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Android-based 4-tier physics test app to identify student misconception profiles

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ABSTRACT

Misconceptions in physics learning are still common at the upper school level. Misconceptions lead to low ability to understand students' concepts in studying physics. Physics misconceptions experienced by students are difficult to detect. This study aimed to develop an Android-based assessment application with a four-tier diagnostics test instrument that can be used to detect student physics misconceptions early on. Product development is carried out by developing physics instruments for class X, XI, and XII levels and then developing an Android-based assessment application. The results showed that this application received a positive response from teachers and students. In addition, the application is able to detect physics misconceptions experienced by students.

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1. INTRODUCTION

The achievement of student learning outcomes in the subject of High School (SMA) physics in Indonesia is still unsatisfactory [1], [2]. Student learning problems must be known to the teacher in order to determine the right steps to overcome the problem [3]. One of the reasons for the low achievement of student learning outcomes in Physics subjects, it is suspected that students have experienced misconceptions [4]–[6]. It is this misconception that becomes a source of doubt for the student when it contradicts the new concepts, he learns that later become indecisive. Students do not give a correct explanation regarding the concept of physics according to what scientists have agreed on. Misconceptions arise as a result of the initial knowledge of students not yet in accordance with the way of scientific thinking, but based on feelings [7], [8]. In addition, misconceptions occur from the daily experiences [9], [10] that students experience when interacting with the surrounding environment. Through these experiences students will build their own theories in their minds that are not necessarily true. If the intuition formed is not correct, it will be very difficult to correct because it has unintentionally consistently been the wrong concept of physics has become a handle.

Misconceptions are a classic problem that occurs in the world of education [11], [12]. Misconceptions to date are often occurred and experienced by students. Misconceptions do not only occur in students in Indonesia [6], [13]–[16], but many students in other countries also experience misconceptions [6], [17]–[21]. Misconceptions occur at several levels of education ranging from elementary school [22]–[24], junior high school [5], [25], senior high school [26], [27], undergraduate [28], [29], and postgraduate school [30], [31].

Misconceptions that occur in students will have a bad impact on the understanding of subsequent concepts that are more complex so that treatment of students who experience misconceptions is needed.

Misconceptions are thoughts, ideas or explanations about a phenomenon that occur but are not accurately supported by the physical principles accepted by the student [32], [33]. Some literature uses different word choices for misconceptions. Other terms of misconceptions are: alternative conceptions, conceptual difficulties, misunderstandings and others. Of the various terms used in some literature, misunderstanding or alternative conceptions are the more commonly used terms today. Misunderstandings that occur in students can come from physical experience, direct observation, intuition, teaching in school, teaching outside of school, social environment, culture, language, textbooks or other teaching materials, and teachers [34].

One way to find out misconceptions in students is by diagnostic tests [35]. The use of diagnostic tests at the beginning and the end of learning can help teachers find student misconceptions in the material being studied. A good diagnostic test can provide an accurate picture of the misconceptions a student is experiencing based on the error information he or she made. A good diagnostic question not only shows that students do not understand a certain part of the material, but can also show how student thinks in answering a given question even if their answer is incorrect.

The four-tier diagnostic test is a development of the three-level multiple-choice diagnostic test. The development of three-level multiple choice is found in the addition of the level of confidence of students in choosing answers and reasons. The first level is a multiple-choice question with three tricks and one answer key that students must choose from. The second level is the level of confidence of students in choosing answers. The third level is the reason students answer the question, in the form of three choices of reasons that have been provided and one reason is open. The fourth level is the level of confidence of students in choosing a reason. The level of confidence developed is in the range of numbers one to six accordingly. The advantage that a level choice diagnostic test has is that through a four-level diagnostic test [36]–[38], the teacher can: i) distinguish the level of confidence of the answers and the level of confidence of the reasons chosen by the student so that it can dig deeper into the strength of the student's concept understanding; ii) diagnose the misconceptions that students experience more deeply; iii) determine the parts of the material that require more emphasis; iv) plan better learning to help reduce student misconceptions.

