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The Students' misconceptions profile on chapter gas kinetic theory

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Abstract. Students have conception and misconceptions in the learning process. Misconceptions are caused by the teacher, students, and learning source. In the previous study, the researcher developed a misconception diagnosis instrument using three-tier on chapter gas kinetic theory. There are 14 items including 5 sub-chapters on gas kinetic theory. The profile of students' misconceptions shows that students have misconceptions in each sub-chapter. The cause of misconceptions came from preconceptions, associative thinking, reasoning, intuition, and false negative. The highest cause of misconception in this chapter is student's humanistic thinking.

1. Introduction

Humans have a structure of knowledge in the brain like boxes containing meaningful information that is different. The same experience for some people will be interpreted differently by each individual and stored in different boxes. Piaget said that each new experience is associated with the known structure in the brain's structure [1]. Different information owned by students sometimes causes some students to have a concept that is not in accordance with the scientific concepts. The mismatch of concepts that students possess with the concept of experts can be called using several terms such as "children's ideas" [2], "mental model" [3-5], "alternative conceptions" [6-10], "misconceptions" [11-16], and so on. The term "misconceptions" is used in this study.

The term "misconceptions" is going to be used for students' conceptions that contradict the scientific concept [16]. Vamvakoussi and Vosniadou used the "misconceptions" as a label for synthetic concepts that mismatch with the accepted view and that form student's attempt to integrate the existing knowledge with new information before a deeper conceptual change occurs [16].

The cause of misconception can come from various sources, including textbooks, teachers, and students themselves. In Physics subjects, students often experience misconceptions on the abstract material. Teachers will have more difficulty in explaining abstract concepts because there are no real examples in the daily life of the students. One example of the abstract material in Physics is the Gas Kinetic Theory. Based on the questionnaire given to the students of Driyorejo Senior High School, there are still many students who do not understand the material about gas kinetic theory, even though the material has been taught. This is corroborated by the students' test results on the gas kinetic theory



material that shows more than 40% of students have values below minimum standards. According to one teacher at Driyorejo Senior High School statement, students are more focused on memorizing the formula so that students are less understanding of the concepts of gas kinetic theory. This leads to misconceptions in students.

It can't be denied that students build their own knowledge while learning. But, because students do not have a scientific frame of mind that fits to serve as a benchmark so that students are having errors in constructing their knowledge. This causes of the students' misconceptions. Misconceptions can happen because of the students' learning difficulties. 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 [17]. Further, Azizah et.al identified the problem-solving difficulties of high school students caused by several factors, partly because of the material being studied, the learning activities in the classroom, and the teacher's teaching style [18]. Suparno states some of the things that are causing misconceptions originating in students, among others, (1) preconceptions or early concepts of students, (2) student associative thinking, (3) humanistic thinking, (4) reasoning, (5) false intuition, (6) the stage of cognitive development of students, (7) the students' abilities, and (8) interest in student learning [19].

Misconceptions can be identified by providing diagnostic tests to students. Diagnostic tests are assessment tools which are concerned with the persistent or recurring learning difficulties that are left unresolved and are the causes of learning difficulties [20]. These diagnostic test instruments bring to light the disparity between what we want our students to know or learn and what they really know or learn. Habibulloh et.al developed the Certainty of Response Index (CRI) as the diagnostic test instrument to reduce the students' misconceptions on Photoelectric Effect topic [21]. There are many kinds of methods to identify the student's misconceptions such as interviews, open-ended tests, multiple-choice tests, multiple-tier test [16]. The multiple-tier tests consist of two-tier, three-tier, and four-tier tools of the diagnostic test. The three-tier diagnostic test is a diagnostic test instrument consisting of three levels of questions, the first level of which contains the usual multiple-choice questions, the second level contains the choice of reason, and the third level contains questions relating to the belief in the answer chosen in two the previous level [22-23]. Compared to the two-tier diagnostic test, this three-tier diagnostic test is more effective to distinguish between nonconformist students and students who have the misconception with the added question of belief in choosing the answer [23]. Using three-tier diagnostic test, it can be known the profile of students who understand the concept, students who have experience misconception, and students who do not understand the concept.

