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Mechanical Wave Concept Inventory: Developing The Diagnostic Test Four-Tier For Evaluation

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ABSTRACT
Challenging for teachers in producing learning evaluation instruments that can diagnose students' abilities as well as student misconceptions was important. The diagnostic test four-tiers is one of the best assessment to diagnose students' misconceptions about physics concepts so that Mechanical Wave Concept Inventory has been developed in which form four-tiers diagnostic test. The instrument of the research are student sheet responses, and expert judgment reviews. Research and development frameworks' was included five processes that curriculum analysis processes, creating the design of the product, developing processes, implementing processes, and evaluating processes. The Pearson correlation sig. (2-tailed)resulted in which average r-count coefficient of 0.447 whose test instrument was concluded as valid. Alpha Cronbach's coefficient which was value of 0.90>0.70, so that the instrument was categorized as soon as possible reliable. Expert judgment index in which an average value of 0.87, that is categorized as very good. The quality of the questions was distributed with a classification of 24 good questions, 12 enough questions, and 4 bad questions. The difficulty level of the questions is divided into 7 questions in which easy categories as well as 33 questions in the medium category. Mechanical wave concept inventory was declared valid and reliable as well as good quality.

INTRODUCTION

21st-century science learning paradigm was oriented to developing the ability of communication, critical thinking skills creation, developing the scientific literacy, able to effective collaboration and increasing problem-solving skills [1]. Learning was included problem-solving such as able to apply the scientific approach, constructing knowledge, developing an innovative idea, and creating knowledge [2] [3]. The purpose indicates that Indonesian 21st-century national education is not only directed to make a learner knowledgeable but also to adopt a scientific attitude [4].

The students' integrated science process skills which are interpreting data, formulating hypotheses, planning experiments, and applying concepts. It was generating student conceptual changes and encouraging students to carry out investigative activities, improve various skills as well as perform process skills [5].The ability of thinking is examining activities which are reflections, critical, and creative. It was oriented to scientific processes who are involved in a concept, applicability of the concepts, collecting the data was resulted by observing, the analysis of information, and making decisions to conclude about sciences. There are many learning models will be increasing the mastery of concepts which are cooperative learning [6], inquiry learning [7], problem-based learning [8], project-based learning [9], and 5E- learning cycle: quantum teaching [10] [11]. Learning that only emphasizes theoretical concepts can cause students to lack in mastering scientific concepts. Lack of conceptual mastery can lead to misconceptions [12]. The mastery of concepts is one of the important things that is an indicator of the degree of mastery sciences for students [13]. The concept is part of meaning objects who have specific characteristics' .The conceptions are an interpretation of the meaning of objects in science by students' who are learning about the object. A misconception is a concept contradicts scientific definitions, instead of definitions approved by experts of particular field [14]. According to Fowler, misconceptions are the improper definite about the meaning of objects, not only incorrect used of concepts but also incorrect related to the concepts hierarchy between them [15]. It will distinguish about three definitions which are concepts, conceptions, and misconceptions.

The concept inventory (CI) is one of the best instrument that measures about misconceptions. It's a collection of questions who should be answered, respond, or hold by the students who are taking the test. Concept inventories usually are criterion referenced, composed of multiple-choice questions with only one correct answer per question, and a series of distractors which are incorrect or irrelevant answers often based on students' commonly held misconceptions [16]. The evaluation instruments were used to simplifying evaluation activities, able to describe the data according to the fact [17]. It's going to a prediction about students' achievement in the class. If the students' achievement was poorly conditioned so that the learning models have been failed. The diagnostic test is a measurement test both of strength and weakness conceptualization who is students learning about science. The result of the diagnostic test should be considered to following actions by the teacher. The diagnostic test usually in the form of specific questioners or schematic instructional depends on the purpose of indicators [18]. One of the important things about the result of the diagnostic test identifies the reason for who students don't understand the concepts [19]. The purpose of the result of a diagnostic test which is identification about the attainment of learning targets, and clarifying the reason "why are students getting misconception?". Basically the diagnostic tests was developing which are multiple choices diagnostic test [18], two-tiers diagnostic test [20] [21], three-tiers diagnostic test [22], and four-tiers diagnostic test [23]. There are many diagnostic tests that have been developed in physics learning such as Newton's Laws of motion [24], The simple electrical circuit [25], thermal, temperature and thermodynamic cycle [26] [27], The potential different in parallel electrical circuit [28], the optical geometry [29], the static fluids [23], the kinetic molecular theory of liquids [30], and the moon phases concept [16],

