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Detecting Students' Misconception in Simple Harmonic Motion Concepts Using Four-Tier Diagnostic Test Instruments

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ABSTRACT

This research aims to develop the test instrument that is feasible in terms of validity, reliability, and difficulty level and to identify students' misconceptions in simple harmonic motion concepts. The development stages used in this research were the modifications result from Oriondo & Dalo-Antonio, which included: (1) planning and design development, (2) trying out, and (3) measurement and interpretation of results. The instrument has been developed and categorized as effective because it is declared valid and reliable based on the criteria of the lowest and highest limit of the INFIT MNSQ which is 0.77 and 1.30, all test items are fitted with the PCM model, and the instrument's reliability has an item reliability value of 0.73 with a good category. The test instrument was applied to 60 students of the tenth-grade of senior high school. Based on the results, the four-tier test instrument developed was able to identify students' conceptual understanding of 36.4%, and 17.7% of students only understood parts of concepts, 40.7% of students experienced misconceptions, and 5.2% of students did not know the concept. The biggest misconception occurred in the subtopic frequency of simple harmonic motion by 75%, the relationship of the rope length with the pendulum vibration period by 60%, and 58.3% about the relationship between the total spring constant and the spring frequency. The instrument developed in this research was able to detect students' misconceptions, especially student learning experiences about simple harmonic motion.

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INTRODUCTION

The misconception is one of the factors that affect students' physics conceptual understanding that can produce a different concept of scientific concepts (Kirbulut & Geban, 2014; Gurcay & Gulbas, 2015; Widiyatmoko & Shimizu, 2018). The misconception is formed on students thinking who are trying to build an understanding of the problem-solving process and archive new information into their cognitive structures based on imperfect student's reasoning ability (Kamilah & Suwarna, 2016; Ling, 2017; Tumanggor *et al.*, 2019).

Physics misconceptions occur in many physics materials, including kinematics concepts (Zulfiani *et al.*, 2014; Wiyono *et al.*, 2016), static and dynamic fluid concepts (Wijaya *et al.*, 2016; Sholihat *et al.*, 2017; Irwansyah et al., 2018), states of matter (Kirbulut *et al.*, 2014), photoelectric effects (Taslidere, 2016), static electricity (Hermita, 2017), heat and temperature (Gurcay *et al.*, 2015), optical geometry and optical instruments (Fariyani *et al.*, 2017; Gurel *et* *al.*, 2017; Widiyatmoko & Shimizu, 2018), magnetism concepts (Hermita, 2017), concepts of atomic nuclear (Yusrizal & Halim, 2017), astronomy concepts (Kanli, 2015), energy and momentum concepts (Afif *et al.*, 2017).

One of the interesting physics material to be discussed is simple harmonic motion. The general properties of simple harmonic motion require understanding and analytical abilities to be able to relate it to physical phenomena. Students' understanding of related concepts shows that the majority of students have obstacles in learning physics, including misconceptions about restoring force and mathematical operational correlations to real motion, especially phase angles (Somroob & Wattanakasiwich, 2017). Students' other difficulties are defining the equilibrium position, and also the relationship between frequency and amplitude, and students assume that the amplitude depends on the frequency or period value (Nugraha *et al.*, 2019). Research from Sugara *et al.* (2017) revealed that students were still wrong in using relevant knowledge when solving physics problems, even though students had already conducted their experiments and discussed it with the teacher. Based on the arguments revealed by students, it shows that students' understanding of the spring-mass system frequency is not strong.

Misconception can obstacle the assimilation process of new knowledge after learning, so it must be detected immediately. Identification of misconceptions correctly has become the main step to get an understanding of student learning, detecting misconceptions required appropriate instruments to reveal students' conceptual understanding (Gurel *et al.*, 2017; N Hermita *et al.*, 2017). There are many instruments used by researchers to identify students' misconception, including using CRI (*Certainly of Response Index*), clinical interview, concept maps, essay tests, open-response questionnaires, practicum with question and answer, or using diagnostic tests (Zulfiani *et al.*, 2014; Kamilah *et al.*, 2016; Gurel *et al.*, 2017; Sholihat *et al.*, 2017).

The state of conception that the students have is closely related to the confidence level in the students' conception. Therefore the appropriate test instrument for diagnosing the state of students' conception is diagnostic tests. Various diagnostic test formats have been developed by researchers to diagnose students' misconceptions on simple harmonic motion, including instruments in the multiple-choice form with open reasons (Nugraha *et al.*, 2019; Sugara *et al.*, 2017) and the conceptual test survey format (Somroob *et al.*, 2017). The diagnostic test has been designed with the conception confidence level to classify students' conception levels, namely a multiple-choice diagnostic test with the four-tier format (Afif *et al.*, 2017; Hermita *et al.*, 2017; Krisdiana *et al.*, 2018).