Wiyono et.al used the three-tier diagnostic test instrument to identify the junior school students' misconceptions on motion topic [24]. The motion of three-tier diagnostic instrument effective to found and described the students' misconceptions on motion topic [24]. In the previous study, the three-tier diagnosis test developed on gas kinetic theory material. This instrument used to diagnose the students' misconceptions on chapter gas kinetic theory. This study describes the students' misconceptions profile on chapter gas kinetic theory.

2. Research Methods

The three-tier diagnostic test instrument for the gas kinetic theory (GKT) given to 34 students of Driyorejo Senior High School to identify the students' misconceptions and the cause of misconceptions. The GKT responses categorize into five categories based on the adoption and adaptation of Kutluay [25] research, showed by Table-1. Besides that, the answer of students reasoning analyses to know the cause of the students' misconceptions.

14 **Table 1.** The combination of three-tier test answer (adaptation from Kutluay research [26]).

Phenomena (P)	Reasoning (R)	Confidence	Category
First-tier	Second-tier	Third-tier	
True	True	Sure	Understand the Concept (UC)
True	True	Unsure	Less Understand the Concept (LUC)
False	False	Sure	Do Not Understand the Concept (NUC)
True	False	Unsure	Guessing (G)
True	False	Sure	Misconceptions (M)
False	True	Sure	
False	False	Sure	

30 3. Results and Discussion

The identification of students' misconceptions used the GKT three-tier diagnostic test consist of 14 test items shows that many students have the misconception. In addition, many students categorized into do not understand the concept. Tabulation of the student's combination of answers using the three-tier diagnostic test shown in Table 2.

Table 2. The combination of student's answer categories.

The number of item test	Combination of three-tier answer categories				
	UC	LUC	NUC	G	M
1	7 (22.58)	1 (3.23)	7 (22.58)	6 (19.35)	10 (32.26)
2	7 (21.88)	3 (9.38)	8 (25.00)	4 (12.5)	10 (31.25)
3	4 (12.9)	2 (6.45)	8 (25.81)	4 (12.9)	13 (41.94)
4	0 (0)	9 (0)	8 (25.00)	4 (12.5)	20 (62.5)
5	6 (20.7)	3 (10.3)	5 (17.24)	7 (24.24)	8 (27.6)
6	4 (12.9)	2 (6.45)	5 (16.13)	4 (12.9)	16 (51.61)
7	6 (17.65)	5 (14.7)	9 (26.47)	6 (17.65)	8 (23.53)
8	3(9.1)	4 (12.1)	7 (21.21)	7 (21.21)	12 (36.4)
9	0 (0)	0 (0)	8 (23.53)	7 (23.53)	19 (55.88)
10	2(6.25)	0 (0)	10 (31.25)	6 (31.25)	14 (43.75)
11	6 (18.75)	1 (3.13)	6 (18.75)	4 (18.75)	15 (46.88)
12	1 (3.22)	1 (3.23)	7 (22.58)	7 (22.58)	15 (48.39)
13	0 (0)	0 (0)	10 (30.3)	7 (21.22)	16 (48.50)
14	1 (3.12)	2 (6.25)	7 (21.88)	3 (9.37)	19 (59.38)

UC = Understand the Concept, LUC = Less Understand the Concept, NUC = do Not Understand the Concept, G = Guessing, M = Misconceptions

Based on Table 2, there were no students who understand the concept (UC) in test items 4, 9, and 13. Students' understanding of the material of ideal gas properties, gas laws, and kinetic energy of the gas is still very weak. While in the category of not understanding the concept (NUC), students most included in the category for test items 10 and 13. The test item contains the sub-material of the laws of the ideal gas. Students do not understand the concept (NUC) can happen because students quickly forget what he has learned. 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. Item test no. 4,9,10, and 13 are not included in the LUC category. This indicates that there were no students who have not understood the concept. It also means that students are confidently choosing answers at the first and second level, but there were answers into other categories. Category guessing (G) can be caused by students who did not understand the concept of the concept of the item so that in addition to the students answer wrong on the first or second level, students are also not sure of the answer he

chose. On the whole items there are a percentage of students in the guess category, but under 25% in the guessing category. The following describes the understanding of the student's concept in each sub-chapter.

