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Development of a Five-Tier Diagnostic Test to Reveal the Student Concept in Fluids

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Abstract

This study aims to develop a five-tier form of fluid misconception diagnostic assessment and to reveal the profile of student's conceptual understanding in maritime-based schools in the city of Tegal. This study used a 4D model (defining, designing, developing, and disseminating). The sampling technique used purposive sampling. The research samples were Bahari Vocational School Tegal, Al Maarif Vocational School Tegal, and Nahdlatul Ulama Senior High School Tegal. Methods of data collection used documentation, questionnaires, tests, and interviews. Expert validation states that the instrument was valid, has good readability, was easy to understand, and the sentence structure was correct. The reliability of the instrument is 0.958 and declared reliable. A total of 39 questions were categorized as medium, and one question was easy. The discrimination power of the questions obtained was that 30 questions were accepted, eight questions were received with a little improvement, and one question needed improvement. Seventy student misconceptions were identified from seven fluid sub-concepts. The biggest misconception, as much as 46.5% was found in the buoyancy sub-concept, while the smallest misconception was found in the application of Pascal's law at 35.2%. The most dominant misconception is that the deeper a point in the fluid is, the greater the buoyancy. Students assume that the greater the depth, the greater the fluid pressure, so that the buoyancy force is greater. Students believe that buoyancy is influenced by fluid pressure. This misconception is influenced by conceptual appreciation and intuition in daily life.

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INTRODUCTION

The conceptions that arise in students are caused by factors including: daily life intuition, the learning process, textbook reading, student knowledge as separate pieces, specific theoretical frameworks and conceptual appreciation (Linuwih, 2011). Often the conceptions that appear in students are different from the concepts believed by experts. Conception that is different from experts and is believed to be true is called a misconception (Ibrahim, 2013). Misconceptions are found in various subfields of physics, including fluid matter. Identification of student misconceptions must be carried out by the teacher in order to remediate student misconceptions so that learning outcomes are more effective. One way to explore and identify student misconceptions is through diagnostic tests. The use of diagnostic tests can be done at the beginning and end of learning to reveal student's understanding of concepts (Mardapi, 2012).

Misconceptional diagnostic tests can be in the form of multiple-choice and are considered to be more efficient (Türker, 2015). There are various forms of multiple-choice diagnostic tests being developed, one of which is the Four-tier diagnostic test. Four-tier diagnostic test is a diagnostic test which consists of four levels, namely: the first level is a multiple choice question with four distractors and one answer key that the student must choose. The second level is the level of student confidence in choosing answers. The third level is the student's reason for answering the question, in the form of five choices of reasons that have been provided. The fourth level is the level of student confidence in choosing reasons (Amin, 2016).

Fariyani (2017) developed a four-tier diagnostic test to reveal the misconceptions of physics in geometric optical material and obtained the results of the instruments developed that are valid and can reveal the misconceptions of class X students on geometric optical material. Kaltakci (2012) developed a four-tier diagnostic test to reveal geometric optical misconceptions and found that the four-tier diagnostic instrument developed was valid. Fratiwi (2016) regarding the development of a four-tier diagnostic test instrument to reveal student misconceptions on Newtonian law material and it was found that the instruments he developed were valid. Students sometimes believed that the statement of the reason for the answer was correct, but were not sure that there was a cause-and-effect relationship between the answer and the reason for the answer. When given more than one reason for the correct answer, students often hesitated to determine whether the reason had a cause-and-effect relationship (correlation) to the chosen answer, so it is necessary to specify the belief in the reason for the answer to be two, namely belief in the truth of the reason for the answer and belief in the causal relationship; the effect (correlation) between the answers and the reasons for the answers, so it is necessary to develop a four-tier test to a five-tier format.

METHOD

The population of this study was all maritime-based vocational and high school students in the city of Tegal. The sampling method used was purposive sampling technique, and obtained year ten merchant ship nautics of Vocational School Tegal, year ten merchant ship nautics of Al Ma'arif Vocational School Tegal, and year eleven of Nahdlatul Ulama Senior High School Tegal.

