Analysis Students’ Conception Using Four-Tier Diagnostic Test for Dynamic Fluid Concepts

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Abstract. Based on the interview carried out by the authors to the students in Senior High School 1 Sidoarjo, East Java on Physics subject, it was obtained the fact that the Physics lesson was considered as a difficult subject. The most reason was that Physics contained many formulas and concepts which were not clearly taught by the teacher. Such situation has potentially caused misconceptions to the students. This paper reports the work to identify the conceptions of 11th grade Science class students of Senior High School 1 Sidoarjo, East Java on Dynamic Fluid concepts using a four-tier format of misconception diagnostic test. The causes of misconceptions were analyzed based on the internal aspects of students, namely preconception, associative thinking, humanistic thinking, incomplete or wrong reasoning and wrong intuition. The instrument consists of 15 numbers of multiple choice questions. The results showed that most students have scientific conception while the rest experienced misconception. The most misconception occured on the Bernoulli’s Law and its applications due to incomplete reason.

1. Introduction
When asked, many students in Senior High School 1 Sidoarjo, East Java responded that Physics was a difficult subject. They argued that Physics contains many formulas and concepts. Unfortunately, the teachers quite often did not explain the concepts satisfactorily. These situations caused students to be reluctant to study the lesson at home. Besides, the quiz scores earned by students are frequently not satisfying. If such learning atmosphere took place continuously, this potentially disrupt the students’ understanding on the other concepts. Basically, in daily life, via interaction of a student with surrounding objects, with the family members or with society in the neighbourhood, a student has gained initial knowledge on Physics concepts. For example, when someone wants to make his body smell nice, what he has to do is pump the perfume bottle by pressing the lid so that the liquid perfume in the bottle will move up through the capillary tube in the bottle and explode out into the body. If for some reasons the capillary tube hole is blocked by something (for example by dust), one can insert a small wooden stick (e.g. toothpick stick) into a blocked tube and shake it up and down quickly. In this way, blocking is reopened. Students may not realize that perfume bottles work according to Bernoulli’s law, i.e. when the capillary tube in a perfume bottle is blocked, it causes a zero cross-sectional area so that the liquid in the bottle is blocked. In Figure 1, when a blocked capillary tube has been opened, the tube has a cross-sectional area so that the perfume liquid is pumped out properly.
Figure 1. Perfume liquid is sprayed smoothly from the bottle because there is no block in the capillary tube in the bottle.

Students assumed that the perfume liquid can spread out to the body because of the large pressure given by someone on the bottle lid causing the velocity of pump was large. The difference between the student's assumption and the concept of physics on the Bernoulli's law can lead to misconception [1]. The causes of misconceptions basically can arise from internal and external aspects of students. The external aspects include teachers, textbooks and any other sources [2]. While the internal aspects of misconception causes are originating from students themselves. Those include: preconceptions, associative thinking, humanistic thinking, incomplete reasoning, intuitive thinking, imperfect stages of cognitive development and low interest in a lesson. Among those internal aspect of misconception causes, only the first five are investigated in this work.

This present paper is devoted to analyse the conception of 11th grade students in Science class of Senior High School 1 Sidoarjo, East Java in Dynamic Fluid concepts using four-tier diagnostic test and identify the causes of misconceptions based on the internal aspects.

2. Method

2.1 Sample

The instrument of four-tier based misconception diagnostic test consists of 15 number of multiple choice questions and was tested on 32 numbers of students in 11th grade of Science class of Senior High School 1 Sidoarjo, East Java. The student participants had learned the Dynamic Fluid concepts during the previous semester.

