Exploration of the Students’ Conceptions Profile on Chapter Gas Kinetic Theory through Four-Tier Diagnostic Test and Interview

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Abstract. This study aimed at exploring the conception profile of grade eleventh on the kinetic theory of gas material through the four-tier diagnostic test and semi-structured interview. The discussion of conception in this study included Understand of the Concept (U), Partial Understanding (PU), Misconceptions (M), Not Understand the Concept (NU), and Un-Code (UC). Conception profiles were obtained after the second trial to 34 students of grade eleventh as a whole, which resulting the profile map of conceptions: The Understand the Concept (U) 22%, Partial Understanding (PU) 29%, Misconceptions (M) 31%, Not Understand the Concept (NU) 18% and Un-Code (UC) 0%. Meanwhile, the interviews process aimed at determining the suitability of students' answers using the four-tier diagnostic test instrument with student answers.

1. Introduction
Physics is one of the natural sciences in which learn about nature and phenomena or natural phenomena and their interactions. This phenomenon experienced by someone is referred to as experience that will become embedded in the human mind. The memory from experience is an initial knowledge or initial concept that someone has. The initial concept is then interpreted by themselves and when someone interprets the concept, the interpretation they make is not always following the concept should. “One’s interpretation of a concept is called conception” [1]. The conception that is not following the scientific concept is called misconception [2]. “Misconception is one's understanding of a concept that is not following the concept recognized by experts. It is not uncommon that students' concepts, even though they do not fit into scientific concepts, can last long and are difficult to repair or change during formal education”. This is usually due to their concept that it is, although wrong, but can explain some of the problems they are facing in their lives. The type of misconception that occurs most often is not because of students' misunderstandings during the teaching and learning process, but because of the initial conceptual errors (preconceptions) that students take informal classes [3].

Misconceptions can arise from everyday experiences experienced by students when interacting with their surroundings. Through this experience, students will build their theories in their minds which are not necessarily true. “The intuition is not correct, resulting in it will be very difficult to repair because accidentally consistently the wrong physics concept has become a handle” [1]. One of the things that cause students’ misconceptions is that they often associate physical phenomena with
events that occur in daily life, resulting in incompatibility [4]. “There are external factors and internal factors in student learning difficulties, internal factors can be a lack of interest and lack of motivation to learn while external factors are lack of media variation and learning methods” [5].

Diagnostic tests are one way to find out student misconceptions. “One way to know students’ misconception is through a diagnostic test. The use of a diagnostic test can help the teacher to discover students’ misconception”. [6]. Gas kinetic theory is one example of physics learning material that occurs in students' misconception because this material learns something abstract, like ideal gas which does not exist in the universe.

This study used a four-level diagnostic test to identify students' conceptions in the kinetic theory of gas. The four-tier diagnostic test is the development of three-level diagnostic tests by adding confidence to each answer and reason. Increasing the level of confidence in diagnostic tests requires students to be more careful in choosing answers [7]. “The four-tier diagnostic test is the development of three-level diagnostic tests by adding confidence to each answer and reason. Increasing the level of confidence in diagnostic tests requires students to be more careful in choosing answers”. The four-tier diagnostic test is “the refinement of the similar diagnostic test with the three-tier format which only consists of the first three components” [8].

The purpose of this study is to determine the feasibility of the four-tier diagnostic test instruments from aspects of practicality and effectiveness aspects that have been developed to identify students' conceptions in the Gas Kinetic Theory material and determine the conception profile of 11th grade of science class on the material of Kinetic Gas through a four-tier diagnostic test.

