An investigation of students’ conceptual understanding levels on fluid dynamics using four-tier test

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Abstract. Student repeatedly have difficulties in understanding complex physics concepts, such as fluid dynamic concept. It is occurred because the students’ conceptual understanding is low, thus indicating a low student mental model. The study aims to describe the students’ conceptual understanding levels on fluid dynamic using four-tier diagnostic test. A four-tier diagnostic test is a multiple-choice diagnostic test that have four tiers consist of answer tier, confidence ratings for the answer tier, and reason tier. The instrument test utilized to describe students’ conceptual understanding level regarding to the mental models. This research uses a descriptive-quantitative method. The data were analyzed using the four-tier diagnostic test rubrics that were used in related literature to analysis students’ conceptual understanding levels. The subject of this study is 24 students in the eleventh grade (16-17 age in average) at high school in Bandung. The results show that students’ conceptual understanding levels mostly in sound understanding/SU (35.27%), partial understanding/PU (42.91%), alternative understanding/AC (17.82%) and no understanding/NU (4%). Based on the result, four-tier test is able to use for investigating conceptual understanding levels.

1. Introduction

Physics is the study of physical phenomena consisting of many abstract concepts to explain the phenomenon [1]. In other words, students are required to be able to explain a physical phenomenon based on concepts in physics studies. The concepts in physics are interconnected each other, physics also related with the influence of the variables to the other physical quantities [2]. So, students must have a good conceptual understanding in physics concept. In practice, students have different levels of conceptual understanding for each concept. In some concepts, for example in fluid dynamic concept students often have difficulty to describe the concepts from the equation [3] and explaining a phenomenon based on the concept of fluid dynamics that have been studied. For example, in Bernoulli’s principle, students often do not understand the physical meaning of the equation.

\[ P_1 + \frac{1}{2} \rho v_1^2 + \frac{1}{2} gh_1 = C \]  

These conditions indicate that student's conceptual understanding is low of fluid dynamics concept, this also indicates a low students’ mental model. Each student will have the different level of understanding for each concept. To classify the student’s understanding level can use the diagnostic tests.
1.1. Conceptual understanding levels
The word concept has many insights in science. Conceptual understanding is an important thing in studying science, including physics [4]. Students are understanding the concepts when they are able to represent concepts in their own language either verbally, computational, mathematical equations, images, graphs or scientifically correct diagrams [2,5].

In learning materials or concepts that are closely related to the environment and daily life, high school students will have an initial idea or conception before they learn in the classroom, the initial knowledge that students have acquired in various ways, either through previous learning, experience, daily life and other [6,7]. Therefore, to make them understand the correct concept scientifically is very much dependent on the knowledge or conceptions of previous students [6]. To analyze students’ level of understanding can be done using a diagnostic test instrument, such as an ordinary multiple-choice test (FCI, ECI FMCE, FMCI etc.), open-ended questions, and four-tier tests [7-10]. Conceptual understanding is classified into several levels [5,11], described by Table 1 below.

Table 1. The criteria of conceptual understanding level.

| Conceptual Understanding Level | Criteria | Example of sub-concept in dynamic fluid |
|-------------------------------|----------|----------------------------------------|
| Sound Understanding (SU)      | Students understand the concept and can explain a phenomenon using a valid and scientific concept | Here is a graph showing the kinetic energy of K water element as it travels along the horizontal pipe on the x axis. |
|                               |          | Based on the graph above, so $r_A < r_C < r_B$. |
|                               |          | Since the value of K increases when the value of v in the fluid increases, and v increases as it passes through a narrowed cross-sectional area. |
| Partial Understanding (PU)    | Students understand only partial concepts and can only explain a phenomenon validly and scientifically | The student understands that and v increases as it passes through a narrowed cross-sectional area, but can’t find the relationship between K and v. |
|                               |          | Students understand that the value of K increases when the value of v in the fluid increases, but can’t explain the relationship of increasing the value of v cross-sectional area. |
| Alternative Conception (AC)   | Students have incorrect conceptions | Students believe that based on the graph that $r_A > r_C > r_B$, with the following graph bellow. |
1.2. Fluid dynamic four-tier diagnostic test

Fluid Dynamic-Four tier Diagnostic Test is an instrument developed to identify student's level of understanding on the concept of dynamic fluid. The four-tier diagnostic test is a development of two-tier and three-tier, consist of four tier answers; tier answers, confidence levels of answers at the 2nd and 4th tiers, and tier the reasons for choosing tiered answers [8-10]. The four-tier test is the development of a two-tier diagnostic test that only consist of the first tier of the question in the form of multiple choice and the second tier of reason for choosing an answer on the 1st tier [11]. Fluid Dynamic-Four tier Diagnostic Test adapted from the development of FMCI (Fluid Mechanic Concept Inventory) which is a test with this instrument is used to identify students' conceptual understanding and misconceptions on dynamic fluid materials [10].

