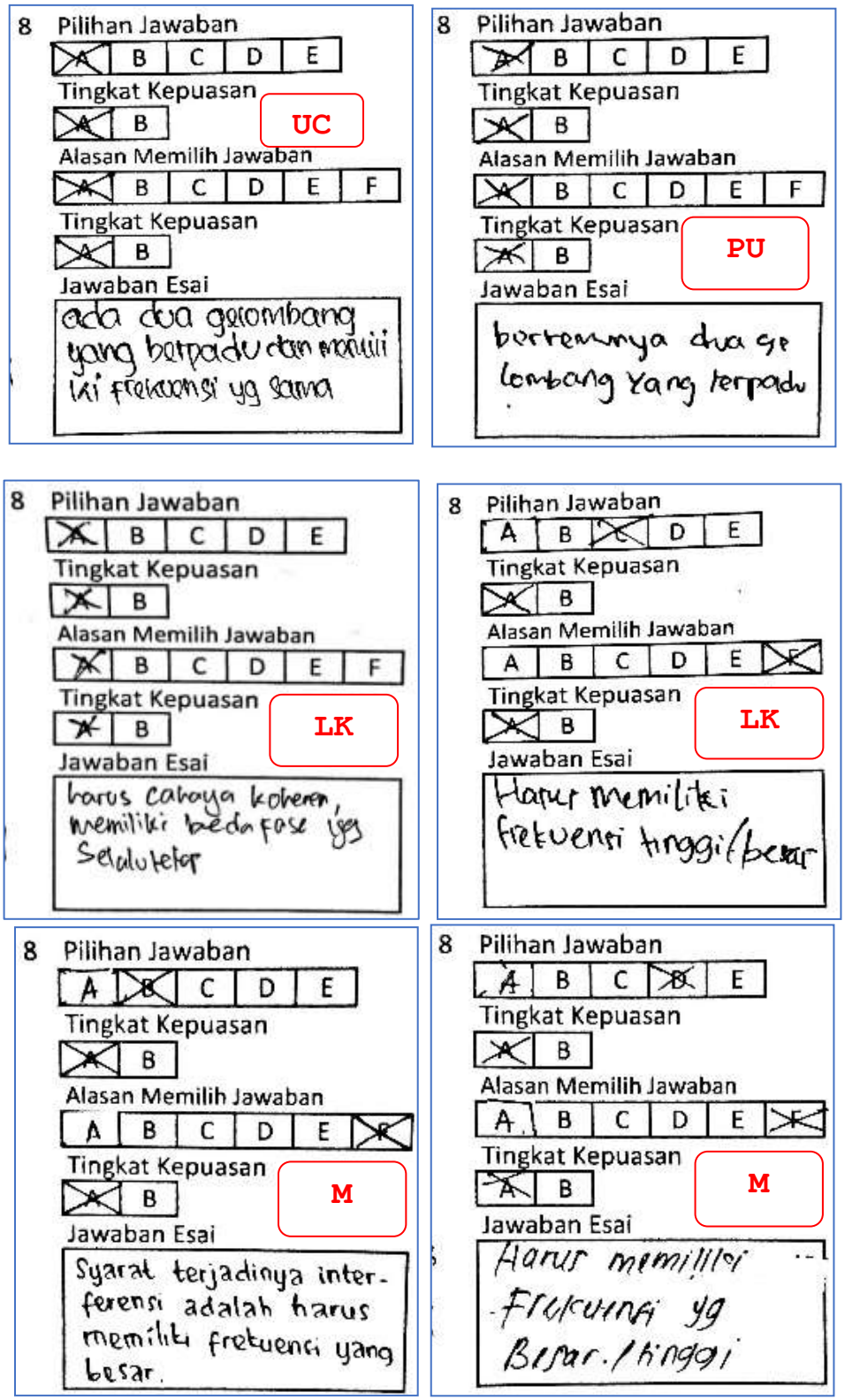


Figure 4 Some combination of students' answers on question number 8

Question number 8 was a question of sub-concepts Water Wave Properties where students were asked to choose the correct image related to Water Wave Interference. The fifth-step answer of students who experienced Partially Understand (PU) indicates that ‘interfered water waves are chime waves'. While the fifth-step answers of students who experienced Lack of Knowledge (LK) and Misconception (M) indicate that ‘interference must be waves that have a large frequency’.

