Four-Tier Diagnostic Test With Certainty of Response Index on The Concepts of Fluid

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Abstract: The four-tier diagnostic test with certainty of response index (CRI) is an instrument that can be used to identify student misconceptions. This instrument is the result of development of a three-tier multiple-choice diagnostic test equipped accompanied by the students’ confidence level. This instrument which is intended for fluid concepts learning material was developed through the following stages: analysis, design, development, implementation and evaluation (ADDIE). The results of expert validation indicate that the developed instrument is valid. Furthermore, the instrument was tried-out to the twelfth grade students of class Science 1 of Senior High School 1 Pagelaran to determine the validity, reliability, level of difficulty, and the differentiating power of each question. There are twenty items out of twenty-five items that were feasible to be used in identifying the students’ misconceptions.

Keywords: four-tier diagnostic test, certainty of response index, CRI, misconception

1. Introduction
The current Indonesian education system requires an assessment of students as a whole which is summarized in three major aspects, namely cognitive, psychomotor, and effective. Assessment is carried out in order to measure the expected achievement of learning indicators. In addition, it can also be used to overcome learners' learning problems [1]. One of the problems often found in physics learning is misconception [2]. The misconception is a concept that is not in accordance with a concept recognized by experts [3-5]. Several studies have been conducted stating that misconceptions are found in the field of physics, in which the field of physics is a branch of science that studies natural events in everyday life and prioritizes mastery of concepts [6-9]. The results of observations conducted at the twelfth-grade students of class science 2 (IPA 2) SMANegeri (State Senior High School) 1 Pagelaran showed that there have been misconceptions, for example in the fluid material. According to students, objects that are submerged in water are because they are heavier than water, while objects that float in water are caused by the object being lighter than water. This concept of understanding should not be allowed to happen.

Learning difficulties and students' misconceptions must be known by the teacher so that appropriate steps can be taken to overcome them [10]. Learning difficulties and students’ misconceptions must be known by the teacher so that appropriate steps can be taken to overcome them [11-12]. One of them is by choosing a good model and media[13]. In addition, the way to...
find out about misconceptions is by conducting diagnostic tests[14]. The use of diagnostic tests at the beginning and at the end of learning can help teachers to find students' misconceptions in the material being studied[15]. A good diagnostic test can certainly provide an accurate picture of the misconceptions experienced by students based on the error information made. Good diagnostic questions not only show that students do not understand certain parts of the material but also can show how students think in answering questions given even though their answers are incorrect[16]. Diagnostic tests of misconception are presented in various forms, for example, interviews, open questions and essays, multiple choice tests, and multilevel choice tests [17]. Each form of the diagnostic test has its own advantages and disadvantages. However, according to Reynolds[18] multiple choice tests have the advantage of being versatile, efficient, objective, easy to use, and less affected by someone in certain multiple choice answers. In addition, multiple choices also have weaknesses which cannot distinguish correct answers due to the right reasons or wrong reasons[19-18]. Thus other diagnostic tests need to be developed that can answer these shortcomings. One of them is the development of multilevel multiple choice tests for the purpose of compensating for deficiencies or completeness in general multiple choice tests[20].

There are several multilevel multiple choice tests including two-tier (two levels), Three-tier (three levels). Two-tier (two levels) is a two-level multiple choice test that provides answers and reasons for students to choose from[18] but it cannot distinguish between wrong answers caused by not understanding concepts or misconceptions and not being able to distinguish correct answers caused by understanding the concept or guessing[11]. The Three-tier (three levels) is a multiple choice test in which students are given several alternative choices of answers, reasons, and levels of confidence in answering questions[21]. However, it has a weakness, namely when students are asked about the level of confidence in the first and second stages simultaneously, it is not clear whether students have different levels of confidence between the first and second stages [18]. So that in this Three-tier diagnostic test the proportion of interpretation could be too low for not understanding the concept and it could be too high for the understanding the concept[22]. Until now, there are still difficulties in distinguishing between students who experience misconceptions and those who do not know the concept, without distinguishing between the two it will be difficult to determine the next step because improving misconceptions is not the same as improving students who do not understand the concept [23]. Therefore a more complex multilevel test instrument is needed in identifying misconceptions, namely the development of Four-tier diagnostic test with CRI.