The four-tier diagnostic test was describing misconceptions, because of furnishing the reason for your answer, explaining about the reason, and your confidence levels answer. As following table 1, the diagnose cognitive criterion for the four-tier diagnostic test which are correct concepts, misconceptions, and incorrect concepts [23]. Limitations or drawbacks of multiple-choice, such as: (1) The student guesses variants contribute to errors and reduce the reliability of the test. (2) The selected options do not provide in-depth insight into students' ideas or conceptual understanding, (3) Students are forced to choose any answer from the options list is very limited, which prevents them from building up, organize and present their own answers. (4) difficulties to write multiple choice questions are good [31]. Diagnostic tests were developed to try to minimize these deficiencies by (1) consider the answer guesses of students with a combination of assessment indicators answer then categorized; (2) A description about the comprehensive and varied (new) of the diagnostic tests developed to be able to provide insight for students; (3) Given the empty space for the students to answer the other options not available. Based on the description of deficiencies and how tests are developed able to overcome the problems encountered. Uncover misconceptions in students the necessary diagnostic

tests form the four-tier which is different from the multiple-choice test normal, in which couldn't distinguish the correct answer due to the reason that right from those caused by the wrong reasons [32].

The mastery concepts about mechanical waves propagation are consisting of the characteristic about mechanical waves, both the function and the equation waves, the symptom of mechanical waves propagation, and applying mechanical waves in the daily life sciences. The mechanical wave propagation is not only conversions of energy but also change the momentums in the form of periodic oscillation without flitting the propagation medium.

Concept inventory is the result of developing an assessment of who students are important to learning physics [33]. There are several forms of the test which are used to measure the students' achievement about the concept. It's consisting of Programme for International Student Assessment (PISA), Progress in International Reading Literacy Study (PIRLS), and Trends in International Mathematics and Science Study (TIMSS). The form of test both TIMSS test and PISA test was higher-order thinking skills (HOTS) lesson. Students' Higher Order Thinking Skills (HOTS) can be honed by gradually developing new concepts from their multiple representation abilities [34]. If we refer to PISA, there are several descriptions about criterion conceptual understanding who students have been achieved. The first one, students have to explaining in their familiar situations based on evidence. The second one, students have better knowledge that was able to apply in their familiar situations so that are making decisions based on simply observing. The third one, students able to identify problem who are suitable about the contexts, students' had wielded factual knowledge who are able to explain the phenomenon with simplifying the form so that making a conclusion based on factual knowledge. The fourth one, student was creating inferences about science which is integrating knowledge with daily life sciences so that able to reflecting their actions and communicating the suggestion based on scientific evidence. The fifth one, students was identifying complexity scientific issue which is applying the scientific concepts, classifying the concepts, choosing a correct concept, and evaluating their scientific evidence where is suitable about the problem. They were able to investigate the concepts who have better initial knowledge. students' were applying critical thinking skills which are put up to explaining the concept based on the scientific evidence and constructing the argues' through critical analysis processes. The Sixth one, students conceptual understanding which is explaining the concepts about sciences both applying and identifying the concepts. Students' was inferenced a lot of learning references and some alternatives explanation about sciences. Students' should be used to decision making based on scientific evidence. students' thoroughly both critical thinking and reasoning about sciences. The conceptual understanding was used to support the solution. Students' able to developing sciences who have growth up personality skills, sociality connecting, and conclusion about a global issue [35]. More the greatest conceptual understanding will be reflecting in their students ability to solve the problem.

METHOD

The mechanical waves concept inventory (MWCI) was developed by using research and development (R & D) design. Research frameworks' is consisting about five processes which are curriculum analysis processes, creating the design of the product, developing processes, implementing processes, and evaluating processes. The research flow starts from literature studies and field studies, finding potential problems, collecting data in the form of a list of potential problems encountered, design of predetermined diagnostic tests based on the criteria to be developed, product development processes, testing to see the correlation of student answers. Regarding the items developed, product revisions based on product trial considerations, expert judgment, product assessment results based on product trial considerations and expert judgment considerations, display of mechanical wave concept inventories, documentation of student understanding profiles after doing the diagnostic test.