Misconceptions in physics learning are one of the factors that cause learning outcomes and mastery of physics concepts of students in the low category. Misconceptions occur continuously experienced by students, but teachers do not know how to know the profile of students in understanding physics concepts correctly. The absence of instruments that can measure misconceptions is one of the reasons that misconceptions experienced by students in student learning. In addition, the speed of knowing the level of misconceptions is also a problem faced by teachers. Therefore, in accordance with technological developments, it is necessary to develop an assessment application that is able to find out the profile of misconceptions quickly so that the information can be used by teachers to prepare appropriate physics learning strategies.

The results of understanding students' concepts with a four-level diagnostic test take a long time to know the results. This is because it is necessary to be careful in checking the results of students' answers from each level of the questions given. Along with the development of technology and information used in the learning process, it is necessary to develop an assessment application that can help teachers in knowing misconceptions. Developed application that can be used on smartphones especially those based on Android. The development of this application is expected to help students and teachers in knowing the level of misconceptions in the physics metrics studied, so that it can be known from an early age and teachers can design the right learning strategies. This research is one of the strategic steps to design an assessment application that is oriented towards improvement. This study aims to identify student misconceptions in physics lessons using an Android-based assessment application.

2. RESEARCH METHOD

The research was conducted at State Senior High School 4 Semarang, Indonesia. There were 45 students consisting of each of classes Mathematics and Natural Science, X-3, XI-2, and XII-5 as the subjects of small-scale trials and 90 students of classes Mathematics and Natural Science X-1, XI-1, and XII-3 were the subjects of the wide-scale trial. The research subjects for the final field test were 270 students of class X, XI, and XII consisting of classes X-2, X-4, X-5, XI-3, XI-4, XI-5, XII-1, XII-2, and XII-4.

This research employed a research and development (R&D) approach. The product produced in this study is an Android-based assessment application that contains a four-tier diagnostic test instrument (four-level diagnostic test) to uncover student misconceptions in physics subjects. This research procedure was carried out using the research and development procedure. The research stage consists of: needs analysis and information collection, research goal setting, product development, small-scale trials, product revision, broad-scale trials, product revision, field tests, final product revision, dissemination and implementation. The product development stages consist of: analysis of learning tools, preparation of test question grids, writing question items as well as question review, question revision, and making an Android-based assessment application.

The data collection method consists of documentation, interview, questionnaire, and test methods. Interviews were conducted with teachers to find out the teacher's opinion regarding the four-tier diagnostic test and the assessment application developed. Questionnaires are distributed to students, consisting of assessment questionnaires and response questionnaires. Assessment questionnaires are given during small-scale and broad-scale trials, while response questionnaires are given during final field trials.

The data analysis carried out includes validity, reliability, difficulty level, differentiating power, questionnaire analysis, student misconception analysis, and interpretation of four-tier diagnostic test results. Validity testing using the validity of the contents conducted by nine expert lecturers. Reliability testing using Cronbach's alpha formula. Interpretation of student misconceptions is carried out by classifying students in groups of understanding, partially understanding, not understanding, and misconceptions. The interpretation of the four-tier diagnostic test results can be seen in Table 1. To find out students' misconceptions in physics subjects using data in Table 1, the instrument developed based on its type has four levels, consisting of questions, answers, confidence levels of answers, reasons, and confidence levels of these reasons. The four-tier diagnostic test instrument framework is shown in Table 2.