The Four-tier diagnostic test is the development of a three-tier multiple-choice diagnostic test[24]. The development is in the addition of the level of confidence in choosing the reason. The first level is a multiple choice question with three deceptions and one answer key that must be chosen by students. The second level is the level of confidence of students in choosing answers. The third level is the reason students answer questions, in the form of three choices of reasons provided and one written reason. The fourth level is the level of confidence of students in choosing reasons [11]. The advantage possessed by the Four-tier diagnostic test are: (1) distinguishing the level of answer confidence and the level of confidence of the reasons chosen by students so that they can look-up deeper about their strength of conceptual understanding, (2) diagnosing misconceptions experienced by participants thoroughly, (3) determining the parts of material that require more emphasis, (4) planning better learning to help reducing students’ misconceptions[25,11]. The combination of answers for the Four-tier diagnostic test is presented in Table 1 [11,12].
Table 1 The Answer Combination of Four-tier diagnostic test

| Category               | Answer | Confidence Level | Reason | Reason's confident level |
|------------------------|--------|-----------------|--------|--------------------------|
| Understanding the Concepts | Correct | Confident       | Correct | Confident                |
|                        | Correct | Unconfident     | Correct | Unconfident              |
|                        | Correct | Confident       | Correct | Unconfident              |
|                        | Correct | Unconfident     | Correct | Confident                |
| Not Understanding The Concepts | Correct | Unconfident     | Wrong  | Unconfident              |
|                        | Wrong   | Unconfident     | Correct | Unconfident              |
|                        | Wrong   | Unconfident     | Wrong   | Unconfident              |
|                        | Correct | Confident       | Wrong   | Unconfident              |
|                        | Correct | Unconfident     | Wrong   | Unconfident              |
|                        | Correct | Confident       | Wrong   | Unconfident              |
|                        | Correct | Confident       | Correct | Confident                |
|                        | Correct | Confident       | Wrong   | Unconfident              |
|                        | Correct | Confident       | Wrong   | Confident                |
|                        | Correct | Confident       | Wrong   | Confident                |
| Misconception          | Wrong   | Confident       | Correct | Unconfident              |
|                        | Wrong   | Confident       | Correct | Confident                |
|                        | Wrong   | Confident       | Wrong   | Unconfident              |
|                        | Wrong   | Confident       | Wrong   | Confident                |
|                        | Wrong   | Confident       | Wrong   | Confident                |

CRI is used to measure the level of confidence in answering each question given[26]. The level of confidence developed is in the range of numbers from one to six according to the research conducted by [27]. This level of confidence will make it easier and save time in analyzing one's misconception [14]. With the developed Four-tier diagnostic test with CRI, student misconceptions can be well identified. The CRI confidence level is presented in Table 2, namely [28-29]:

Table 2 CRI Confidence Rate Scale

| Category         | Scale | Confidence Level |
|------------------|-------|------------------|
| Guessing         | 0     | Low/Unconfident  |
| Very Unconfident | 1     |                  |
| Unconfident      | 2     |                  |
| Confident        | 3     | High/Confident   |
| Very Confident   | 4     |                  |
| Highly Confident | 5     |                  |

2. Research Methods

This study employed the Research and Development(R & D) method. The product of this study is the Four-Tier Diagnostic Test with CRI which is an instrument to identify students' misconceptions in the fluid material. The procedure of this study was carried out using the ADDIE research and development procedure, where the development model consisted of five stages, namely analysis, design, development, implementation, and evaluation[30][31]. The details of the development of the Four-Tier Diagnostic Test with CRI is presented in Figure 1.
The needs analysis was carried out by observation and interviews with teachers and students in SMA N 1 Pagelaran. Likert scale was used to obtain the data of experts validation. The percentage of the average of the total score was calculated using the formula [33]. The instrument’ field testing was carried out on twelfth-grade students of class science 2 of SMA Negeri 1 Pagelaran, consisted of 30 students. The field testing was used to determine the level of validity, reliability, level of difficulty, and the differentiating power of the instrument. The validity of the tested questions was calculated using Karl Pearson Correlation formula in Budiyono [30]. The reliability was calculated using the Cronbach alpha formula. If $r_{\text{calc}}>r_{\text{table}}$ then the instrument is reliable.[34]. The next was the differentiating power tests [34], the results were then categorized according to the provisions[34]. Furthermore, the level of difficulty of the question was calculated, and the results were categorized according to the provisions[35]

3. Results and Discussion

The results of observations and interviews with teachers and students of SMA N 1 Pagelaran show that there have been misconceptions in physics learning. For this reason, an instrument is needed that is able to identify these misconceptions appropriately. So far, teachers at SMA N 1 Pagelaran have never measured the level of student misconception. In addition to the unavailability of instruments to measure misconceptions, the teacher also assessed that the existing instruments were not too appropriate to measure misconceptions, for example, two-tiers, three-tiers, or four-tiers diagnostic test that have not integrated with CRI.