The advantage of a four-tier diagnostic test is that it can explore students' deeper conceptual understanding due to their confidence level in the answer and reason choice. Therefore, this research will develop a four-tier diagnostic test instrument systematically to detect students' conceptual understanding and misconceptions on simple harmonic motion material. Although many test instruments are used to identify students' misconceptions on physics material that have been discussed in the literature, there are no reports that discuss four-tier test instruments to identify each sub-topic on simple harmonic motion concepts. This research is expected to be used as a reference for teachers, educators, and other researchers to identify which sub-topics are the biggest misconceptions about simple harmonic motion.

METHODS

This research aimed to develop the diagnostic test instrument that is feasible in terms of the validity analysis, reliability, and difficulty level of the test instrument and to detect students' misconceptions in simple harmonic motion (SHM). The research stages presented in Figure 1 refer to the making of test instruments made by Supahar & Prasetyo (2015). The development stages of the test instrument include three stages, namely (1) planning of test, (2) trying out, and (3) measurement. The development stages of the test instrument were the modification result of Oriondo & Dallo-Antonio (1984).

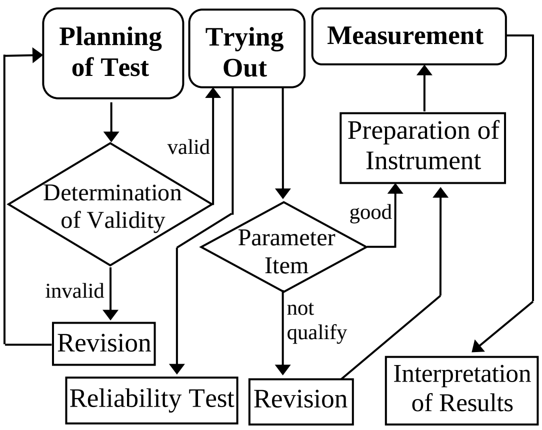


Figure 1. The Research Procedure

The research was conducted at SMA and Madrasah Aliyah in Yogyakarta Special Region from February to May 2019. The sampling technique uses simple random sampling. The subjects of this research were students of class X MIPA consisting of 2 classes at SMA Negeri 1 Banguntapan and two classes at MAN 3 Yogyakarta. Trying out stage on the assessment instrument involved 113 respondents, and the measurement stage involved 60 respondents.

The research procedures are: (1) The test planning stage includes the determination of test objectives, compiling test item indicators and rubrics, designing test items, determining validity by experts, revising, and designing instruments. The design of the test items in the multiple-choice and the reasons form with giving four scoring criteria. (2) Trying out stage is carried out to determine the instrument feasibility, such as the determination of content validity through Focus Group Discussion (FGD) activity with the determination carried out by experts (Mardapi (2017). Trying out were conducted to 113 students, then the items were analyzed by reviewing the item parameters, namely item validity, reliability, and difficulty level of the instrument, so the instrument could function before the measurement stage was carried out to respondents.

Data were analyzed using the Quest program. Data obtained in the form of 4 categories of polytomous data were analyzed according to Partial Credit Model (PCM), and the test suitability results were observed from the MNSQ INFIT parameters that met the *fit statistics* criteria based on PCM. (3) Measurement stage includes the test design based on the results of trying out, and interpretation of measurement results based on the combination of the answers to the four-tier diagnostic instrument and is applied to 60 students to see misconception in SHM material.

The four-tier diagnostic instrument has four categories of respondent distribution. The four-tier instrument format was made in several choices and explanations, as shown in Figure 2 (Hermita *et al.*, 2017).

(Problem Description)
Answer (Tier-I):
A. Alternative Choice of first answer
B. Alternative Choice of second answer
C. Alternative Choice of third answer
D. Alternative Choice of fourth answer
E. Alternative Choice of fifth answer
Confidence Level (Tier-II):
A. Alternative choice if "Sure" of the selected answer
B. Alternative choice if "Unsure" of the selected answer
Scientific Reason for My Answer (Tier-III):
A. Alternative Choice of first reason
B. Alternative Choice of second reason
C. Alternative Choice of third reason
D. Alternative Choice of fourth reason
E. Open Reason
Confidence Level (Tier-IV):
A. Alternative choice if "Sure" of the selected reason
B. Alternative choice if "Unsure" of the selected reason

Figure 2. four-tier test format

Analysis of the respondents' answers distribution classified in the category of decision answers about conceptual understanding with the students' classification guidelines in *Understand the Concept* (UC), *Understand Partial of Concepts* (UPC), *Misconception* (MSC) dan *Not understand the Concepts* (NC) categories shown in Table 1 (Gurel, Eryilmaz & McDermott, 2015).