Table 1. Decision making for four-tier test

1st tier	2nd tier	3rd tier	4th tier	Decision
Correct	Confident	Correct	Confident	Understanding
Correct	Confident	Correct	Not confident	Partial understanding
Correct	Confident	Correct	Not confident	Partial understanding
Correct	Confident	Wrong	Confident	Partial understanding
Correct	Confident	Wrong	Not confident	Partial understanding
Correct	Confident	Wrong	Confident	Partial understanding
Correct	Confident	Wrong	Not confident	Partial understanding
Wrong	Confident	Correct	Confident	Partial understanding
Wrong	Confident	Correct	Not confident	Partial understanding
Wrong	Not confident	Correct	Confident	Partial understanding
Wrong	Confident	Wrong	Not confident	Not understanding
Wrong	Not confident	Wrong	Confident	Not understanding
Wrong	Confident	Wrong	Not confident	Not understanding
Wrong	Confident	Wrong	Confident	Misconception

Table 2. The four-tier test diagnostic instrument framework

1. Question	2. The confidence level of the selected answer	3. Reasons toward the selected answer	4. The confidence level of the selected reason
A. Option	A. Confident	A. Option	A. Confident
B. Option	B. Not confident	B. Option	B. Not confident
C. Option		C. Option	
D. Option		D. Option	

3. RESULTS AND DISCUSSION

The results or products developed in this study are four-tier test diagnostics instruments and Android-based assessment applications. The stage carried out is to develop an instrument and then test it to an expert to see the validity of the instrument. After the instrument developed is valid and reliable, then create an assessment application by inputting and programming the finished instrument into an Android-based application. The results of the product developed in the form of a four-tier diagnostic test instrument and the Android Make-up Assessment Application are broadly presented in Table 3. The four-tier diagnostic test physics instrument developed has the following characteristics, namely that each question item developed has four levels. The first level is a multiple-choice question with three deceptions and one answer key that students must choose from. The second level is the level of confidence of students in choosing answers. The third level is the reason students answer the question, in the form of three choices of reasons that have been provided and one open reason. The fourth level is the level of confidence of students in choosing a reason. The level of confidence in choosing answers and reasons is divided into two scales, namely being sure and unsure.

The test results are analyzed and interpreted to find out the misconceptions experienced by students. Misconception analysis was performed on students in its entirety and every student, for each item of the question. Each student may experience misconceptions on the material they have studied. Some people argue that students' misunderstanding of a concept of physics is something natural and can be considered as the lack of success of the teaching and learning process [39]. However, it is very important to develop an evaluation tool that can detect misconceptions experienced by students. This is because the misconceptions that occur will take root in students and hinder students from studying the material at the next level. One of the tools that can be used to detect student misconceptions is a diagnostic test.

Table 3. Four-tier diagnostics test instrument product overview and assessment applications

Developed products	Content
Four-tier diagnostics test question grid	Sub-subjects, question indicators, level categories questions, number of questions
Instructions for working on the question	Instructions for students in doing the questions
Four-tier diagnostics test questions	Title, subject, class, subject, time workmanship, test questions, answer choices, level the confidence of choosing the answer, the choice of reason, the degree beliefs of choosing a reason
Answer key	Question number, answer choice and choice of correct reason
Answer sheet in the app	Name, class, absence number, question number column, column answer choice, answer confidence level, column choice of reason, reason confidence level column
Scoring guidelines	Guidelines for scoring and determining test results
Guidelines for interpretation of results	Guidelines for classifying the answers that students give
Test results in the application	The test results are in the form of a screen display and can also be downloaded in the form of a PDF file

The four-tier diagnostics test instruments developed are physics questions for classes X, XI, and XII with a total number of instruments as many as 18 instruments with details of four instruments for class X, seven instruments for class XI, and seven instruments for class XII. The materials developed for the four-tier test diagnostics instrument in class X are the regular circular motion and parabolic motion, Newton’s Law of motion, Newton’s Law of gravity, and impulse and momentum. While the materials developed for four-tier test diagnostics instruments in class XI are balance materials & dynamics of rotation, elasticity and Hooke’s Law, static and dynamic fluids, temperature and heat, kinetic theory of gases and thermodynamics, waves and optical tools. For materials developed for four-tier test diagnostics instruments in class XII are electrostatic materials, magnetic fields, electromagnetic induction, alternating currents and voltages, light waves, relativity, and atomic nuclei and radioactivity.