3.1. Sub-chapter the ideal gas properties

Based on Figure 1, item test number 1 has the largest understanding concept percentage among other items, 22.58%. While the test item number 2 has a concept percentage of 21.88%. The percentage of misconceptions (M) in test items 1 and 2 respectively 32.26% and 31.25%. This shows that from a total of 34 students, about 11 students have misconceptions on the sub-chapter properties of the ideal gas.

In the first item test, the tube contains the ideal gas and the students are asked to choose a statement related to the characteristics of the ideal gas. The correct answer is "the gas particles will experience a change in direction of momentum when collided with the tube wall" with the choice of reason 'When colliding the wall, the particle changes the direction of the velocity so that the particle also changes in the direction of momentum'. Ideal gaseous particles experience complete tubing with walls. When subjected to collisions with walls, the particles change in the direction of speed so that the direction of momentum also changes.

Item test 2 is presented about the motion of the ideal gas particles and the student must determine the particle motion correctly. The correct answer to the test item number 2 is 'move randomly in all directions' with the choice of reason 'gas particles move randomly in accordance with Brownian motion'. A poor student's understanding of the properties of the ideal gas causes the student to be ambiguous in determining the characteristics of the characterizing the ideal gas and movement of ideal gas particles resulting in misconception.

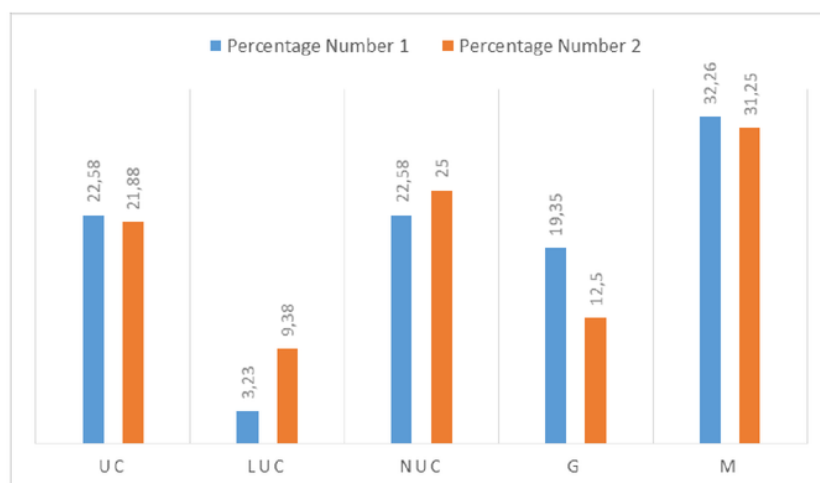


Figure 1. The percentage of Understand the Concept (UC), Less Understand the Concept (LUC), do Not Understand the Concept (NUC), Guessing (G), and Misconceptions (M) for item test number 1 and number 2.

3.2. Sub-chapter gas state equation

Test items that contain the equation of the gas state are on test items 3 and 6. Percentages for each category of students understanding the concept on test items 3 and 6 are shown in Figure 2.

Based on Figure 2, the percentage of students experiencing misconception is 41.94%. Misconceptions occur when the student incorrectly gives an answer at the first or the second level, Item test number 3 presented two images. The first picture is a pump in the normal state that the end is closed. The second

image is a pump image with a closed end and pressed from the top. The student determines the movement of the gas molecule after the pump is pressed. The correct answer for this test item is "the molecule is more often subjected to collisions". While, the correct reason is "when pressed, the scope of the gas gets narrower." The high percentage of misconceptions on the item test shows that students' understanding is still wrong in determining the movement of gas particles in the pump when the pump is pressed.