2. Method
This type of research uses the ADDIE (analysis, design, development, implementation, and evaluation) model. After going through the stages of analysis, design, and development in the first trial, 14 questions were obtained which were said to be valid from 18 questions tested. So that the second trial is implementation to determine the student conception profile and evaluation is the result of the study and there are no changes to the four-tier diagnostic test instrument.

| Table 1. Combination Category Answers Four-Tier Diagnostic Test. |
|---|---|---|---|---|
| No | Category | Answers | Confidence Level | Reasons | Confidence Level |
| 1 | Understand the Concept (U) | Correct | Sure | Correct | Sure |
| 2 | Correct | Sure | Correct | Not Sure |
| 3 | Correct | Not Sure | Correct | Sure |
| 4 | Correct | Not Sure | Correct | Not Sure |
| 5 | Correct | Sure | Incorrect | Not Sure |
| 6 | Correct | Not Sure | Incorrect | Sure |
| 7 | Correct | Not Sure | Incorrect | Not Sure |
| 8 | Incorrect | Sure | Correct | Not Sure |
| 9 | Incorrect | Not Sure | Correct | Sure |
| 10 | Incorrect | Not Sure | Correct | Not Sure |
| 11 | Correct | Sure | Incorrect | Sure |
| 12 | Incorrect | Sure | Correct | Sure |
| 13 | Incorrect | Sure | Incorrect | Not Sure |
| 14 | Incorrect | Not Sure | Incorrect | Not Sure |
| 15 | Incorrect | Not Sure | Incorrect | Not Sure |
| 16 | Misconception (M) | Incorrect | Sure | Incorrect | Sure |
| 17 | Un-Code (UC) | There is “tier” which aren’t answered or the answers is more than one available option |
The second trial to determine the conception profile through four-tier diagnostic test instrument with a sample of 34 students of 11th grade. There were four categories to distinguish the level of conception of students based on the combination of answers given by students through the four-tier diagnostic test. The conceptual categories referred to are given in Table 1. Additionally, the results of semi-structured interview were coded manually with simple qualitative coding [9].

3. Results and Discussion

Based on the results of the second trial, the students' conception analysis was based on the combination of Four-Tier Diagnostic test answers according to Table 1, with student conception categories including, Understand the Concepts (U), Partial Understanding (PU), Misconceptions (M) and No Understand the Concept (NU). Based on the results of the second trial that have been done, it can be seen the level of student conception [10-12,15]. The recapitulation of the results of conception calculations for each student based on the categories in Table 2.

Table 2. Recapitulation of the results of conception calculations for each student.