The variables of this study were the validity and feasibility of the five-tier formatted assessment product and the student's understanding of the concept of the fluids in maritime-based schools in the city of Tegal.

The research procedure used the 4D method according to Thiagarajan (1974) which consists of four steps, namely define, design, develop, and disseminate, but this research was limited to the development step due to time considerations and implementation limitations. The steps are shown in Figure 1.

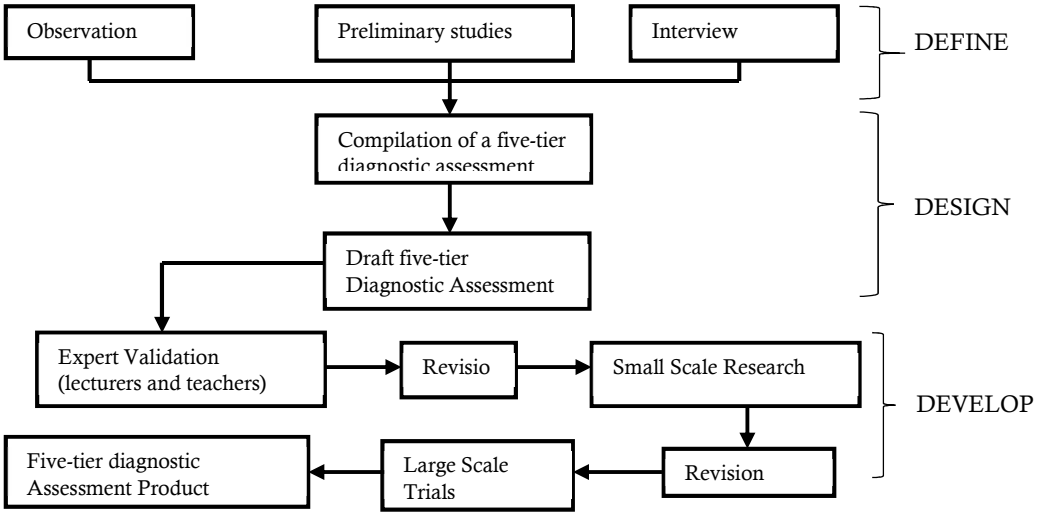

Figure 1: Assessment Development step in the Five-Tier form

Identification of student's conceptual understanding was done by interpreting the results of the written test answers and deepening them with interviews. The results of the interpretation of student's answers were then grouped and analyzed quantitatively by the percentage method. Student's understanding of concepts was grouped into three, namely understanding concepts, not understanding concepts, and misconceptions. Students indicated misconceptions were then conducted interviews to explore the causes of misconceptions.

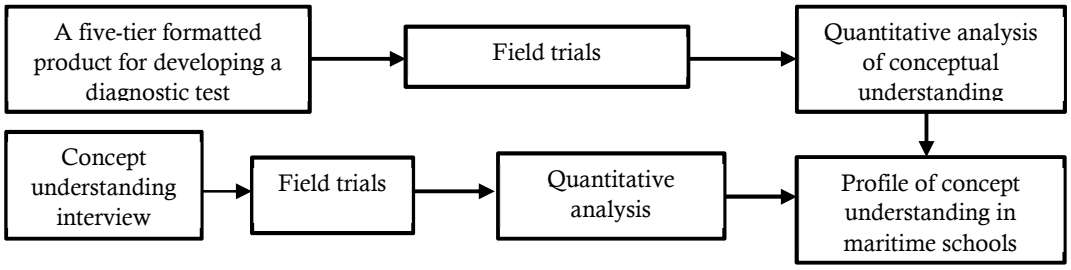

Figure 2. Identification of Student's Concept Understanding

Interpretation of student's answers was carried out with the answer combination category developed from the categories according to Gurel (2015), then an itemized analysis of each student was carried out and the percentage of each student's understanding was sought and categorized according to the category according to Sudijono (2009) in Table 1