1.3. Fluid dynamic concept

Dynamic fluid is one of physics concepts studied in various scientific disciplines [10] at various levels of education, one of them at the high school level. In the dynamic fluid concept, high school students study at least some sub-content that is the ideal fluid feature, discharge, continuity equation, Bernoulli’s principle and Torricelli’s theory. The dynamic fluid can be interpreted as a moving fluid [12], and is a concept studied after the concept of static fluid. In some sub-concepts on dynamic fluids apply some concepts on static fluids, such as pressure, hydrostatic pressure etc., so to be able to explain a phenomenon related to fluid dynamics students must also understand the concept of static fluid. Therefore, the effort in understanding this concept encounters distinct complexities and difficulties.

2. Methods

2.1. Design study

This research uses descriptive-quantitative design method. Descriptive research is research that describes the state of the variable or phenomenon under study [13]. While quantitative research describes a situation or phenomenon by collecting numerical data which is analyzed using mathematical based methods [13]. Descriptive-quantitative method is a research method that combines descriptive and quantitative methods. In this study attempts to collect data quantitatively and conduct a quantitative
analysis to then describe or classify the data into several predetermined categories. In this study the scholars were asked to work on the diagnostic test instrument and the data was then analyzed quantitatively to be able to describe and classify the level of scholars' conceptual understanding descriptively.

2.2. Participant
The participant of this study are 24 students in the eleventh grade (9 male and 15 female, 16-17 age in average) at one of senior high school in Bandung city. Students come from diverse backgrounds, whether domicile, family background, or economic situation. Almost all students are domiciled in the city of Bandung, and come from families with middle to upper economy.

2.3. Instrument
This study was conducted to measure the students' understanding on the concept of fluid dynamics using the Fluid Dynamic-Four tier Diagnostic Test diagnostic test. Students are asked to do 12 pieces of questions in the form of four-tier for 45 minutes. Here is an example of a form of questions done by students.

**Figure 1.** The example question of Fluid-Dynamic Four-Tier Test.

The following table shows a combination of four-tier test answers used to classify students' level of understanding [14].

| Category                        | Answer Combination | Level confidence of the answer | Reason          | Level confidence of the reason |
|---------------------------------|--------------------|--------------------------------|-----------------|--------------------------------|
| Alternative Conception (AC)     | False              | Sure                           | False           | Sure                           |
| No Understanding (NU)           | False              | Sure                           | False           | Not Sure                       |
|                                 | False              | Not Sure                       | False           | Sure                           |
|                                 | False              | Not Sure                       | False           | Not Sure                       |
| Sound Understanding (SU)        | True               | Sure                           | True            | Sure                           |
| Partial Understanding (PU)      | True               | Sure                           | True            | Note Sure                      |
|                                 | True               | Not Sure                       | True            | Not Sure                       |
|                                 | True               | Sure                           | False           | Sure                           |
3. Result and Discussion

Based on the results of student answers data shows that the level of students' understanding on dynamic fluid material can be analyzed by using Fluid Dynamic-Four tier Diagnostic Test. The level of students' understanding is classified into 5 levels: SU, NU, AC, PA, and NR. Based on the results of data analysis obtained results shown by Table 3 below [14].

Table 3. Student’s conceptual understanding level on fluid dynamic concept.

| No. item | Sub Concept                  | SU | PU | AC | NU | NR |
|----------|------------------------------|----|----|----|----|----|
| 1        | Ideal Fluid                 | 2  | 19 | 1  | 1  | 0  |
| 2        | Debit                       | 17 | 4  | 2  | 0  | 0  |
| 3        | Continuity equation         | 7  | 16 | 0  | 0  | 0  |
| 4        | Bernoulli’s Principle and It’s application | 8   | 12 | 2  | 0  | 0  |
| 5        | Torricelli’s theory         | 5  | 12 | 4  | 2  | 0  |
| 6        |                             | 19 | 3  | 1  | 0  | 0  |
| 7        |                              | 4  | 11 | 7  | 1  | 0  |
| 8        |                              | 3  | 11 | 6  | 3  | 0  |
| 9        |                              | 10 | 13 | 0  | 0  | 0  |
| 10       |                              | 10 | 3  | 10 | 0  | 0  |
| 11       |                              | 10 | 1  | 9  | 3  | 0  |
| 12       |                              | 2  | 13 | 7  | 1  | 0  |
| Average (%) |                        | 35,27 | 42,91 | 17.82 | 4.00 | 0  |