| No | Number of Conceptions | Percentage (%) | Total (%) |
|----|-----------------------|----------------|-----------|
|    | U  | PU  | M  | NU | U  | PU  | M  | NU |
| 1  | 3  | 4   | 2  | 5  | 21.43 | 28.57 | 14.29 | 35.71 |
| 2  | 8  | 3   | 3  | 0  | 57.14 | 21.43 | 21.43 | 0  |
| 3  | 8  | 3   | 3  | 0  | 57.14 | 21.43 | 21.43 | 0  |
| 4  | 2  | 1   | 8  | 3  | 14.29 | 7.143 | 57.14 | 21.43 |
| 5  | 1  | 2   | 4  | 7  | 7.143 | 14.29 | 28.57 | 50  |
| 6  | 1  | 7   | 5  | 1  | 7.143 | 50  | 35.71 | 7.143 |
| 7  | 6  | 5   | 3  | 0  | 42.86 | 35.71 | 21.43 | 0  |
| 8  | 0  | 6   | 1  | 7  | 0  | 42.86 | 7.143 | 50  |
| 9  | 1  | 6   | 6  | 1  | 7.143 | 42.86 | 42.86 | 7.143 |
| 10 | 6  | 2   | 5  | 1  | 42.86 | 14.29 | 35.71 | 7.143 |
| 11 | 0  | 8   | 0  | 6  | 0  | 57.14 | 0  | 42.86 |
| 12 | 6  | 3   | 3  | 2  | 42.86 | 21.43 | 21.43 | 14.29 |
| 13 | 3  | 2   | 9  | 0  | 21.43 | 14.29 | 64.29 | 0  |
| 14 | 2  | 4   | 7  | 1  | 14.29 | 28.57 | 50  | 7.143 |
| 15 | 0  | 3   | 5  | 6  | 0  | 21.43 | 35.71 | 42.86 |
| 16 | 2  | 5   | 5  | 2  | 14.29 | 35.71 | 35.71 | 14.29 |
| 17 | 3  | 2   | 7  | 2  | 21.43 | 14.29 | 50  | 14.29 |
| 18 | 0  | 6   | 4  | 4  | 0  | 42.86 | 28.57 | 28.57 |
| 19 | 1  | 7   | 3  | 3  | 7.143 | 50  | 21.43 | 21.43 |
| 20 | 2  | 4   | 5  | 3  | 14.29 | 28.57 | 35.71 | 21.43 |
| 21 | 9  | 3   | 2  | 0  | 64.29 | 21.43 | 14.29 | 0  |
| 22 | 1  | 2   | 7  | 4  | 7.143 | 14.29 | 50  | 28.57 |
| 23 | 6  | 1   | 6  | 1  | 42.86 | 7.143 | 42.86 | 7.143 |
| 24 | 2  | 3   | 8  | 1  | 14.29 | 21.43 | 57.14 | 7.143 |
| 25 | 2  | 4   | 2  | 6  | 14.29 | 28.57 | 14.29 | 42.86 |
| 26 | 6  | 4   | 4  | 0  | 42.86 | 28.57 | 28.57 | 0  |
| 27 | 3  | 6   | 5  | 0  | 21.43 | 42.86 | 35.71 | 0  |
| 28 | 0  | 6   | 2  | 6  | 0  | 42.86 | 14.29 | 42.86 |
| 29 | 0  | 6   | 0  | 8  | 0  | 42.86 | 0  | 57.14 |
| 30 | 4  | 3   | 5  | 2  | 28.57 | 21.43 | 35.71 | 14.29 |
| 31 | 3  | 7   | 4  | 0  | 21.43 | 50  | 28.57 | 0  |
| 32 | 8  | 2   | 4  | 0  | 57.14 | 14.29 | 28.57 | 0  |
| 33 | 6  | 3   | 5  | 0  | 42.86 | 21.43 | 35.71 | 0  |
| 34 | 1  | 6   | 6  | 1  | 7.143 | 42.86 | 42.86 | 7.143 |
Based on Table 2, the percentage of the conception of each student was obtained based on each conception category, including Understanding the Concept (U), Partial Understanding (PU), Misconceptions (M) and Not Understanding the Concept (NU). The percentage of the conception of all students can be seen in Figure 1.

![Figure 1. Percentage of the conception profile of 11th grade of science class.](image)

Based on the percentage in Figure 1 above, it shows that the percentage of conception profiles 34 students of 11th grade of science 4th class of the 14 questions tested were for the U (Understand the Concept) category of 22%, PU (Partial Understanding) 29%, M (Misconception) 31%, 18% NU (Not Understand the Concept) and 0% for the UC (Un-Code) category, because there are no identified students there are levels that are not filled, or answer more than one at the same level. “Not understanding the concept can also occur because students were not listening to students on going or because the methods used by teachers were boring so that students did not listen during the lesson so there are some concepts that are not understood by students” [12-13,15-17].

### 3.1. Analysis of Profile Conception through Four-Tier Diagnostic Tests and Interviews

The following are examples of student conceptions obtained through four-tier diagnostic tests and interviews, conducted interviews to determine the suitability of students' answers using the four-tier diagnostic test instrument with student answers, where the four-tier diagnostic test there are reasons for the third level. Interviews were conducted after a series of trials took place to student representatives and interview results were analysed using manual coding techniques. [13,15-17]. For the participant from the interview processes were coded as a pseudonym name.

In number 9, students named Asa are categorized as Not Understanding the Concept because they choose the wrong choice of choices and choice of reasons, and are not sure of the choice of answers and reasons are chosen.