Scoring is given by giving a score of 1 for the correct choice of answer and choice of reason and a score of 0 is given for the choice of answer as well as the choice of wrong reason. The level of belief is divided into only two, namely sure and unsure. To get a reliable instrument, it is necessary to carry out a validation process for the items developed. Validation was carried out by nine experts. Validation is carried out to determine that the instruments used are feasible and can measure those to be measured, in this study it is a student misconception. The measurement of validity is determined by the instrument, the subject being measured, and the officer making the measurement. Therefore, the measurement of validity should be carried out by a person who is truly an expert in his field. The developed diagnostic test instrument has been declared valid by the validator. This shows that the test question items developed have been in accordance with the content of physics material for classes X, XII, and XII and can be used to uncover student misconceptions.

The validity of the test questions is assessed for each item by an expert and each question item consists of 20 aspects of assessment, including material, language, and construction aspects. A detailed assessment of each question item is carried out so that the test questions used are really feasible and can measure what is to be measured, namely student misconceptions. If the assessment is carried out globally, it will not be known which items have weaknesses and where the weaknesses of the questions lie. Assessing each question item in detail will make it easier to detect parts that need improvement. After the validity process is carried out, a reliability test is then carried out on the developed instrument.

Reliability is the level of questioning in assessing what you want to assess. Reliability states the extent to which the results of a measurement can be trusted. The reliability analysis resulted in an average value of reliability against the 18 instruments developed of 0.913. That is, the test questions developed are reliable. Bradshaw *et al.* [40] also developed a diagnostic test with an average reliability of 0.988. Caleon and Subramaniam [41] obtained a reliability score of 0.92 for the four-level diagnostic test they developed. Research on another four-level diagnostic test developed by McClary and Bertz [42] resulted in a reliability value of 0.41. Some of the results of the study showed that the four-level diagnostic tests developed in this study were relatively good. This means that the diagnostic tests developed have a level of ability to reveal misconceptions experienced by students in physics subjects [43], [44].

A good test question must be valid and reliable [45]. In addition, the test questions must have a good level of difficulty and distinguishing power. The degree of difficulty and distinguishing power are characteristic of test questions, including four-level diagnostic test questions. The characteristics (difficulty) of the question items of the final product developed is in the range between 0.28 to 0.77. The differentiating power of the questions can distinguish well, the number of differentiating powers is in the range between 0.26 to 0.78.

A question with good differentiating power can distinguish between smart students and less good students. This is in accordance with Nugraeni, Jamzuri, and Sarwanto [46] who stated that a good test item must be able to distinguish students who really master the material from those who do not. Test questions with poor distinguishing power cannot be used. This is because if the test questions cannot distinguish between smart students and students who are less good at it, the test goal will not be achieved.

The difficulty level of most of the four-tier diagnostic test questions developed is in the moderate category. This is because a good diagnostic test question is a question with a moderate level of difficulty. A moderate level of difficulty is needed so that students who are less good at it do not have too much difficulty in doing questions and students who are good at doing problems are not too easy to do. The selection of questions with a moderate level of difficulty is also in accordance with Wahyuningsih, Rusilowati, and Hindarto [39] which use questions with an average level of moderate difficulty for diagnostic tests.

Furthermore, instruments that are already valid and reliable are inputted into an Android-based assessment application called “4-Tier Physics Test.” This application has been programmed based on scoring guidelines and a result interpretation table to group students in the categories of understanding concepts, partially understanding, not understanding and misconceptions. Furthermore, this application is tested to several experts in the field of computers to ensure that this application runs well and make the right decision results. The results of the expert stated that there are some suggestions for improvement related to the writing of quantities and units as well as the appearance of images and tables that are sometimes not visible. After that, the application is fixed and declared feasible for use. This application is used to measure the level of physics misconceptions of students of classes X, XI, and XII.

The analysis was carried out to determine student misconceptions by looking at the level of student confidence in choosing the right answers and reasons. The belief value of showing a negative result indicates that the student cannot distinguish what they understand and what they do not understand, or in other words the student experiences a misconception without them knowing it. A recapitulation of the results of the analysis of the interpretation of student misconceptions is presented in Table 4.