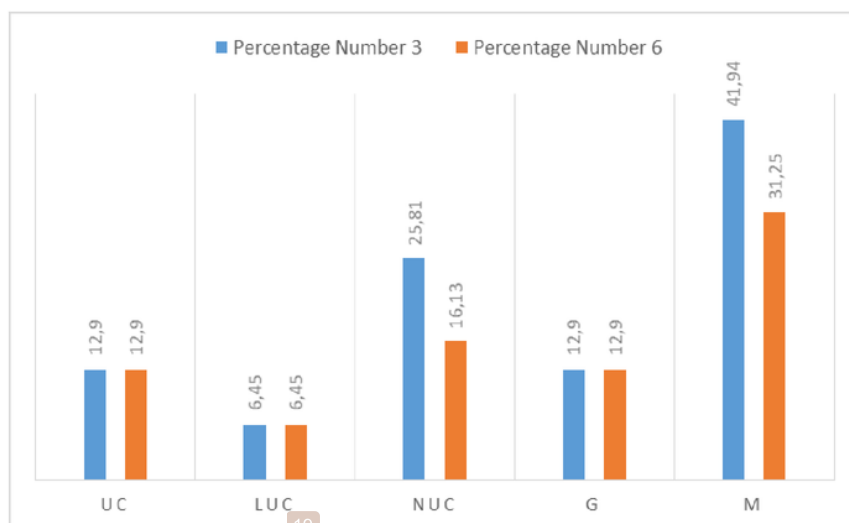


Figure 2. The percentage of Understand the Concept (UC), Less Understand the Concept (LUC), do Not Understand the Concept (NUC), Guessing (G), and Misconceptions (M) for item test number 3 and number 6.

For the percentage of student misconception on item test 6, is big enough, that is equal to 51.61%. On this point, there are four tubes which have the same number of molecules and are being heated to a certain temperature on each tube. Nearly half of students experience misconceptions because students confidently answer but misread the tubes that have the most pressure to the smallest. In addition, the category of misconception also comes from answers that students choose on the second level is also wrong. The answer the student should have chosen is "tube 4 > tube 3 > tube 2 > tube 1" on the reason "the greater the temperature, the faster the molecular movement increases the pressure".

3.3. Sub-chapter ideal gas laws

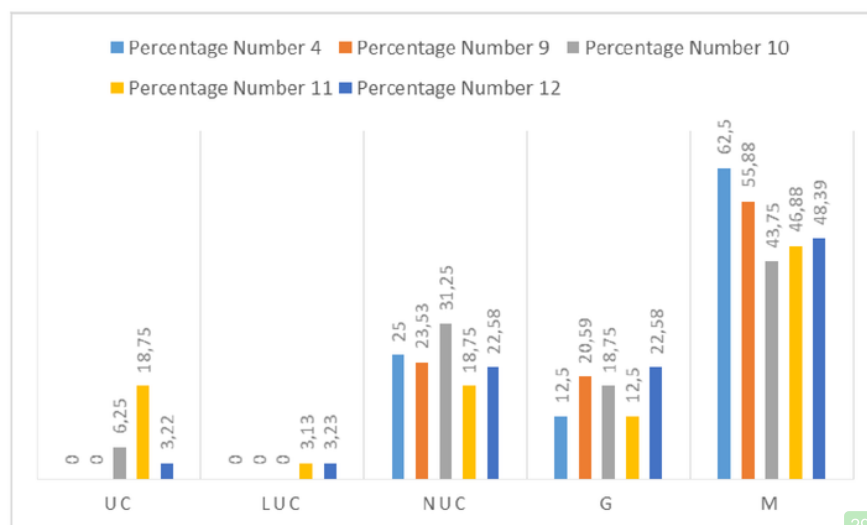


Figure 3. The percentage of Understand the Concept (UC), Less Understand the Concept (LUC), do Not Understand the Concept (NUC), Guessing (G), and Misconceptions (M) for item test number 4, 9, 10, 11, and 12.