Table 1. Decision category of the answers level combination

Answer (1st tier)	**Confidence Level** (2nd tier)	**Reason** (3rd tier)	**Confidence Level for Decision** (4th tier)	**Decision Category**
True (T)	Sure (S)	True (T)	Sure (S)	Understand the concept (UC)
True (T)	Sure (S)	True (T)	Unsure (U)	Understand Partial of Concepts (UPC)
True (T)	Unsure (U)	True (T)	Sure (S)	Understand Partial of Concepts (UPC)
True (T)	Unsure (U)	True (T)	Unsure (U)	Understand Partial of Concepts (UPC)
True (T)	Sure (S)	False (F)	Unsure (U)	Understand Partial of Concepts (UPC)
True (T)	Unsure (U)	False (F)	Unsure (U)	Understand Partial of Concepts (UPC)
False (F)	Sure (S)	True (T)	Unsure (U)	Understand Partial of Concepts (UPC)
False (F)	Unsure (U)	True (T)	Unsure (U)	Understand Partial of Concepts (UPC)
False (F)	Sure (S)	False (F)	Unsure (U)	Understand Partial of Concepts (UPC)
False (F)	Unsure (U)	False (F)	Unsure (U)	Understand Partial of Concepts (UPC)
True (T)	Sure (S)	False (F)	Sure (S)	Misconception (MSC)
True (T)	Unsure (U)	False (F)	Sure (S)	Misconception (MSC)
False (F)	Sure (S)	False (F)	Sure (S)	Misconception (MSC)
False (F)	Unsure (U)	False (F)	Sure (S)	Misconception (MSC)
False (F)	Sure (S)	True (T)	Sure (S)	Not Understand the concepts (NC)
False (F)	Unsure (U)	True (T)	Sure (S)	Not Understand the concepts (NC)

RESULTS AND DISCUSSION

The planning and design stages are consistent with the research method. Test instruments that have been prepared in the draft must be validated before use. The content validity of an item can be proven by using V-Aiken's coefficients. The instrument standard declared valid is 0.75, with the smallest category scales of the V-Aiken's coefficient is 2, and the largest is 7 (Aiken, 1985). V-Aiken's coefficient value is obtained from the number of experts (*n*). V-Aiken's coefficient value has a range of -1 to 1 (Bashooir & Supahar, 2018).

Validation can also be determined by *Classical Test Theory* (CTT) or *Item Response Theory* (IRT). *Rasch model* is a part of IRT that can be done using the *Quest* program. The item is declared valid if the *INFIT MNSQ* value is in the range of 0,77 to 1,30 (Subali & Pujiati, 2012).

This research uses five category scales and eight assessors consisting of experts and teachers so that the V-Aiken's table score is 0.75 based on the standard determined by Aiken's V. Assessments carried out by each assessor can include the suitability between learning objectives and indicators, the content suitability, choice of answers, language or the instrument suitability as a measurement tool. Based on the content validity analysis, the results of the data item category are shown in Table 2.

Table 2. Content validity analysis based on V-Aiken

Items Number	**V-Aiken Coefficient**	**Category**
1	0,77	Valid
2	0,76	Valid
3	0,76	Valid
4	0,76	Valid
5	0,77	Valid
6	0,76	Valid
7	0,76	Valid
8	0,75	Valid
9	0,76	Valid

Table 2 shows that the results of the analysis using Aiken's V were in the range of scores from 0.75 to 0.77. Following the Aiken-V standard criteria, the item is valid if V-Aiken ≥ 0,75 so that the analysis results can be stated that nine items are categorized as valid and can be used for further research.

Trying out stage was carried out to 113 students in Yogyakarta. The items are declared as valid if the analysis with the Partial Credit Model (PCM) uses the *Quest* program, having an *Infit MNSQ* value in the range of 0.77 to 1.30 (Subali & Pujiati, 2012). Information obtained from trying out with the Quest program includes item validity, reliability, and item difficulty levels. The item validity can be known through the Quest output by observing the value of *Infit MNSQ* and *Output MNSQ*. *Infit MNSQ* and *Output MNSQ* show the compatibility of each item with PCM. The results of item validity testing are shown in Table 3.