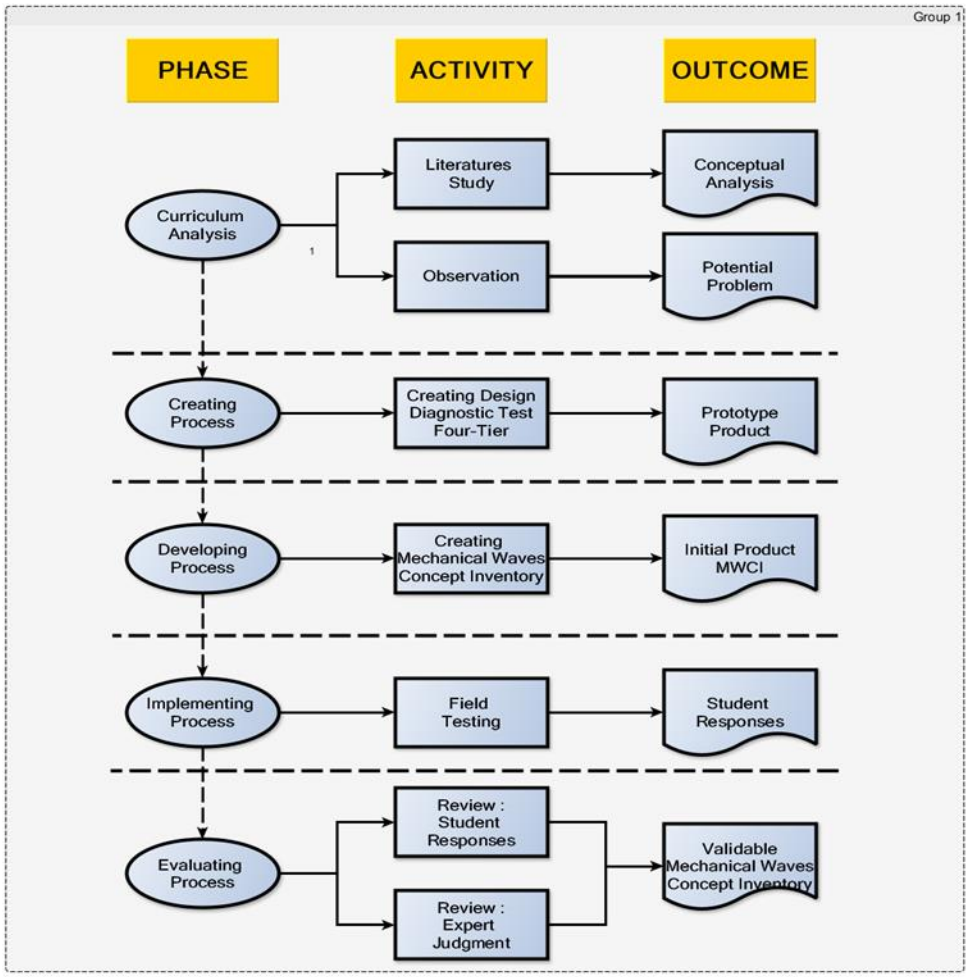


Fig 1. *Method of Developing the Mechanical Wave Concept Inventory*

As following figure 1 that was explained the development processes of MWCI. 1st process in this research has started with literatures study and field study. It is not only discovers the potential problem but also dawn process for conducting a research. This process will a produce a study plan, conceptual analysis mechanical wave propagation, mapping conceptual, question indicators. 2nd process was collecting the data which is listing of the potential problem. 3rd process was creating the design of four-tier diagnostic test that has been depend on some criteria in which this research. In this process will produce diagnosing criterion indicators and specification product. 4th process was implementing processes that activity was field testing to have some student responses. field testing was implementing for 40 student in SMA Negeri 1 Palembang. 5th process was evaluating processes that were determined not only in student responses review but also in expert judgment review. It's going to validated mechanical waves concept inventory.

Table 1. The Diagnose Cognitive Criterion For the Four-Tier Diagnostic Test

Criterions	**Interpretations criterion based on the answer combinations**			
	Correcting the answer	**Confidence levels**	**Correcting the reason**	**Reason confidence levels**
Correct the Concepts	Correct	Surely	Correct	Certainly
	Correct	Surely	Correct	Uncertainly
	Correct	Unsurely	Correct	Certainly
	Correct	Unsurely	Correct	Uncertainly
Misconceptions	Incorrect	Surely	Correct	Certainly
	Incorrect	Surely	Correct	Uncertainly