2.2 Instrument

The instrument of four-tier misconception diagnostic test on the Dynamic Fluid concepts was developed by the authors. The developed questions cover several sub-concepts, namely: Continuity Equation (CE), Bernoulli's Law (BL), Theory of Torricelli (TT) and Application of Bernoulli's Law (AB). Before the developed instrument was tested to the participants, an initial trial test was conducted to the 40 number of new students (the commencement years of 2018) in Physics Department, Universitas Negeri Surabaya selected randomly in order to collect the first- and second-tier answers and reasons to the questions. The collected data on the answers and reasons was analysed; the selected and common reasons were occupied to develop the instrument. The validity and reliability test of the developed instrument was provided in Kurniawati and Ermawati result [3].
2.3 Data Analysis

The four-tier diagnostic test can detect student’s misconception by distinguishing the level of student’s conception into seven categories based on the combination of student’s answers (see Table 1) [4]. As mentioned, each question had one correct answer and one correct reason. Other options contain alternative conceptions. Therefore, student responses were analysed based on the alternative conception [5]. Student responses are grouped into seven categories as in Table 1, namely: a) scientific conceptions (SC) that is when the answers and reasons are correct and they are very confident in the answers and reasons; b) lack of knowledge-guessing (LKG) is when the answer or the reason is correct, but the student is not sure of any answer or reason; c) lack of knowledge-deficiency (LKD) is when the reason is correct, but the answer is wrong and student not sure of any answer or reason d) false positive (FP) is defined when the answer is correct and the reason is wrong, but they are sure of the answer and the reason; e) false negative (FN) is a condition that is contrary to false positive; f) Misconceptions (MSC) is when the answer and the reason is wrong but they are sure of the answer and the reason; g) cannot be encoded is when one, two, three or all are not answered.

**Table 1. Categories of combination four-tier answers**

| No. | Option       | Confidence | Reason | Confidence | Categories |
|-----|--------------|------------|--------|------------|------------|
| 1   | Correct      | Sure       | Correct| Sure       | SC         |
| 2   | Correct      | Sure       | Wrong  | Sure       | FP         |
| 3   | Wrong        | Sure       | Correct| Sure       | FN         |
| 4   | Wrong        | Sure       | Wrong  | Sure       | MSC        |
| 5   | Correct      | Sure       | Correct| Not Sure   | LKG        |
| 6   | Correct      | Not Sure   | Correct| Sure       | LKG        |
| 7   | Correct      | Not Sure   | Correct| Not Sure   | LKG        |
| 8   | Correct      | Sure       | Wrong  | Not Sure   | LKG        |
| 9   | Correct      | Not Sure   | Wrong  | Sure       | LKG        |
| 10  | Correct      | Not Sure   | Wrong  | Not Sure   | LKG        |
| 11  | Wrong        | Sure       | Correct| Not Sure   | LKG        |
| 12  | Wrong        | Not Sure   | Correct| Sure       | LKG        |
| 13  | Wrong        | Not Sure   | Correct| Not Sure   | LKG        |
| 14  | Wrong        | Sure       | Wrong  | Not Sure   | LKD        |
| 15  | Wrong        | Not Sure   | Wrong  | Sure       | LKD        |
| 16  | Wrong        | Not Sure   | Wrong  | Not Sure   | LKD        |
| 17  | If one, two, three or all are not answered | Cannot be encoded | | |

SC = scientific conception, MSC = misconception, FN =false negatives, FP =false positives, LKG = lack of knowledge guessing, LKD = lack of knowledge deficiency.

The level of student’s understanding can be categorized by calculating the answers % from each of these categories for each question using the following equation [6],

$$PJ = \frac{n_x}{n_s} \times 100\%$$

(1)

Where PJ is the answer % of each question, n_x is the number of students who categorised as scientific conception (SC), misconception (MSC), lack of knowledge guessing (LKG), lack of knowledge deficiency (LKD), false positives (FP), false negatives (FN), cannot be encoded (TKD), and n_s is the total number of student participants. Table 2 shows one of 20 total numbers of questions of four-tier misconception test developed in this work.
### Table 2. Example of a four-tier question on the Dynamic Fluid concept