Table 1. Student's Understanding Categories

Percentage	Category
$0 \leq M < 30$ %	Low
30 % $\leq$ M < 60 %	Medium
60 % $\leq M < 100$ %	High

RESULTS AND DISCUSSION

The product in this research is a concept understanding assessment consisting of a five-tier diagnostic test grid, a five-tier diagnostic test instrument with fluids material, answer keys, answer sheets, scoring guidelines, and results interpretation guidelines. Five-level diagnostic tests, namely: multiple choice conceptual questions with one answer key and four cheaters, the level of confidence in the answer, four reasons for answers with one open reason, the level of confidence in the correctness of the reasons for answers, confidence in the correlation of answers with reasons.

Instrument validation was carried out by five validators consisting of two physics education study program lecturers and three physics teachers. Validity uses content validity with assessment components including: suitability of material, question construction, and grammar. The final results of the validation by the validator obtained that of the 40 questions, there were 29 questions used without revision and 11 questions were used with slight revisions.

The test for legibility and easy understanding of the questions was carried out on ten year ten students of Nahdlatul Ulama Senior High School Tegal. The results show that the instrument developed has a good readability and good sentence structure accuracy and is easy to understand.

Product trials were carried out on 40 year ten students of Nahdlatul Ulama Senior High School Tegal. The results are used to measure the validity, reliability, difficulty level, and distinguishing power of the questions. Data analysis and processing were carried out with the use of SPSS software. The validity test used the product moment correlation formula from Karl Pearson (Arikunto, 2010) and the results obtained were 30 questions were declared valid, and 10 questions were invalid. The reliability test uses the Alpha Cronbach formula because the assessment uses a score of 0.1, and 2 with a minimum standard of reliability value (0.600) (Sujarweni, 2014). The results of calculations using SPSS software obtained the value of r_{cal} = 0.958 so that the assessment is reliable. A total of 39 questions were categorized as medium, and 1 question was easy. The discriminate power of the questions obtained was that 30 questions were accepted, eight questions were accepted with little improvement, and one question needed a lot of improvement.

Table 2. Student's Understanding of the Concepts of Each Sub-concept

No	Competence tested	Concept understanding (%)			Category of misconceptions
		Understand the concept	Do not understand	Misconceptions	
1	Hydrostatic pressure	18.6	32.2	42.9	Medium
2	Buoyant force	23.7	32.7	46.5	Medium
3	Application of Archimedes' law	25.2	33.3	41.5	Medium
4	Pascal's Law	19.6	45	35.2	Medium
5	Continuity equation	32.8	18.2	40.2	Medium
6	Bernoulli's Law	25.5	31.4	35.7	Medium
7	Application of Torricelli's Theorem	22.3	29.4	41.4	Low

It was accordance with Samsudin, *et al*. (2017) that development of a four-tier diagnostic test to identify student's misconceptions on the topic of effort and energy which construct validity was obtained for 15 item items, namely: three questions had high validity, five questions were sufficient, two questions

were low, four questions were very low and one invalid questions, the reliability of the assessment obtained a count value of 0.63 with the high category, the level of difficulty with the results: nine questions were categorized as difficult and six questions were categorized as medium. Pujayanto, *et al*. (2018) developed a four-stage diagnostic test on kinematics and found that the assessment was reliable based on the calculations with the Alpha Cronbach formula. The profile of conceptual understanding of students by using a sample of 102 students from three maritime schools in the city of Tegal is presented in Table 2.

From Table 2, it is found that the biggest misconception was found in the sub-concept of buoyancy (Archimedes law) as much as 46.5%, while the lowest misconception is in the sub-concept of applying Pascal's law as much as 35.2%. Misconceptions on fluid material in general were 38.8% and categorized as medium. The average percentage of student's understanding of the concept of fluid material in general is presented in Figure 3, while the misconceptions identified in each fluid sub-concept, the various misconceptions that stand out for each sub-concept are presented in Table 3.