	Incorrect	Surely	Incorrect	Certainly
	Incorrect	Surely	Incorrect	Uncertainly
	Incorrect	Unsurely	Incorrect	Certainly
	Incorrect	Unsurely	Correct	Certainly
	Incorrect	Unsurely	Correct	Uncertainly
	Incorrect	Unsurely	Incorrect	Uncertainly
	Correct	Surely	Incorrect	Uncertainly
Incorrect	Correct	Unsurely	Incorrect	Uncertainly
Concepts	Correct	Surely	Incorrect	Certainly
	Correct	Unsurely	Incorrect	Certainly

Table 1 describes the classification of the level of understanding of the concept which is divided into three criteria, namely correct the concepts, misconceptions, and incorrect the concepts. Understanding the concept occurs when students can find a link between multiple choice alternatives and alternative reasons where students can answer correctly along with the reasons for the answer. Misconception occurs when students cannot correctly answer the questions posed even though the reason for choosing the right answer is. Incorrect the concept occurs when students cannot explain the reasons for choosing answers even though they have answered the questions correctly.

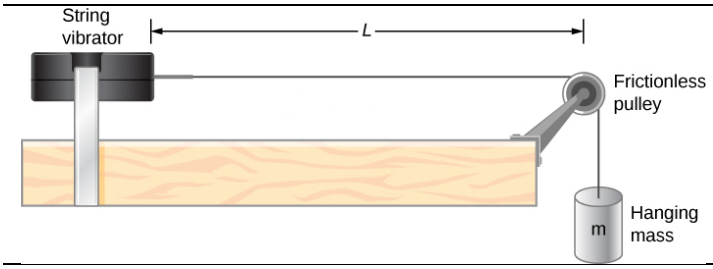
The diagnostic test validity has used by Pearson Correlation Sig. (2-Tailed), meanwhile measuring the consistency level of the diagnostic test items used Alpha Cronbach. The quality of the questions is obtained by looking for both the index of distinguishing power and the level of difficulty of the questions.

RESULTS AND DISCUSSIONS

The diagnostic test four-tiers is one of best assessment to diagnose students' misconceptions about physics concepts [36] [37]. There are some research about diagnosing misconceptions in physics material such as density [38], fluid [23], dynamic fluid [39], geometrical optics [36], heat and temperature [40], work and motion [41]. The instrument in this research was giving some information about analytical mechanic wave characteristics, mechanical wave propagation, analysis stationary wave through the melde experiment, in which the information about student misconceptions. Diagnosing student misconceptions is explained by reviewing student responses that according to category of the student answers combination. figure 1 was delineated mechanical wave concept inventory as diagnostic test four-tiers that consist of some sections which are question indicators, stem questions, multiple-choices alternatives, discussion, alternative reasons, knowledge dimensions. Several branch for creating MWCI which are question indicators, stem questions, multiple-choices alternatives, discussion, alternative reasons, knowledge dimensions, HOTS levels, and HOTS analysis. Based on the methods that was conducted, The design MWCI in which table 2 has described.

Table 2. Mechanical Waves Concept Inventory

Question Indicators :	
Students were able to analyze mechanical waves propagation on the string through Melde experiments based on identifying physical quantities of the waves precisely.	
Stem Questions :	**Multiple-choices alternatives :**
Tension on the rope given by way of hanging a mass of at one end as following the picture below. If the rope was vibrated by the vibrator, it will generate a wave. How to get faster propagation waves on the rope	a) Add to the object's mass that is hung on one end of the rope. b) Replace the rope with rope mass greater than the initial state. c) Reduce the mass of the object that hung on one end of the rope. d) Using a shorter leash and a larger



mass.

e) .....

Discussion :

The wave motion can be regarded as a transfer of energy and momentum from one point in space to another point without the displacement of material. In the mechanical waves, like waves on a string. Energy and momentum transferred by disturbances in the medium. Rope vibrated in various ways. The propagation disturbance to the rope along the rope. Disturbances are transmitted due to the nature of the elastic medium. The rapid propagation of waves on a string is the physical quantities wavelength determined by the elasticity of the medium and inertia factor.

$$v = \sqrt{\frac{F}{\mu}}$$

$$F = m_{object} \bullet g \; ; \; \mu = \frac{m_{rope}}{L}$$

If the tension on the rope is greater, the greater the wave propagation speed, because each string segment is closer to each other.

If the density of the linear medium is greater, the greater the inertia factor of the string too. Instead of the slower the wave will propagate.

The analysis of the answers to the following statement:

Adding to the mass of the object that hung on one end of the rope. the greater the mass of the object that is hung on the end of the rope, the greater the tension applied to the rope. If the tension on the rope bigger, then the wave propagation speed in the larger rope.