| Number of Tier | A sample of question |
|---------------|----------------------|
| One-Tier      | ![Diagram](A, B, C)  |
|               | Water flows from pipe A to pipe C as shown by the arrow in figure above. The pipe has a different cross-sectional area (A). If the velocity of flow on Pipe A is $v_A$, the velocity on Pipe B is $v_B$, the velocity on Pipe C is $v_C$ while the cross-sectional area ratio A, B and C is 8:3:5, then velocity ratio in Pipes A, B, and C is (modified from: Aprita, 2018[7]) |
|               | a) $v_A > v_C > v_B$ |
|               | b) $v_A > v_B > v_C$ |
|               | c) $v_A < v_C < v_B$ |
|               | d) $v_A < v_B < v_C$ |
| Two-Tier      | The level of confidence of answers |
|               | 1. Sure |
|               | 2. Not sure |
| Three-Tier    | Reasons for answer |
|               | a) The velocity of water in Pipe B is greater than the velocity of water in Pipes A and C because the diameter of Pipe B is smaller than the diameter of Pipe A and B so that the current flowing in Pipe B is the heaviest |
|               | b) The velocity of water in Pipe A is greater than the velocity of water in Pipes B and C because the diameter of Pipe A is greater than the diameter of Pipes B and C so that the current flowing in Pipe A is heavier (R) |
|               | c) The velocity of water in Pipe A is greater than the velocity of water in Pipes B and C because when water is in Pipes B and C, the energy slows down so that the current velocity slows (A) |
|               | d) The velocity of water in Pipe C is greater than the velocity of water in Pipes A and B because Pipe C is the last pipe so that more water is accommodated and causes a large velocity (H) |
| Four-Tier     | The level of confidence of reasons |
|               | 1. Sure |
|               | 2. Not sure |

As mentioned, the first-tier of the diagnostic test instrument is a multiple choice answer, the second-tier is the level of confidence of the answers at the first-tier, the third-tier is the reason for the answers given at the first-tier. The choice of reasons (in Table 2) were chosen based on five types of misunderstanding originating from the students themselves, namely preconception (P), associative thinking (A), humanistic thought (H), incomplete or wrong reasoning (R) and wrong intuition (I). With the choice of these reasons, the possible causes of students’ misconceptions can be detected easily. The fourth-tier is the level of reason confidence on the third-tier.

The reason chosen by students who suffered misconceptions are grouped based on the cause and this was calculated using the following equation,

$$PPM = \frac{n_X}{n_M} \times 100\%$$  \hspace{1cm} (2)

Where PPM is cause of misconception %, $n_X$ is the number of students who detected suffered preconception (P), associative thinking (A), humanistic thought (H), incomplete or wrong reasoning (R) and wrong intuition (I), and $n_M$ is the total number of students who suffered misconception.

### 3. Results and Discussion

The identification of conception profiles of 32 numbers of student participants in the Dynamic Fluid concepts was shown in Figure 2.
In Figure 2, the highest misconception % were Bernoulli's Law and Application of Bernoulli's Law. There are (30-40)% and (20-30)% of students who were detected to have misconceptions. The most reason is that the participants were just memorizing the formulas without understanding the concepts. For example, question No. 4 (Bernoulli Law concept): "A house has a water pipeline with 3 different diameters \( d_1 \), \( d_2 \) and \( d_3 \) respectively, where \( d_1 < d_2 < d_3 \) as shown in Fig. 4. Watervelocity in \( d_1 \), \( d_2 \) and \( d_3 \) are \( v_1 \), \( v_2 \) and \( v_3 \) respectively. If water flows from left to right as shown by the arrow on the figure, what is the ratio of fluid pressure in pipes 1, pipe 2 and pipe 3?" Nearly 40 % of total numbers of students are misconception due to this question. The students assumed that when water flows in the pipe with diameter of \( d_3 \), the fluid pressure will be smaller than the similar pressure when water flows in the pipe with diameter of \( d_2 \). They assumed that in a small cross-sectional area (\( d_2 \)), the fluid pressure will be greater than the fluid pressure at the large cross-sectional area (\( d_3 \)). However, the correct concept according the book of Young and Freedman [8] is when the fluid in a large cross-sectional area, the fluid pressure is also large while when it passes through a small cross-sectional area (\( d_2 \)), the fluid pressure is also small. Thus, it is clear that students suffered of misconception due to the difference between the understanding of students and the correct concept of physics.