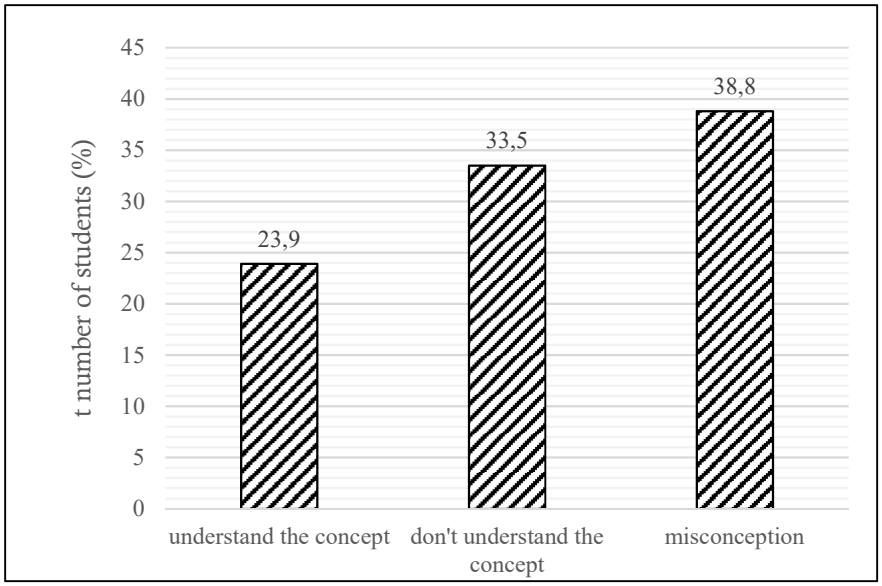

Figure 3. Student's Understanding of Fluid Material Concepts

The biggest misconception of 46.5% with a medium amount category was found in the buoyancy sub-concept (Archimedes law), while the smallest misconception was in the sub-concept of applying Pascal's law with a percentage of 35.2% and was categorized as medium. This is in line with Sholihat, *et al*. (2017) regarding the identification of misconceptions and their causes by using a four-tiered assessment of dynamic fluid material: the continuity principle where misconceptions were found as many as 28% of the total number of students. Aprita, *et al*. (2018) examined the understanding of the concept of dynamic fluids using a four tier assessment, obtained as many as 29.21% of students misconceptions which were found in all dynamic fluid sub-concepts. Salma, (2015) examined the development of E-diagnostic to identify high school student's understanding of physics concepts with static fluid material, it was found that 11.1% of students understood the concept of static fluids.

Table 3. Misconceptions for Each Sub-concept and Their Causes

Sub-concept	Various misconceptions	Causative factor
Hydrostatic pressure	The acceleration due to gravity in oil is smaller than in water.	Intuition in daily life
	Pressure by the fluid depends on the shape and volume of the vessel	Intuition in daily life
Buoyancy	The deeper a point in the fluid is, the greater the buoyancy force is experienced.	Conceptual appreciation
	At the same depth, the pressure by the wider sea will be greater than the narrow sea	Intuition in daily life
Application of Archimedes' law	Different liquids that occupy each vessel with the same volume will have the same buoyancy force.	Intuition in daily life and a specific theoretical framework
	Things float, float, and sink depending on the weight of the object.	Intuition in daily life
Pascal's Law	The greater the area of the two cross-sections of the vessel, the greater the lift.	Textbook reading
	The fluid flow rate in the narrowed pipe decreases exponentially.	Learning Activities
The continuity equation	In a pipe with a narrow area, the fluid flow rubs against the pipe wall so that turbulence, and fluid velocity decreases exponentially..	Learning Activities
	The speed of water in the pipe is proportional to the area of the pipe. The larger the pipe area, the greater the speed.	Intuition in daily life
Bernoulli's Law	Fluid flowing over a small cross-sectional area will have a smaller water flow rate.	Daily life intuition and conceptual appreciation
	If the air pressure above the vertical pipe is high, the liquid in the pipe is pushed upward.	Conceptual appreciation
Application of Torricelli's Theorem	The higher the time the vessel empties the water in the vessel the longer it is.	Intuition in daily life
	The distance that the water reaches from the leak pipe depends on the volume of water in the vessel and the height of the support seat.	Intuition in daily lifeand a specific theoretical framework