Given the question of the four-tier diagnostic test, Asa assume that “when the tube in the picture has the same number of gas molecules each tube is heated to reach the temperature as shown”. “If sorted, the tube that has the biggest pressure to the smallest is "Tube 1> Tube 2> Tube 3> Tube 4"”, with the reason "the greater the temperature of the gas undergoing expansion thereby reducing the gas pressure". The reason given by Asa was obtained based on the results of the interview,

Asa said, "When the gas molecule is heated it decreases, then the pressure at a high temperature is small".

In number 14 students named Putri are categorized as Misconceptions because they are wrong in choosing answer choices and choice of reasons, but are sure of the choice of answers and reasons have chosen. When the balloon that has been blown to expand is inserted into the syringe, then two different treatments are carried out, namely in condition 1 and condition 2. In "condition 1" when a balloon is placed in the syringe then the injection is pressed and in "condition 2" when the balloon in the syringe is then withdrawn. Note that the injection tip is also closed. If using Boyle's Law approach.
Given the question of the four-tier diagnostic test Putri assume the process that occurs in "condition 1" and "condition 2" is when "condition 1" the size of the balloon "enlarges" while the "condition 2" size of the balloon "shrinks", with the reason "pressure inside the syringe is bigger than the air pressure in the balloon, so the collision between particles gets faster so the volume of the balloon gets bigger".

The reasons given by Putri were obtained based on the results of interviews,

Putri said, "When pressed, there is air pushing into the balloon, so the balloon enlarges and when the balloon is pulled it shrinks because the air in the balloon is interested too".

In question number 16 students named Bening are categorized as Not Understanding Concepts because they answer the answer choices incorrectly, are sure of the answers chosen and choose the wrong choice of reasons, unsure of the reasons chosen. Bening considers when a burning candle is placed in a container filled with water that has been mixed with dyes. Then a burning candle placed in the water is covered by glass, then if using an approach based on Gay-Lussac's Law.

Given the question of the four-tier diagnostic test Bening assume the process that occurs in a glass is "the fire on the candle stays on and the volume of water in the glass decreases". For the reason "the burning candle in the glass produces heat, so the temperature in the glass increases, then the temperature in the glass is lower than the temperature outside the glass". The reason given by Bening was based on the results of the interview.

Bening said, "Because the flame is burning to produce heat, the pressure is large which pushes the water out".

3.2. Results of Student Conception on Gas Kinetic Theory Material

Based on the results using the four tier diagnostic test in 11th grade of science class obtained recapitulation of the conception profile of students' on the kinetic theory of gas from 14 questions tested according to the conception categories namely Partial Understanding (PU), Misconceptions (M), and No Understand the Concept (NU), and also in accordance with sub material and cognitive realm on the questions being tested. Recapitulation The profile of students' conception of the kinetic gas theory is given in Table 3.