Furthermore, the other sub-concepts that shows high misconception % is on the concept of Application of Bernoulli's Law (see Figure 2). For example, the question No. 14: "A plumber builds a pipe system consists of pipe A, pipe B, pipe C and pipe D as shown in Figure 14. The four pipe have different radii (\( R_A \), \( R_B \), \( R_C \) and \( R_D \) respectively). The radius of the pipe B is \( R_B = 2 \) cm, \( R_A = 0.5 R_B \), \( R_C = 3R_B \) and \( R_D = 2R_B \). Each pipe has a vertical pipe with the same diameter to each other. If the horizontal pipe is filled with water, the water will also fill the vertical pipe. The air pressure in the vertical open pipe is 1.0 atm. Sort the increase in water from highest to lowest among the four vertical pipes". The students answered that water in the vertical pipe of the horizontal pipe with smallest radius (\( R_A \) pipe) increases highly than the other vertical pipes. However, the correct answer is the opposite one, i.e. the increase of water level in the vertical pipe is obtained in the horizontal pipe with largest radius. The reason is that in a pipe with large radius, the fluid pressure in such pipe will also large. This gives rise water to rise on the vertical pipe.
Scientific conception or well understanding the concept was also recorded in Figure 2, especially for the concepts of Continuity Equation (64 %) and Theory of Torricelli (47%). The Continuity Principle discusses Equations $A_1 (v_1) = A_2 (v_2)$ where the multiplication between the pipe cross-sectional area ($A$) and velocity of fluid ($v$) is constant. The velocity of fluid will therefore increase when the cross-sectional area of the pipe reduces, and vice versa. For students who have good understanding on the concept of the continuity equation, they have no difficulty in solving the problems. For example, the question No. 2: "A boat crosses a river that has two different width ($l_1$ and $l_2$, where $l_1 > l_2$) as shown in Figure 2. The velocity of water flow in cross section $l_1$ and $l_2$ are $v_1$ and $v_2$ respectively. How do you compare the speed of the river current felt by someone who is driving a boat in the width of river $l_1$ and in the width of river $l_2$?". Of the 32 participants, 64 % of them can answer the question well. In other words, they understood the concept well or scientific conception.

The last is Torricelli’s Theory which explains the state of fluid that slides out of a hole in a tube that has leaked. For example, the question Number 6 is "A pipe in Figure 7 has two different heights, $h_1 = 1$ m and $h_2 = 5$ m measured from the surface of the floor. The cross-sectional area of the pipe both at height $h_1$ and at height $h_2$ is the same, namely $A$. Water is flowed from the height of $h_1$ to the height of $h_2$. What is the ratio of fluid pressure between at point $h_1$ and point $h_2$?" 47 % of total participants can answer the question correctly. They argued that the velocity of water coming out from the pipe hole depends on the distance of the hole to the surface of the water.

![Figure 3](image-url)

Figure 3. Distribution of causes of student’s misconception on the sub-concepts in the Dynamic Fluid concepts. P = preconception, A = associative thinking, H = humanistic thought, R = incomplete or wrong reasoning and I = wrong intuition.

Figure 3 depicts the distribution of misconception causes in the Dynamic Fluid concepts arises from the internal aspect of students. The highest cause of misconception in the sub concepts Continuity Equation (CE) is due to wrong intuition (I) which is more than 40 %. None of misconception is due to preconception (0 %). For Bernoulli’s Law sub-concept, more than 55 % of the misconception is due to associative thinking, 25 % is due to humanistic thought, 15 % is due to incomplete reasoning and none of the cause is due to preconception. Further, around 55 % of all participants experienced misconceptions because of associative thinking in the Theory of Torricelli. That is the dominant cause of misconception. The rest, namely 25 % is caused by humanistic thinking, 10 % is due to preconception and another 10 % is due to incomplete reasons. Finally, the main cause of misconception in the
Application of Bernoulli's Law concept is 35% due to wrong intuition, 26% is due to associative thinking, 20% arises from preconception, 11% caused by wrong intuition and another 10% is due to humanistic thought.

4. Conclusion
This work reveals that misconceptions indeed took place in the Dynamic Fluid concepts and the dominant causes is associative thinking. Having this results, it is recommended for Physics teachers in Secondary High School, especially in the Senior High School 1 Sidoarjo, East Java to take a concrete action to anticipate the misconception by involving the students to empirical learning experiences.

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