Replacing rope with a mass greater than the initial state. the greater the mass of the rope, the greater the linear mass density rope. Inertia factor becomes increasingly large, causing waves propagate with the wave propagation speed is relatively slower than the initial state.

Reducing the mass of the object that hung on one end of the rope. This statement causes the magnitude of the tension provided on the rope will be smaller. If the rope tension got smaller, the slower waves on the rope will get slower.

Using a shorter leash and a larger mass. The shorter the rope used, the greater the resulting mass density (rope mass = constant). If the rope linear mass density greater, then the greater the inertia factor so fast propagation through the medium of the rope relatively slower.

Alternative Reasons:	**Knowledge Dimensions :**
Rope tension influenced by the mass of rope hanging on a rope. The greater the linear rope density, the greater the wave propagation speed. Waves propagation isn't affected by the mass of which is hung on one end of the rope. The length of the rope affects the rapid propagation of waves on a rope.	Factual Dimensions Conceptual Dimensions

HOTS Levels :

Level 5 : Students' was identifying complexity scientific issue which is applying the scientific concepts, classifying the concepts, choosing a correct concept, and evaluating their scientific evidence where is suitable about the problem. They were able to investigate the concepts who have better initial knowledge. students' were applying critical thinking skills which are put up to explaining the concept based on the scientific evidence and constructing the argues' through critical analysis processes.

HOTS Analysis :	
Identify the problem to be resolved	How to generate a wave that has the attributes of wave propagation speed is relatively faster ?.
Identify important linkages obtained information to solve the problem	Identification of the information related to the problem, namely the tension straps that are influenced by the weight of objects that are hung on the end of the rope. Understanding of other physical quantities such as the mass of rope, long rope, rapid propagation of waves on a string.
Designing a model to solve the problem	The rapid propagation of waves on a string affected by the rope tension and the linear mass density of the string. The greater the tension rope is given, the greater the wave propagation speed is generated. If the linear mass density rope enlarged, the rapid propagation of waves generated gets smaller. $$v = \sqrt{\frac{F}{\mu}}$$ Based on Melde's experiments, tension on the rope given by way of hanging a mass of at one end. So that the tension rope is affected by heavy things hanging. A heavy object is proportional to the tension produced rope. $$F = m_{object} \bullet g$$ As for the linear mass density of the rope is determined by the mass of the rope per unit length of rope. $$\mu = \frac{m_{rope}}{L}$$

Based on table 2 it can be explained that the Question indicator is an assessment indicator that has been determined based on the curriculum analysis process which refers to the learning objectives to be achieved by students. STEM questions are part of a statement or order that students must find a solution to. Multiple-choice alternatives are options given to solve the problems contained in the item questions. Discussion is an explanation of the framework for solving problems after students choose multiple-choice alternatives (this section is only for teachers) and will be discussed with students at the end of the lesson. Alternative reasons are the reasons for choosing the right answer option, in this section it is hoped that there is a relationship with multiple-choice alternatives. Knowledge dimensions are the dimensions of knowledge that play a role in finding solutions to problems in the items. There are 4 knowledge dimensions, factual, conceptual, procedural, and meta-cognition. HOTS levels are problem-solving levels that students must have in order to find the right concept to solve the problem in the item questions. HOTS analysis is a framework for simplifying existing problems, which in this section students are associated with identifying problems, Identify important linkages obtained information to solve the problem, and designing a model to solve the problem.

Field tests have been carried out on 40 student samples and testing the validity of the items using item analysis. The Pearson correlation sig. (2-tailed) was used in the item analysis, so that the results obtained from 40 items were 36 valid items and 4 invalid items. Table 4 and table 5 were explained the significance of the correlation coefficient of students' answers. The Pearson correlation yields a mean r-count coefficient 0.447, when compared with r-table which a value of 0.312 for 40 samples so that the test instrument is valid.