Table 3. Test parameter fit statistics

Items	Infit MNSQ	Output MNSQ	Status	Category
1	0,86	0,90	Item fit	Valid
2	0,97	1,45	Item fit	Valid
3	0,95	0,96	Item fit	Valid
4	1,18	1,25	Item fit	Valid
5	1,22	1,26	Item fit	Valid
6	0,84	0,82	Item fit	Valid
7	1,02	0,98	Item fit	Valid
8	0,84	0,77	Item fit	Valid
9	0,86	0,77	Item fit	Valid

Table 3 shows that each item matches the 1-PL PCM model. The items stated were fit for the *Infit MNSQ* model between 0.77 to 1.30, and the *Outfit MNSQ* value was between 0.5 to 1.5 (Boone et al., 2014).

The reliable instrument is an instrument that is used several times to measure the same object, will produce the same data. The valid and reliable instrument for data collection, it is expected that research results will be valid and reliable. Reliability can be said as a consistency degree or the constancy of an instrument (Sugiyono, 2016). Test reliability shows the test scores can describe the ability of students who take the test. Test reliability is known by observing item reliability and person/case reliability in item statistics using the *Quest* program shown in Table 4.

Table 4 Analysis of instrument reliability estimates

Reliability	Reliability Coefficient
Summary of Item Estimates	0,73
Summary of Case Estimates	0,70

Table 4 shows the case reliability value of 0.70 and item reliability of 0.72. Based on the criteria stated by Sumintono & Widhiarso (2015), the value stated that the items in the instrument were reliable, and the consistency of students' answers was good. This shows that diagnostic instruments are acceptable because the reliability of the items is good enough.

The difficulty level of items or difficulty index is an opportunity to correctly answer the items at a certain level of ability, which is generally expressed in the form of an index. Good items are items that are neither too difficult nor too easy for diagnostic purposes. The difficulty level of the item can be known through the *Quest* program. The item difficulty index can be seen from the Quest output in Table 5.

Table 5. Item difficulty index analysis

Item Number	Difficulty	Category
1	0,09	Good
2	0,68	Good
3	0,77	Good
4	0,09	Good
5	1,24	Good
6	-0,22	Good
7	-1,16	Good
8	-0,46	Good
9	-1,03	Good

Based on Table 5, the difficulty level is in the range of scores -1.16 to 1.24. All items are in the score range of -2.0 to +2.0, so that the instrument is said to be good. The difficulty level of the items is in the range of easy, medium, and difficult. An item that has the difficulty level to +2.0 is classified as a difficult item, while an item with difficulty level to -2.0 is classified as an easy item.

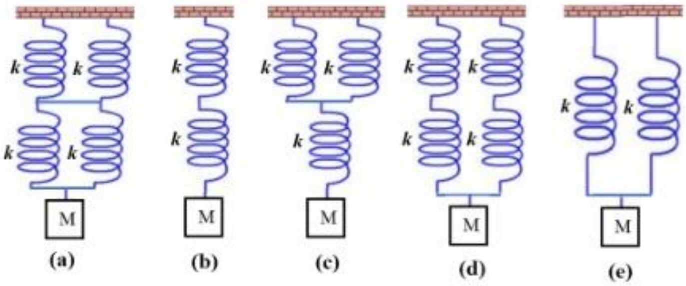
The measurement stage in this research includes the preparation of test instruments based on the results of previous trying out. Test instruments that have been arranged to diagnose student misconceptions on each sub-topic of the simple harmonic motion concepts have followed the four-tier test format. The results of students' misconceptions analysis are shown in Table 6.

Table 6. Conceptual understanding percentage in each number of subtopic

No	Misconceptual Potential Subtopic	Students Misconception Number				Misconception Percentage of Each Subtopic
		UC	UPC	MSC	NC	
1	The rope length is inversely proportional to the vibration period on the pendulum	17	6	36	1	60
2	The vibration period is affected by the pendulum’s swinging mass	20	6	32	2	53,3
3	Misconception about the frequency of simple harmonic motion	6	5	45	4	75
4	The increase on spring length is directly proportional to the total spring constant	10	19	28	3	46,7
5	The total spring constant is inversely proportional to the spring frequency	2	17	35	6	58,3
6	The direction of the restoring force is in the same direction as the force applied	27	11	14	8	23,3
7	The deviating force will not cause a period of vibration	41	11	7	1	11,7
8	The restoring force direction of the spring is always towards the direction of the deviating force	36	8	13	3	21,7
9	Vibration working on a spring that is given an object is not caused by deviation	37	12	10	1	16,7
	Percentage of Decision Categories	36,4	17,7	40,7	5,2	

The analysis of 60 students of class X MIPA obtained results of understanding various concepts in terms of the four-tier instrument test decision categories. The overall data proves that 36.4% of students understand the concept of simple harmonic motion, 17.7% of students only understand parts of concepts, 40.7% of students experience misconceptions, and 5.2% of students do not understand the concept of simple harmonic motion. one of the four-tier diagnostic instruments that have been developed on the simple harmonic motion topic is shown in Figure 3 below.