| Sub Material         | No Question | Cognitive Realm | Identification of Student Conception (PC, M, NU)                                                                 |
|----------------------|-------------|-----------------|----------------------------------------------------------------------------------------------------------------|
| Ideal Gas Properties | 6           | C4              | • When the particles collide perfectly with the wall it will increase in speed (speed increases).               |
|                      | 7           | C4              | • When the tube contains ideal gas, it collides with the wall and changes the direction of momentum because the energy is constant, so the speed is constant so the direction of momentum changes. |
|                      | 3           | C4              | • When the tube contains ideal gas, colliding with the wall will lose speed because momentum equals zero which results in a reduction in speed after hitting the wall. |
| Gas State Equation   | 3           | C4              | • When the Ideal Gas in a vessel is compressed (pressed), the gas will experience an increase in temperature because the pressure given is large so that the volume... |
| Sub Material | No Question | Cognitive Realm | Identification of Student Conception (PC, M, NU) |
|--------------|-------------|-----------------|------------------------------------------------|
|              |             |                 | of gas in the vessel gets smaller, then there is the addition of gas particles due to higher temperatures due to compressed vessels. |
|              |             |                 | • When the Ideal Gas in a vessel is compressed (pressed), the gas will experience a decrease in the particle rate because the speed of the particle rate is increasingly limited due to the smaller volume because the vessel is compressed, the smaller the space in the vessel. |
|              |             |                 | • When the air in a closed system with a fixed number of particles. If compressed at a constant temperature, the air particles will not move because the movement of particles is only affected by the size of the container. |
|              |             | C4              | Isochoric constant pressure |
|              |             |                 | • When an ideal gas in a closed space undergoes an isochoric process the pressure changes and the gas makes an effort. |
|              |             | C4              | Isothermal graph is the relationship between pressure and temperature when volume is constant. |
|              |             | C4              | The greater the temperature of the gas that is expanding so that it reduces the gas pressure. |
|              |             | C4              | The pressure is inversely proportional to the temperature so that the pressure will be half-fold when the gas is pushed and the volume of gas becomes half of it. |
|              |             | C5              | Balloons are elastic so that when a balloon that has been blown is inserted into the injection in a closed state, the size of the balloon shrinks when pulled. |
|              |             | C5              | The air pressure in a balloon is greater than the pressure of the syringe so that when the volume of air is drawn in the balloon shrinks. |
|              |             | C5              | The pressure in the syringe is greater than the air pressure in the balloon, the collision between the particles gets faster so that the volume of the balloon gets bigger when the injection is pressed. |
|              |             |                 | • When the balloon in the tube is given hot water it will erupt because the greater the temperature the greater the pressure, the greater the volume of the balloon |
|              |             |                 | • When the balloon in the tube is given hot water it will erupt because the greater the pressure at high temperatures, the smaller the volume. |
|              |             |                 | • The fire on the candle goes out the candle flame dies due to lack of oxygen and the volume of water entering the glass remains. |
|              |             |                 | • The flame in the candle stays on and the volume of water in the glass decreases. |
### Identification of Student Conception (PC, M, NU)

| Sub Material | No. | Question | Cognitive Realm |
|--------------|-----|----------|-----------------|
| Kinetic Energy of Gas Molecules | 13  | C4       | - A number of ideal gases in a closed tube are heated isochoric so that the temperature rises to four times the original temperature does not change kinetic energy because the volume is fixed. |
| | | | - A number of ideal gases in a closed tube are heated isochoric so that the temperature rises to four times the original temperature; the average kinetic energy of the molecule is twice the original. |
| Molecular Speed | 18  | C5       | - Water bubbles when cooking water with a pan and the lid because the bubbles are moving slowly and the movement of the pot lid is not affected by bubbles. |

### 4. Conclusion

Regarding the main research problems and the findings which were obtained of the research, it can be strong-minded based on research from 34 students of 11th grade of science class., it can be seen that the conception profile of 34 students of 11th grade of science 4th class out of 14 questions tested overall is for the category of Understanding the Concept (U) 22%, Partial Understanding (PU) 29%, Misconceptions (M) 31%, Not Understanding the Concept (NU) 18%, and Un-Code (UC) 0%. The findings were also supported by the results of semi-structured interview. Therefore, this developed four-tier diagnostic test with the kinetic theory of gas is proper to use.

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Appendix

Example of test item of four-tier diagnostic test instrument

9. Look at the picture below

![Image of four tubes with different temperatures](image1)

“Each tube in the image has the same number of gas molecules. Each tube is heated to reach the temperature as shown” [11]. “If sorted, the tubes that have the greatest pressure to the smallest are...”

a. “Tube 1 > Tube 2 > Tube 3 > Tube 4”
b. “Tube 1 > Tube 3 > Tube 2 > Tube 4”
c. “Tube 4 > Tube 3 > Tube 2 > Tube 1”
d. “Tube 4 < Tube 3 < Tube 2 < Tube 1”
e. “All tubes have the same pressure”

Level of confidence in the answer above:

![Confidence scale from 1 to 6]

Reason

a. As long as the tube is closed, the gas pressure inside is the same and the temperature does not affect the pressure level.
b. Gas pressure is inversely proportional to temperature, so the greater the gas pressure in the tube is closed, the lower the temperature.
c. Because the gas pressure is proportional to the temperature, so the greater the gas pressure in the tube is closed, the greater the temperature.
d. The greater the temperature of the gas that is expanding so that it reduces the gas pressure.
e. The heating process does not affect pressure, or the amount of gas temperature does not affect the value of gas pressure.