The items containing the substance of the ideal gas laws are contained in item 4, 9, 10, 11, 12. On these five items are presented phenomena related to the laws of the ideal gas. The following graph of the percentage of misconceptions in each category for items 4, 9, 10, 11, and 12 are shown in Figure 3. Based on Figure 3, the students' misconceptions percentage for that five items are big, even though there are achieved 62.5%. This shows that students do not fully understand about ideal gas laws including the application of that law in everyday life, i.e item 12 when the balloon entering to the two liquids with different temperature, many students wrong to conclude what is happening in the balloon. In accordance with Charles' Law, in enclosed spaces, if the gas pressure is constant, the temperature is directly proportional to the volume. In A tube, with a liquid temperature of 100°C will make the balloon expand because the heat energy from outside the balloon is transferred into the balloon thus making the balloon expand. In tube B, the liquid temperature is smaller than the temperature of the balloon, the heat energy of the balloon is transferred out of the balloon. That's why the balloon on tube B shrinks.

3.4. Sub-chapter gas kinetic energy

The material about gas kinetic energy contains in items 5, 7, 8, and 13. The students understanding concept percentage of gas kinetic energy shows in Figure 4. Based on Figure 4, the student's misconceptions on sub-chapter gas kinetic theory less than that of on sub-chapter ideal gas laws. The highest misconceptions on sub-chapter gas kinetic energy there on test item 13 as much as 48.5%. In question number 13 students have not been able to distinguish the true statement about the kinetic energy of the gas. In addition, the second highest percentage of misconception was found in point 8 of 36.4% of students experiencing misconceptions. In this case, the students have not fully understood the effect of heating or of rising gas temperature in a confined space to the change of kinetic energy of gas particles.

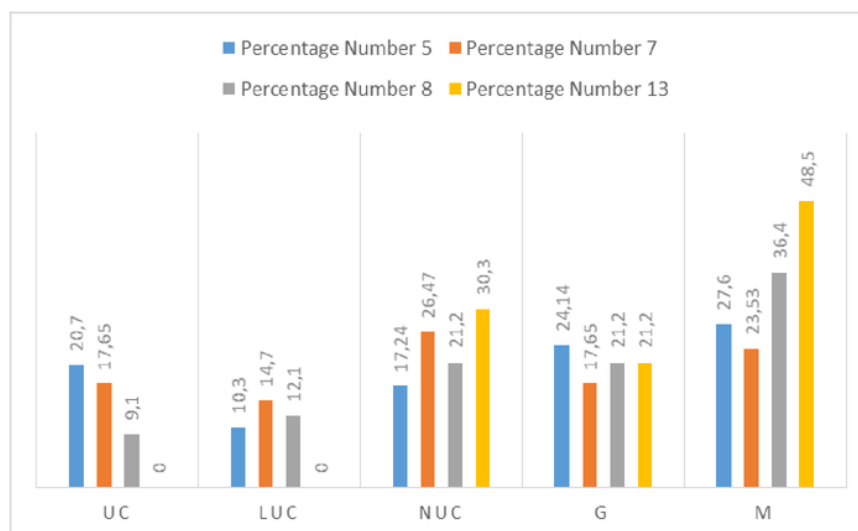


Figure 4. The percentage of Understand the Concept (UC), Less Understand the Concept (LUC), do Not Understand the Concept (NUC), Guessing (G), and Misconceptions (M) for item test number 5, 7, 8, and 13.

3.5. Sub-chapter equipartition of energy

The item that contains the energy equipartition sub is contained in item 14. In this case, three different tubes are presented, then the student selects the statement according to the students according to the inner energy of the three tubes. Here is the percentage of students' understanding of the sub-matter of equipartition of energy.