Wave interference occurs when two or more waves combine and are in the same phase. The frequency does not affect the interference waves.

The Relevant research conducted by Nurfadila et al. (2020) also identified misconceptions in Mechanical Wave concepts. Their research suggested that the cause of the most common misconceptions was student thinking. Of the 7 sub-concepts tested on students, 46% were experienced misconceptions in Medium Wave Propagation sub-concepts and sub-concepts with largest misconception is Superposition with percentages of 49%.

The same research to identified students’ misconceptions on Mechanical Wave concepts was conducted by Widiyanto et al. (2018). In their work, the largest misconception that occurred was no relationship between fast tether rope and hand movement of rope-waving at 47.0%. While the lowest misconception is in the sub-concepts of the direction of wave propagation at 11.8%.

Another study was also conducted by Ansyah et al. (2021) who analyzed the students' profile misconceptions on the Mechanical waves. In their research, they found misconceptions in the concept of Wave Matter, especially on the Superposition, Reflection, Velocity, Frequency and Wavelength concepts. Among the 17 students tested, 15 of them were detected as having misconceptions.

Evaluation Stage

The evaluation stage in this paper is in the *'conclusion'* section.

CONCLUSION

Writing a five-step conception diagnostic test for Mechanical Wave concepts that have gone through the validity and reliability test stages showed that the conception diagnostic test is worth using. In addition, the results of trials conducted on 18 students showed that the test could be used to detect the students’ conception level in Mechanical Wave concepts and the cause of students experiencing misconceptions.

The practical impact of the results of this study is that the conceptual diagnostic test instrument that has been developed will be very useful for teachers in high school to detect the level of conception and potential misconceptions that may be experienced by students so that anticipatory action can be taken immediately by the teachers.

REFERENCE

Abdullah, M. (2017). *Fisika dasar II*. Bandung: Institut Teknologi Bandung.

Aisahsari, R., & Ulfah Ermawati, F. (2019). Validitas dan reliabilitas instrumen four-tier diagnostic test untuk materi arus listrik searah. *Inovasi Pendidikan Fisika*, *8*(2), 565–568.

Amin, N., Wiendartun, & Samsudin, A. (2016). Analisis instrumen tes diagnostik dynamic-fluid conceptual change inventory (dfcci) bentuk four-tier test pada beberapa sma di bandung raya. *Prosiding SNIPS 2016*, *1*(1), 570–574.

Anam, R. S., Widodo, A., Sopandi, W., & Wu, H. K. (2019). Developing a five-tier diagnostic test to identify students’ misconceptions in science: an example of the heat transfer concepts. *Elementary Education Online*, *18*(3), 1014–1029.

https://doi.org/10.17051/ilkonline.2019.609690

Anggrayni, S., & Ermawati, F. U. (2019). The validity of Four-Tier's misconception diagnostic test for Work and Energy concepts. *Journal of Physics: Conference Series*, *1171*(1). https://doi.org/10.1088/1742-6596/1171/1/012037

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.

Arikunto, S. (2013). *Prosedur penelitian suatu pendidikan praktik edisi revisi*. Jakarta: PT. Rineka Cipta.

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: Conf. Series*, *1013*(1).

Fajriyyah, N., & Ermawati, F. U. (2020). The validity and reliability of five-tier conception diagnostic test for kinetic theory of gases. *Inovasi Pendidikan Fisika*, *09*(02), 117–125.

Hanifah, L., & Ermawati, F. U. (2019). The validity and reliability of four-tier format misconception diagnostic test instrument for momentum and impulse concepts. *Inovasi Pendidikan Fisika*, *8*(2), 575–578.

Isfara, L., & Ermawati, F. U. (2018). Validitas instrumen four-tier misconception diagnostic test untuk materi fluida statis. *Inovasi Pendidikan Fisika*, *7*(3), 429–433.