The percentage level of student understanding for each concept in dynamic fluid is shown in Table 4 below.
Table 4. Student’s conceptual understanding level on fluid dynamic concept.

| Sub-Content                  | Level Understanding |
|------------------------------|---------------------|
|                              | SU      | PU      | AC      | NU      |
| Ideal Fluid                 | 39.58   | 47.92   | 6.25    | 2.08    |
| Debit                        | 29.17   | 66.67   | 0.00    | 0.00    |
| Continuity equation          | 44.44   | 37.50   | 9.72    | 2.78    |
| Bernoulli’s Principle and It’s application | 28.13   | 39.58   | 23.96   | 4.17    |
| Torricelli’s theory          | 25.00   | 29.17   | 33.33   | 8.33    |

Based on the data obtained shows that most students have partial conceptual understanding and sound understanding. In the concept of continuity equation shows the largest percentage of sound understanding level that is equal to 44.44% while in the concept of Bernoulli equations and its application including Torricelli’s theory concept shows a low percentage value on the level of sound understanding compared to other concepts, which is 28.13% and 25%. In the percentage of no understanding it shows that the smallest percentage is in debit concept. This condition is caused by because debit concept is a concept that is closely related to daily life and the situation described on debit problems can be easily imagined by students, so that when explaining the situation depicted on the problem most students can explain the state of the physical variable that will occur even not all students understand the scientific explanation of why the condition in the physical variable occurs. Unlike with the ideal fluid concept, which is a condition that does not occur significantly and is difficult to observe directly. The ideal fluid concept itself is a concept that is in the form of memorization. With such concept characters make this concept more difficult to understand than the concept of debit. Although the percentage of sound understanding in the ideal fluid concept is higher than debit concept, but the percentage of level no understanding and alternative conception on the concept is more than the debit concept. Based on percentage of sound understanding on the Table 4 shows that the concepts that are difficult for students in dynamic fluid material are Bernoulli’s principles and their application includes Torricelli’s theory, as research conducted by Samsudin A et al. [3].

Figure 2. The sample of Student’s answer

Based on Student 5’s answer show that student don’t understand about the concept of Bernoulli’s principle because student can’t explain the relation between pressure and velocity in that question and not satisfied with the answer, moreover from Student 4’s answers, it can be analyzed that students have a misconception about the relationship of pressure (P) with the velocity (v) at different cross-sectional areas. While Student 3 and Student 2 has a partial understanding, shown in the correct understanding of
students related to the relationship of velocity ($v$) with pressure ($P$) according to Bernoulli's principle, but students cannot show a relationship between the cross-sectional area ($A$) of the pipe with the velocity and pressure correctly. This shows that students' understanding is still partial about a phenomenon, because students only understand each concept, whereas when the phenomenon or condition is explained by more than one concept in dynamic fluid most students still have difficulty in combining two or more concepts to explain it. The following shows a sample questions in the form of conditions that combine two or more concepts to explain them as shown in Figure 3. And then the Student 1’s answer shows the sound understanding level, and Student 1’s can explain the condition with combine two concepts there are Bernoulli’s principle and continuity equation scientifically. Here is an example of a form of questions done by students.

**Figure 3.** The example question that consist of more than one concept.

Fluid-Dynamic Four-Tier Test is a diagnostic test developed by researchers to analyze students' level of understanding on dynamic fluid materials. The concept of dynamic fluid is a concept that is widely applied in technology and everyday life so it is important for students to understand the concept is valid and scientific. Based on the data obtained from the research results showed that the level of students' understanding is categorized into four levels, namely SU (35.27%), PU (42.91%), AC (17.82%), NU (4%), and no students answer the question with incomplete (NR = 0%). So, it can be concluded that Fluid-Dynamic Four-Tier Test can be used to analyze the level of students' understanding on the concept of dynamic fluid.

**4. Conclusion**

Fluid-Dynamic Four-Tier Test is a diagnostic test developed by researchers to analyze students' level of understanding on dynamic fluid materials. The concept of dynamic fluid is a concept that is widely applied in technology and everyday life so it is important for students to understand the concept is valid and scientific. Based on the data obtained from the research results showed that the level of students' understanding is categorized into four levels, namely SU (35.27%), PU (42.91%), AC (17.82%), NU (4%), and no students answer the question with incomplete (NR = 0%). Based on these results, most students have a sound understanding of each concept but have difficulties when explaining a situation or phenomenon by combining two or more concepts well and scientifically. So, it can be concluded that Fluid-Dynamic Four-Tier Test can be used to analyze the level of students' understanding on the concept of dynamic fluid.

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