The curriculum used in SMA Negeri 1 Pagelaran is the 2013 curriculum. Curriculum analysis was focused on analyzing core competencies and basic competencies. Basic fluid material competencies consist of:3.3 Applying static fluid laws in everyday life; 4.3 Designing and conducting experiments that utilize static fluid properties, along with presentations on the results of experiments and their uses; 3.4 Applying dynamic fluid principles in technology, and 4.4 Creating and testing simple projects that apply the principle of fluid dynamics. Based on the analysis, the questions’ specification was made only in the C1 to C3 domains, because the Basic Competence domain is limited to C3 only, the domains are required to be able to apply fluid concepts in daily life according to the understanding and development of knowledge owned. It can be seen that the students were at the age of 12 above so that
the domains are appropriate to be applied to the students. According to the theory of Jean Piaget in [36][37] states that the age of 12 years and above is a formal operational stage in which students have the ability to think abstractly with developments in the form of hypotheses, abstracts, deductive, inductive, and logical. The basic competencies 4.3 and 4.4 are not included in the question but only as the experimental stage in the learning process.

Next was the design stage. The design stage begins by making the specification for the questions based on basic competencies 3.3 and 3.4. The sample questions’ specification is presented in Figure 2. Twenty-five questions were made based on the specification.

| Concept               | Indicator                                      | Indicators of Questions                                                                 | Cognitive Level | Number |
|-----------------------|------------------------------------------------|----------------------------------------------------------------------------------------|-----------------|--------|
| Static Fluid          | 3.3.1 Knowing the factors that influence       | Identify factors that influence pressure                                               | √               | 2      |
|                       | influence                                      | Identify a substance in daily life that is included and not including into fluid       | √               | 1      |
|                       | Pascal                                        | Shows a graph of the lift force up to the depth of the object                          | √               | 10     |

**Figure 2** The sample questions’ specification

Questions that have been made were then validated by the experts. The results of the validation by physics, language, and educational evaluation experts are presented in Figure 3:

**Figure 3** The Results of Material Expert Validation, Language Experts, and Educational Evaluation Experts

Figure 3 shows the results of validations conducted by 3 experts. The material expert stated that the developed product is in the feasible category. The language expert and the educational evaluation expert stated that the developed product is in the highly feasible category. Thus, the instrument can be used for field testing. Before the revision was carried out according to the advice given by experts, the researcher revised the product based on some suggestions given by the experts, namely: 1) The sentences of the question must be distinguishable in the use of in, to, and the prepositions, 2) Presentation of the question should have given some instruction since the questions were in the form of multi-level questions and should have been given the CRI confidence level, 3) the image should be in high definition, 4) the questions with wrong calculation number should be corrected with the correct calculation, 5) the questions which language were poorly constructed and overlapped choices should be revised.

The results of the teacher's response toward the developed instrument were basically good; however, the teacher also gave some advice, for example, the sentence used must be understood by the students, the sentences should not be too complex, and should be accompanied by clear images. Furthermore, the field testing phase was carried out to 30 students. The students were asked to work on 25 items of Four-tier diagnostic tests with CRI prepared to obtain the validity, reliability, differentiating power, and the level of difficulty of the instrument. The results are presented in table 6.
Table 3 The Recapitulation of Validity, Differentiating Power, and the Level of Difficulty

| Items | Validity Test | Differentiating Power Test | Level of Difficulty Test |
|-------|---------------|----------------------------|---------------------------|
| 1     | Invalid       | Moderate                   | Quite Hard                |
| 2     | Valid         | High                       | Quite Hard                |
| 3     | Valid         | High                       | Quite Hard                |
| 4     | Valid         | High                       | Easy                      |
| 5     | Valid         | Moderate                   | Easy                      |
| 6     | Valid         | Very High                  | Quite Hard                |
| 7     | Valid         | High                       | Quite Hard                |
| 8     | Valid         | Very High                  | Quite Hard                |
| 9     | Invalid       | Low                        | Quite Hard                |
| 10    | Valid         | Moderate                   | Easy                      |
| 11    | Valid         | High                       | Quite Hard                |
| 12    | Invalid       | Low                        | Quite Hard                |
| 13    | Valid         | High                       | Quite Hard                |
| 14    | Valid         | High                       | Quite Hard                |
| 15    | Valid         | High                       | Quite Hard                |
| 16    | Valid         | High                       | Quite Hard                |
| 17    | Valid         | Moderate                   | Quite Hard                |
| 18    | Valid         | High                       | Quite Hard                |
| 19    | Invalid       | Low                        | Quite Hard                |
| 20    | Valid         | Moderate                   | Quite Hard                |
| 21    | Valid         | Moderate                   | Quite Hard                |
| 22    | Valid         | High                       | Quite Hard                |
| 23    | Valid         | Very High                  | Quite Hard                |
| 24    | Invalid       | Low                        | Quite Hard                |
| 25    | Valid         | Very High                  | Quite Hard                |

The result of the reliability test is \( \alpha_{count} = 0.72 \) which is in the moderate category and it can be concluded that the question is reliable. The field testing resulted in the deduction of the initial items from 25 items into 20. Examples of instruments that have been successfully developed are presented in Figure 4.