Based on Figure 5 on item 14, students who experienced misconception as much as 59.38%. This is much different with the percentage of students who understand the concept of 3.12%. Based on these data, more than half of students are still wrong in answering the number 14 so that it can be concluded that students' understanding is still lacking on this sub-chapter-energy equipartition.

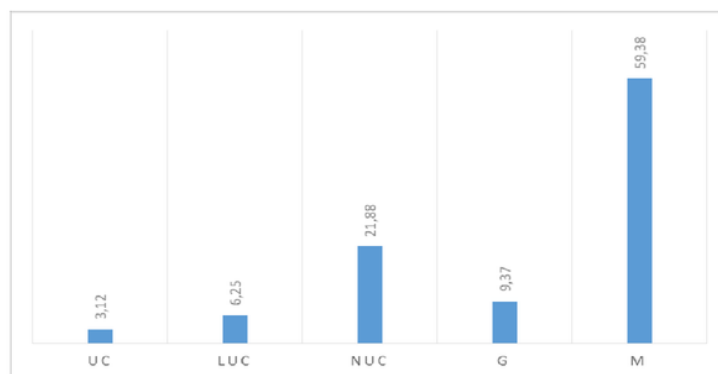


Figure 5. The percentage of Understand the Concept (UC), Less Understand the Concept (LUC), do Not Understand the Concept (NUC), Guessing (G), and Misconceptions (M) for item test number 14.

3.6. The cause of students' misconceptions

Each choice of reason presented in the three-tier diagnostic test instrument is structured on the basis of possible misconceptions that may occur in the student. Based on the causes of misconceptions derived from students according to Suparno [19], in a three-tier diagnostic test instrument used to identify the student's misconception profiles in Driyorejo Senior High School. The misconception causes used in the three-tier diagnostic instrument are (1) preconceptions, (2) associative thinking, (3) reasoning, (4) intuition, and (5) false negative.

The students' misconceptions and the cause of misconception identification for 34 students conducted by analysing the cause of misconception from the student's answer choices for reasoning (second tier). The cause of misconception percentage is shown in the Table 3.

Table 3. The Cause of Misconception Percentage.

Item number	Cause of Misconception (%)					
	Pr	AT	R	HT	I	FN
1	33.33	16.67	25	0	0	25
2	8.333	0	8.333	50	16.67	16.67
3	13.33	0	20	0	46.67	20
4	13.64	4.55	4.55	54.55	13.64	9.09
5	8.33	0	8.33	25	16.67	41.67
6	5.26	36.84	10.53	15.79	15.79	15.79
7	0	0	16.67	66.67	16.67	0
8	38.46	15.38	7.69	7.69	23.08	7.69
9	15	15	50	5	15	0
10	18.75	18.75	6.25	12.5	31.25	12.5
11	11.76	23.53	23.53	0	29.41	11.76
12	27.78	16.67	27.78	0	11.11	16.67
13	29.41	5.882	11.76	23.53	23.53	5.88
14	23.81	19.05	14.29	14.29	19.05	9.52

Pr = Preconception, AT = Associative Thinking, R = Reasoning, HT = Humanistic Thinking, I = Intuitive, FN = False Negative

Based on Table 3, it is known that there are various causes of misconception from the students answer. The cause of misconceptions are: preconception, associative thinking, reasoning, humanistic thinking, intuition, and false negative. Among the cause of student's misconception that existed through this test, humanistic thinking has a highest percentage (66.67%) that respond to the student's misconception in the chapter of gas kinetic theory. The highest percentage of causes of misconception, which is humanistic thinking is on question item number 7 about kinetic energy of gas. In this item, students were trained to analyse the effect of temperature change due to the motion of gas particles in closed container. Students were used humanistic thinking to analyse the condition that given by linking the daily phenomenon which is the gas condition was in open space. The dissonance between given condition and student's humanistic thinking lead to the student's misconception.