The five-tier diagnostic test instrument consists of the first tier multiple choice questions with five answer choices, the second tier the level of confidence in the answers to the selected answers in the first tier made with a certainty of response Index (CRI) six scales (0-6), tier to three, namely four choices of answers with one open reason, the fourth tier is the level of confidence in the correctness of the reasons made with a certainty of response index (CRI) six scales (0-6), the fifth tier is a belief in a cause-and-effect relationship (correlation) between answers with reasons.

Tayibnapis (2008) states that in multiple choice questions the type of relationship between things (cause-effect) and true-false statements requires an analysis of the relationship between things (cause-effect) between the statement and the reason for the statement. Ismail, *et al.*(2015) examined the development of a four-tier format dynamic misconception diagnostic assessment, Kaltacki (2012) examined the development of a four-tiered geometric

optical material assessment, and Fariyani (2017) examined the development of assessment misconception of four-tier geometric optics.

The results of the analysis of the written test and interview data showed that the causes of student's misconceptions were the intuition of daily life, specific theoretical frameworks, reading textbooks, learning, and conceptual appreciation. Students sometimes mention that misconceptions are obtained when reading textbooks, so the cause of the misconceptions they experienced was because of reading text books. Campanario (2006), as quoted by Linuwih (2011) states that there are several errors in textbooks that students usually read, especially those related to material content that greatly affects the formation of conceptions in students. Another student mentioned that he got the misconception from the formula and his own logic so that the misconception he experienced was due to the conceptual appreciation factor.

Linder (1993) as quoted by Linuwih (2011), when faced with contextual problems, students only rely on certain conceptions which are considered to be able to solve problems practically, this is said to be conceptual appreciation (appreciation). Other student's misconceptions were obtained from daily experiences, so that the cause was due to the intuition in daily life. Linuwih (2011) states that student's difficulties in understanding the concept of physics could be caused by the initial conception that developed due to the accumulation of perceptions as a result of interactions with daily life. Some other students stated that they experienced misconceptions due to the teacher's explanation so that the misconceptions they experienced were due to learning factors.

Thaden – Koch *et al*. (2006) as quoted by Linuwih (2011) states that the structure of physics knowledge that is being developed in the minds of students leads them to forget or ignore some of the observations that have been made. Other students experience misconceptions because they have experienced it directly, so that these student's misconceptions were caused by intuition factors in daily life and specific theoretical frameworks.Vosniadou as cited by Linuwih (2011) explains alternative conceptions based on two categories of theoretical structures, namely physics theory with a naive framework (simple) and specific theory (about physics). The theory of the naive framework rests on the presupposition of the nature and origin of the physical phenomena that began to be built in childhood. In other words, the theory of the naive framework rests on intuitive thinking.

CONCLUSION

The five-tier diagnostic test is a five-level multiple-choice test consisting of the first tier, which is a multiple choice conceptual question with five answer choices, the second tier is the level of confidence in the answer to the selected answer on the first tier, third tier, namely four choices of answer reasons with one open reason, fourth tier is the level of confidence in the correctness of the reasons for answers, tier five in the form of belief in the existence of a cause-and-effect relationship (correlation) between answers and reasons for answers. Expert validity test and instrument feasibility level obtained that the assessment developed was valid and met the eligibility requirements. The profile of student's conceptual understanding in maritime-based schools was 23.9% of students understood concepts, 33.5% of students did not understand concepts, and 38.8% of students had misconceptions. The most dominant misconception is that the deeper a point in the fluid is, the greater the buoyancy experienced. This student misconception is influenced by the conceptual appreciation and intuition in daily life.

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