Level of confidence for the reasons above

![Confidence scale from 1 to 6]

14.

![Figure 2: The balloon is blown until it expands](image2)

![Figure 3: Balloons are included in the injection](image3)

Based on the illustration of the picture above (Figure 2 and Figure 3), when the balloon that has been blown to expand is inserted into the syringe, then two different treatments are carried out, namely in condition 1 and condition 2. In condition 1 when a balloon is placed in the syringe then the injection is pressed, and in condition 2 when the balloon in the suture tube is then drawn. Note that the injection tip is also closed. If using Boyle's Law approach. What happens in condition 1 and condition 2 is ...
a. Condition 1 (pressed)  
Fixed balloon size  
Condition 2 (withdrawn)  
Fixed balloon size

b. Condition 1 (pressed)  
Fixed the balloon size  
Condition 2 (withdrawn)  
The size of the balloon is enlarged

c. Condition 1 (pressed)  
Balloon size shrinks  
Condition 2 (withdrawn)  
The size of the balloon is enlarged

d. Condition 1 (pressed)  
The size of the balloon is enlarged  
Condition 2 (withdrawn)  
Balloon size shrinks

e. Condition 1 (pressed)  
Balloon size shrinks  
Condition 2 (withdrawn)  
Fixed balloon size

(Note: Figure was captured from [18])

Level of confidence in the answer above:

1 2 3 4 5 6
Reason
a. The amount of air pressure inside and outside the balloon at the injection is as large as it does not affect the size of the balloon even though it is given a different treatment.
b. The air pressure in the balloon is greater than the pressure of the syringe so that when the volume of air is drawn in the balloon shrinks.
c. The pressure in the syringe is smaller than the air pressure in the balloon so the air in the balloon presses the sides of the balloon so that the volume of the balloon gets bigger.
d. The pressure in the syringe is greater than the air pressure in the balloon, so the collision between particles gets faster so the volume of the balloon gets bigger.
e. Balloons are elastic so that when the balloon has been inserted into the injection closed then the size of the balloon shrinks when pulled.

Level of confidence for the reasons above

16.

(Note: Figure was captured from [19])

Pay attention to the above phenomenon. When a burning candle is placed in a container filled with water that has been mixed with coloring as shown in Figure 1. Then the burning candle placed in the water is covered by a glass, then if using an approach based on Gay-Lussac's Law. So the process that occurs in a glass is...
a. The fire on the candle goes out and the volume of water that goes into the glass is increasing.
b. The flame on the candle goes out and the volume of water entering the glass remains.
c. The fire on the candle stays on and the volume of water entering the glass is increasing.
d. The fire on the candle stays on and the volume of water in the glass decreases.
e. The fire on the candle goes out and the volume of water in the glass decreases.

Level of confidence in the answer above:

a. Fire candles die due to lack of oxygen when the combustion process and pressure in the glass are smaller than the pressure outside the glass.
b. The burning candle in the glass produces heat, so the temperature in the glass increases, the temperature in the glass is lower than the temperature outside the glass.
c. Temperature is proportional to volume, so the higher the temperature in a closed container, the greater the volume of liquid coming out.
d. When the glass covers the burning candle there is an evaporation process, the oxygen in the glass decreases.
e. When the flame on the candle dims the temperature gets lower, the pressure gets lower and the volume of liquid ink increases.
Level of confidence for the reasons above

1 2 3 4 5 6