For the categories of causes of misconceptions derived from humanistic thought (HT), the largest percentage is found in item 7 about the kinetic energy of the gas. At point 7 of this item, students are trained in conceptual knowledge to analyse the effect of temperature changes on the motion of ideal gas particles in the closed containers. Students experience misconception because students attribute phenomena to problems with events occurring in everyday life so that they do not match the ideal gas conditions presented in the question.

3.7. The students' misconceptions profile on chapter the kinetic theory of gas

The dominant student's misconception profile in the kinetic gas theory material is summarized in Table 4.

⁹
Table 4. The list of student's misconceptions on chapter the kinetic theory of gas.

Sub-chapter	Students' misconceptions profile
The Ideal Gas Properties	When the particle strikes the wall, the particle's momentum changes and loses its speed. Collisions between particles produce opposite directions from the direction of the previous motion.
Gas State Equation	The gas in the enclosed space despite suppressed molecular motion remains. The greater temperature of the gas in the enclosed space, the gas undergoes expansion resulting in reduced pressure.
Ideal Gas Laws	Giving pressure from the outside on the opposite side can restore the shape of a dented pimp bulb. The balloon inside the closed syringe can't expand or collapse even though the injecting tube pump is pulled up because the balloon diameter is too small. The wax absorbs the liquid when the candle is covered with glass. When the egg is on the bottle, the air in the bottle is so packed that the bottle can suck the egg. Temperature cannot affect the balloon so that at any temperature change any form of the fixed balloon.
Gas Kinetic Energy	In a closed space, the amount of gas particles is directly proportional to the kinetic energy of the gas. As the kinetic energy increases the gas particles in the closed space also increases. The temperature of the gas in the enclosed space is inversely proportional to the speed of particle motion. When heated, the movement of the gas particles slows down and the gas particles shrink. The kinetic energy of the gas does not depend on the gas pressure
Equipartition of Energy	The energy in a gas is inversely proportional to the temperature of the gas.

4. Conclusion

The student's misconception profile shows that students are experiencing misconceptions throughout the sub-chapter of gas kinetic theory. The highest misconception lies in the sub-chapter of a kinetic energy of the gas caused by humanistic thinking with a percentage of 66.67%.

To overcome misconceptions derived from these students can be tailored to the causes of misconceptions that appear in students. According to Suparno [19], misconceptions derived from preconceptions can be overcome by having students try directly so that students can revise their ideas about the wrong knowledge in students' minds. While misconceptions caused by associative thinking can be overcome by teachers explaining the concept slowly and paying attention to events that make students misrepresent so that students can change their incorrect associative thinking [19]. To overcome misconceptions caused by reasoning, students are confronted with actual events or events so that students can know that the student's thinking is inappropriate. In addition, teachers can also ask students to seek additional information so that students can complete the data they have. Suparno [19] states to overcome misconceptions caused by humanistic thinking, students are invited to see the actual events then the teacher explains in detail so that students do not experience misconception anymore. As for the misconceptions caused by intuition can be overcome by exposing students to events contrary to student intuition through repeated experiments so that student's understanding can be improved [19]. Consequently, conception of physics learning can also be increased [26].

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Appendix

The sample of test item of GKT three-tier diagnostic test instrument:

Item test 2

An ideal gas-filled tube. The following true statement is...

- When the gas particles hit the tube wall, the particles lose energy.
- When the gas particles hit the tube wall, the particles lose their momentum.
- The gas particles will lose speed (still) after colliding with the wall.
- Gas particles will experience a change in speed after a collision with the wall.
- Gas particles experience a change in direction of momentum when collided with a tube wall.