Table 4. Recap of the results of the analysis of the interpretation of student misconceptions

Category	Highest (%)	Lowest (%)	Average (%)
Understand	38.6	2	18.2
Partial understanding	54.7	0	29.6
Do not understand	86.8	0	30.6
Misconceptions	72.5	0	42.7

Based on the results, students tend not to be able to distinguish what they understand and what they do not understand correctly. These results indicate a strong misconception experienced by students. Misconceptions experienced by students will interfere with them in receiving knowledge. The wrong concept has been firmly ingrained in students and they assume the concept they understand is true. They tend to apply concepts they have previously believed in with concepts they have just accepted. This is in accordance with the opinion of Kaur [47] who states that many misconceptions are resistant to change. Lark [48] also states the same thing, namely that misconceptions are difficult to change. The misconceptions experienced will be firmly attached to students because they construct the knowledge. Therefore, it is very important to immediately known whether the student has a misconception and in which part the student has a misconception so that it can be remedied before the concept is firmly embedded in the student. With these results, teachers must be able to distinguish students who can understand concepts well, do not understand concepts, and experience misconceptions in order to work on how to overcome problems appropriately. The problem that often arises is when the teacher will seek treatment but the teacher has problems distinguishing students who understand concepts well, do not know concepts (lack of knowledge), or students who misconceptions. Students understand, do not understand, and misconceptions are grouped into high, medium, and low categories.

Students were classified as understood in the low category at 50.94%; medium by 26.52%; and a high of 22.54%. The results showed that students understood the concepts in physics subjects only 22.54% of all questions tested. Most students have a low level of understanding of physics material. Students do not understand the concept in the high category by 0%. This percentage indicates that there is no student who does not understand the concepts in physics subjects at all. The percentage of not understanding the concept in the low and medium categories was 48.02% and 51.98%. This shows that half of the number of questions tested have not been well mastered by students. Students who do not understand the concept are known from the student's uncertainty in giving answers. The uncertainty was seen from the choice of low confidence level, students experienced misconceptions in the low category of 25.45%, medium at 54.9%, and a high of 19.65%. Almost all students experienced misconceptions as much as 19.65% of the questions tested. Students also experienced moderate misconceptions at half of the number of questions tested. Students have the same belief in a concept that does not fit the concept of the scientist. Their belief in the wrong concept is heightened when their friends also have the same belief in the concept. This needs to be watched out for because misconceptions have been widespread and will certainly cause problems for students in receiving new knowledge.

The misconceptions on the physics of classes X, XI, and XII are almost thoroughly evenly distributed. This is known from the response of students in answering the question. The use of the 4-tier physics test assessment application can help teachers identify physics material that is suspected of misconceptions appropriately [49]. The results of students' work in answering questions with this application are in the form of PDF files that can be downloaded and used as a report to teachers in the field of physics studies related to the level of understanding of physics concepts of each individual student. The response of students and teachers to this assessment application is very positive, because there is no concept understanding assessment application using the Android application. One of the responses said that this application is very easy to use and can be used as a basis for students to test their level of understanding of physics concepts in one of the physics materials. The results of the study can be used as a reference for teachers to make improvements in physics learning [50], [51]. Teachers can find out which parts are detected by students' misconceptions. Thus, teachers can plan learning better to overcome misconceptions experienced by students [52], [53].

4. CONCLUSION

The 4-tier physics test application contains a four-tier diagnostic test instrument consisting of a grid of test questions, instructions for working on questions, test questions, answer keys, answer sheets, scoring guidelines, and guidelines for interpretation of results. The test questions consist of four levels, namely: questions with one answer key and three deceivers, the level of confidence of the answers. The application can identify students' physics misconceptions on physics in class X, XI, and XII. The results of students' work with this application can be used as teachers to plan learning better to prevent physics misconceptions.

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