Table 3. The Interpretation of Validated 1a-10b

No	Pearson Correlation	Interpretation
1a	0.426	Validated
1b	0.326	Validated
2a	0.327	Validated

2b	0.181	Invalidated
3a	0.317	Validated
3b	0.455	Validated
4a	0.419	Validated
4b	0.387	Validated
5a	0.514	Validated
5b	0.363	Validated
6a	0.490	Validated
6b	-0.017	Invalidated
7a	0.597	Validated
7b	0.556	Validated
8a	0.628	Validated
8b	0.226	Invalidated
9a	0.416	Validated
9b	0.591	Validated
10a	0.472	Validated
10b	0.387	Validated

Table 4. The Interpretation of Validated 11a-20b

No	Pearson Correlation	Interpretation
11a	0.532	Validated
11b	0.385	Validated
12a	0.602	Validated
12b	0.543	Validated
13a	0.537	Validated
13b	0.620	Validated
14a	0.625	Validated
14b	0.354	Validated
15a	0.477	Validated
15b	-0.049	Invalidated
16a	0.561	Validated
16b	0.497	Validated
17a	0.549	Validated
17b	0.435	Validated
18a	0.701	Validated
18b	0.529	Validated
19a	0.513	Validated
19b	0.538	Validated
20a	0.467	Validated
20b	0.408	Validated

Meanwhile Alpha Cronbach's used to measure the reliability of the test according to the number of items that have been declared valid on the Pearson correlation sig. (2-tailed). Based on the response data of 40 students to 36 items, the Cronbach's Alpha coefficient in which value is 0.90. The items are interpreted to be reliable in the very high category. Student responses are used to measure the level of difficulty of each item. The level of difficulty is obtained from the comparison between the correct answer and the wrong answer for each item. Table 5 describes the classification of the questions which is difficulty level of the questions.

Table 5. Description of Problem Level of Difficulty

N	40
Mean	0.565
Standard Deviation	0.120
Median	0.550

Number of easy questions	7
Number of Intermediate questions	33
Number of hard Questions	0

The quality of each item can be seen from the index of distinguishing power. Table 5 describes the quality of the 40 multiple choice items. Based on table 6, there are 24 questions in good categories, 12 questions in good enough categories, and 4 questions in bad categories.

Table 6. Description of Distinguishing Power Index (DPI)

N	40
The Highest DPI	0.95
The Lowest DPI	0
Number of good questions	24
Number of enough questions	12
Number of bad questions	4

In this research, validation was also carried out with expert judgment. Several aspects of the assessment that were assessed in the validation process included by technical quality, quality of content and purpose of the items, content feasibility and language eligibility, as well as contextual assessment. Table 8 has describes the interpretation of the expert judgment index.

Table 7. Description of Expert Judgment Index

Aspects Assessment	**Expert Rating Index**	**Interpretation Index**
Technical Quality	0,84	Very good
Quality and purpose of the items	0,87	Very good
Feasibility item	0,89	Very good
Language Eligibility	0,84	Very good
Contextual Assessment	0,91	Very good

The expert judgment process in this study involved 5 reviewer who assessed the instrument. Table 7 was shown that explanation of several aspect assessment by way of expert review phase. Assessment indicators which are aspects of technical quality include the use of editors on STEM questions, alternative answers, and alternative reasons for answers. technical quality also includes the completeness of the material, the breadth of the material, the depth of the material. As for the quality and purpose of the items, the indicators are the appropriateness of the use of instruments in students, conformity with basic competencies, learning indicators, and learning objectives based on concept analysis and item analysis. Feasibility items and language eligibility include indicators for assessing the level of readability and meaning of the questions that can be translated well by students. The contextual assessment aspect includes indicators of the accuracy of concepts, terms and ornaments in questions (pictures, diagrams and illustrations) and the accuracy of facts and data.

CONCLUSION AND SUGGESTION

A challenge for teachers in producing learning evaluation instruments that can diagnose students' abilities as well as student problems. Mechanical Waves Concept Inventory has been developed inform four-tier diagnostic test as an evaluation instrument to diagnose not only student understanding but also student misconceptions on mechanical wave material. The Pearson correlation sig. (2-tailed) resulted in which an average r-count coefficient of 0.447 so that the test instrument was concluded as valid. Alpha Cronbachs' coefficient with a value of 0.90> 0.70, then the instrument is categorized as reliable. Expert judgment index with an average value of 0.87, so the interpretation of the assessment

index was categorized as very good. The quality of the questions was evenly distributed with a classification of 24 good questions, 12 enough questions, 4 bad questions. The difficulty level of the questions is divided into 7 easy categories and 33 questions in the medium category. Mechanical wave concept inventory was declared valid and reliable as well as good quality. The implications of the research will create the concept inventory as evaluation instrument about mechanical wave, so that will describe the profile of student misconceptions and student ability due to mechanical wave concept inventory. It was important things for teacher to improve their project in learning, repair learning processes and health the student misconception in physics lesson especially mechanical wave propagation. Finally, if we could create good assessment, we will evaluate every single student concept and correcting them for the subsequent learning as well as mapping their competency.

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