Jannah, E. M., & Ermawati, F. U. (2019). Validitas dan reliabilitas instrumen tes diagnostik berformat four-tier untuk materi dinamika rotasi dan kesetimbangan benda tegar. *Inovasi Pendidikan Fisika*, *8*(2).

Kurniawati, D. M., & Ermawati, F. U. (2019). The validity of four-tier's misconception diagnostic test for dynamic fluid concepts. *Inovasi Pendidikan Fisika*, *08*(02), 668–671.

Lailiyah, S., & Ermawati, F. U. (2020). Materi gelombang bunyi: pengembangan tes diagnostik konsepsi berformat five-tier, uji validitas dan reliabilitas serta uji terbatas. *JPFT (Jurnal Pendidikan Fisika Tadulako …*, *8*(3), 104–119.

Nurfadila, S., Kaniawati, I., & Liliawati, W. (2020). Identifikasi miskonsepsi dan penyebabnya menggunakan tes diagnostik pada siswa sma kelas 11 materi gelombang mekanik. *Prosiding Seminar Nasional Fisika*, *0*, 99–107.

Putri, W. K., & Ermawati, F. U. (2021). Pengembangan uji validitas dan reliabilitas tes diagnostik five-tier untuk materi getaran harmonis sederhana beserta hasil uji coba. *PENDIPA Journal of Science Education*, *5*(1), 92–101. https://doi.org/10.33369/pendipa.5.1.92-101

Qonita, M., & Ermawati, F. U. (2020). The validity and reliability of five-tier conception diagnostic test for vector concepts. *Inovasi Pendidikan Fisika*, *09*(03), 459–465.

Ramadhani, N. N., & Ermawati, F. U. (2021). Five-tier diagnostic test instrument for uniform circular motion concepts: development, validity, reliability and limited trials. *Jurnal Pendidikan Fisika*, *9*(1), 73–90. https://doi.org/10.26618/jpf.v9i1.4763

Riduwan, R., & Akdon, A. (2013). *Rumus dan data dalam analisis statistika*. Bandung: Alfabeta.

Rohmanasari, F., & Ermawati, F. U. (2019). Validitas dan reliabilitas instrumen tes diagnostik miskonsepsi berformat four-tier pada materi alat optik. *Inovasi Pendidikan Fisika*, *8*(2), 556–559.

Rustandi, A., & Rismayanti, R. (2021). Penerapan model ADDIE dalam

Pengembangan Media Pembelajaran di SMPN 22 Kota Samarinda. *Jurnal Fasilkom*, *11*(2), 57–60. https://doi.org/10.37859/jf.v11i2.2546

Salsabila, F. N., & Ermawati, F. U. (2020). Validity and reliability of conception diagnostic test using five tier format for elasticity concepts. *Inovasi Pendidikan Fisika*, *09*(03), 439–446.

Sari, I. P. M., & Ermawati, F. U. (2021). Instrumen tes diagnostik konsepsi lima tingkat pada materi gerak lurus: pengembangan, uji validitas dan reliabilitas serta uji coba terbatas. *PENDIPA Journal of Science Education*, *5*(2), 152–162. https://doi.org/10.33369/pendipa.5.2.152-162

Sugiyono. (2015). *Metode penulisan pendidikan pendekatan kuantitatif, kualitatif, dan R&D*. Bandung: Alfabeta.

Utari, J. I., & Ermawati, F. U. (2018). Pengembangan instrumen tes diagnostik miskonsepsi berformat five-tier untuk materi suhu, kalor dan perpindahannya. *Inovasi Pendidikan Fisika*, *07*(03), 434–439.

Widiyanto, A., Sujarwanto, E., & Prihaningtiyas, S. (2018). Analisis pemahaman konsep peserta didik dengan instrumen. *Prosiding Seminar Nasional Multidisiplin*, (September), 138–146.

Young, H. D., & Freedman, R. A. (2012). University physics with modern physics 13th edition. In *Pearson-Addison Wesley*.

Zahra, Y., & Suprapto, N. (2019). Analisis kualitas instrumen four-tier diagnostic test untuk Mengidentifikasi profil konsepsi siswa pada materi teori kinetik gas. *Inovasi Pendidikan Fisika*, *08*(03), 830–834.