10.1 Look at the pictures of a ship and a submarine below!

![Picture of a ship and a submarine](image)

Based on the image, the ship could float and the submarine could submerge because…

a. \( \rho_{ship} > \rho_{max \text{ Water}} \) and \( \rho_{submarine} > \rho_{max \text{ Water}} \)

b. \( m_{ship} > m_{max \text{ Water}} \) and \( m_{submarine} < m_{max \text{ Water}} \)

c. \( \rho_{ship} < \rho_{max \text{ Water}} \) and \( \rho_{submarine} = \rho_{max \text{ Water}} \)

d. \( m_{ship} < m_{max \text{ Water}} \) and \( m_{submarine} = m_{max \text{ Water}} \)

e. \( \rho_{ship} = \rho_{max \text{ Water}} \) and \( \rho_{submarine} > \rho_{max \text{ Water}} \)

10.2 CRI Confidence Level

| 0 | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|

10.3 The reason of Answer:

a. \( \rho_{s} > \rho_{f} (\text{Submerged}), \rho_{s} < \rho_{f} (\text{Float}), \rho_{s} = \rho_{f} (\text{Adrift}) \)

b. \( \rho_{s} > \rho_{f} (\text{Float}), \rho_{s} < \rho_{f} (\text{Adrift}), \rho_{s} = \rho_{f} (\text{Submerged}) \)

c. \( \rho_{s} > \rho_{f} (\text{Float}), \rho_{s} < \rho_{f} (\text{Submerged}), \rho_{s} = \rho_{f} (\text{Adrift}) \)

d. \( \rho_{s} > \rho_{f} (\text{Adrift}), \rho_{s} < \rho_{f} (\text{Float}), \rho_{s} = \rho_{f} (\text{Submerged}) \)

e. ……………………………………………………..

10.4 The level of Confidence of the Reason

| 0 | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|

Figure 4 Examples of instruments
The misconceptions could cause low learning outcomes, the learning process, concepts understanding, and disrupting the process of identifying examples of physical phenomena in everyday life [38-40]. Because of the dangerous impact, many studies have developed many types of diagnostic tests include [41] developing two-tier diagnostic tests in detecting misconceptions. Another research was conducted by [42] who developed the three-tier diagnostic test on temperature and heat material to uncover misconceptions, as well as research conducted by [22,18] who developed the four-tier diagnostic test in uncovering misconceptions.

This study produced 20 valid questions with moderate reliability results. The result of experts validation indicates that the developed product is appropriate to be used. The developed four-tier diagnostic test can uncover the misconception in much more detail because it can distinguish between the concepts understanding, not understand the concepts, and misconceptions accompanied by confidence levels and reasons for each answer. Since the developed instrument is equipped with CRI, the students’ confidence level can be seen in answering each question. In line with the research conducted by [25] that four-tier test can be used to see the reasons behind each answer and the students’ level of confidence.

The four-tier diagnostic test is different with the two-tier diagnostic test that cannot be used to see how strongly the students understand the concepts. [11] in the three-tier diagnostic test, the students are given several alternative choices of answers, reasons, and levels of confidence in answering questions [21]. But only gives one opportunity to choose the level of confidence in choosing the answers and reasons for each item, this single level of confidence cannot detect if students have different levels of confidence in choosing answers and reasons [43]. So that the four-tier diagnostic test is much more complete and effective in diagnosing misconceptions since it is accompanied by CRI.

4. Conclusion

The diagnostic test for misconception in the form of the four-tier diagnostic test with CRI in the fluid material is a four-level diagnostic test accompanied by a level of confidence. The instrument was developed following the stages of the ADDIE development model. The results of expert validation indicate that the instrument developed is valid. Furthermore, the instrument was tested to students of science class of the twelfth grade of SMA Negeri (State Senior High School) 1 Pagelaran to find out the value of validity, reliability, level of difficulty, and differentiating power of each question. From the 25 questions that were developed, there were 20 feasible questions to be used in identifying students' misconceptions. So it can be concluded that the research has succeeded in developing Four-tier diagnostic tests with CRI.

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