Q5. A Load (mass M) and some identical springs have the same spring constant (k) forming the spring-load structure systems that follow the design scheme (a), (b), (c), (d), dan (e) shown in the Figure below.



If air friction is ignored, the spring-load design can produce simple harmonic motion or vibrations with different frequencies. Which the spring-load design will have the largest vibration frequency of the five spring-load design?

Answer : A. (a) B. (b) C. (c) D. (d) E. (e) *

Confidence Level : A. Sure B. Unsure

Scientific Reason for My Answer :

A. The total spring constant is directly proportional to the square of frequency *
B. The total spring constant is inversely proportional to the square of frequency
C. The total spring constant is directly proportional to frequency
D. The total spring constant is inversely proportional to frequency
E. ____________________

Confidence Level : A. Sure B. Unsure

Figure 3. The four-tier diagnostic test instrument item

The item development in Figure 3 follows the C4 cognitive level (analyzing) of the revised Bloom's Taxonomy. The analysis showed that only two students (0.03%) had a complete understanding. 35 students out of 60 students experienced misconceptions of 58.3%. The difficulty students lie in the ability to analyze the spring constant with a different spring-load system arrangement. Students calculate the total spring constant based on the number of springs in each system. Students should calculate the spring constant based on a series or parallel arrangement. Students experience difficulty distinguishing between frequency and period in terms of physics concepts or questions in effect, so students cannot determinate the relationships between variables, such as the total spring constant that affects the magnitude of the spring frequency. The results of this research are consistent with the research of Sugara *et al.* (2017), which explains that the greater the mass, the smaller the spring frequency and vice versa. While the relationship between the spring constant and spring frequency is, the greater the spring constant, the greater the spring frequency and vice versa.

The difference between students who understand parts of the concept and students who experience misconceptions is at the level of confidence in the chosen answer. In general, if students are sure of the answers choice and the choice of the reason that have been chosen even though all the choices are incorrect, it can be categorized as students experiencing misconceptions. If students are not sure of the answers choice and reasons choice that has been chosen even though the choice is correct, it can be categorized as students only understand part of the concepts.

Interpretation of results based on the analysis of sub-topics that have the highest level of misconception, 75.0% of students experienced a misconception about the frequency of simple harmonic motion, 60.0% about the relationship of the rope length to the pendulum period, and 58.3%

about the total spring constant is inversely proportional to the spring frequency.

Research Nugraha *et al.* (2019) measure students' conceptions by developing instruments in the form of multiple choices by providing space for writing down reasons openly. Research Somroob & Wattanakasiwich (2017) identifies students' misconceptions with conceptual surveys and tutorial activities in class. The instrument used is similar to the research instrument format Nugraha et al. (2019). A comparison of this research instrument with previous research instruments includes the results of measuring students' conceptual understanding in more detail with the classification of students in other categories of understanding. The advantage of a four-level diagnostic instrument is that it is more efficient and effective in the use of time.

Although the results of data analysis prove that students' misconceptions related to physics material are very large, considerations such as appropriate learning methods or approaches to eliminate misunderstandings are needed. Learning methods developed to overcome misconceptions are analogy methods (Lin & Singh, 2015), and the development of critical thinking (Kuczmann, 2017). These considerations can help to reduce and eliminate students' misconceptions during remediation.

CONCLUSION AND SUGGESTION

The results showed that the development of the test instrument was considered feasible. The use of a four-level diagnostic test instrument can diagnose students' misconceptions about physics concepts. The determination of the decision categories for students is evident from the results of students' answers, including good conceptual understanding, students who only understand part of the concepts, students who experience misconceptions, and also students who do not know the concepts.

The researcher suggests to the next researchers to develop a test instrument with a combination of several concepts of physics material with previous physics material, which aims to repeat the previous learning so that it does not pass without meaning. Other suggestions for using diagnostic test instruments, namely research samples using a variety of schools and a higher number of items

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