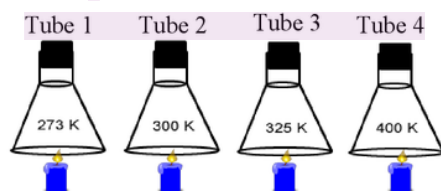
Supportive reasons:

- Particle energy moves on the tube wall.
- When mashing the wall, the particle's momentum is equal to zero so that the particle has no speed.
- Particles that pound the dense walls will lose speed because the walls have a larger inert force.
- When pounding the particles wall changes the direction of the velocity so that the particle also changes the direction of momentum.
- Particles of gas suffer a partial collision with walls so that particle speed changes.
- When pounding the wall of particle energy out of the particle itself the particles lose energy.
-

Are you sure about your answer?

- Sure
- Not sure

Item test 6



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

- Tube 4 < Tube 3 < Tube 2 < Tube 1
- Tube 1 > Tube 2 > Tube 3 > Tube 4
- Tube 4 > Tube 3 > Tube 2 > Tube 1
- All tubes have the same pressure
- Tube 1 > Tube 3 > Tube 2 > Tube 4

Supportive reasons:

- The greater the temperature, the faster the molecular movement increases the pressure.
- As long as the container is covered the gas pressure is the same.
- Warming does not affect pressure.
- The gas pressure is inversely proportional to the temperature.
- The greater the gas temperature undergoes expansion resulting in reduced pressure.
- The hotter the gas molecule container expands the more so that the pressure decreases.
-

Are you sure about your answer?

- Sure
- Not sure

Item test 12



A Tube = 100° C



B Tube = 0° C

Look at the picture above! Each container contains different balloons and liquids. If both containers are closed simultaneously, then the corresponding statement is...

- The balloon on tube A is enlarged, the balloon on tube B remains.
- The balloon on both tubes did not change.
- The balloon on tube A is enlarged, the balloon on tube B shrinks.
- The balloon on tube A is fixed, the balloon on tube B is smaller.
- The balloon on tube A is smaller, the balloon on tube B enlarges.

Supportive reasons:

- Low temperatures do not affect the shape of the balloon.
- The shape of the balloon is not affected by temperature
- In a confined space with the same pressure, the volume is proportional to the temperature.
- The pressure on both tubes is the same so that the balloon does not change.
- Because the balloon is made of an elastic material.
- High temperatures can change the shape of a balloon.
-

Are you sure about your answer?

- Sure
- Not sure

Item test 13

Here is the correct statement relating to the kinetic energy of the gas in a closed space that is

- The balloon under the hot sun has a greater kinetic energy than the balloon inside the house.
- If the balloon is placed in the freezer the kinetic energy of the gas in the balloon increases with the reduced balloon temperature.
- The lower the temperature of a gas, the greater the kinetic energy of the gas.
- Balloons pumped using helium gas can fly because the kinetic energy of helium gas is greater than the kinetic energy of air in general.
- Blowing up the balloon using the pump expands faster compared to blowing the balloon by mouth because the kinetic energy of the gas at the pump is greater than the kinetic energy of the gas in the mouth.

Supportive reasons:

- The scope of the gas in the balloon is narrower so that the particles move faster.
- The greater the temperature of the particle movement balloon the faster the oak increases.
- Low temperatures can save particle motion energy so that the kinetic energy gets bigger.
- By being placed in the particle freezer in a moving stop balloon.
- Helium gas particles move faster than air in general.
- Balloons inside the house get less sunlight.
-

Are you sure about your answer?

- Sure
- Not sure

Item test 14

Three tubes A, B, and C contain the same ideal gas.

– Tubes A and B have the same pressure and temperature as the volume on tube A is twice the volume B

– The C tube has twice the temperature of tube B

Here is the correct statement about the energy in the gas owned in accordance with the above circumstances is...

- a. The inner energy in tube A is equal to the energy in tube C.
- b. The internal energy in tube B is twice as large as the energy in the tube A.
- c. The internal energy in the tube C is twice as large as the inner energy of tube B.
- d. Each tube has the same inner energy.
- e. The inner energy in tube B doubles the inner energy in tube C.

Supportive reasons:

- i. The greater the volume the gas molecules move the more freely.
- ii. The energy in proportion to the volume of a gas.
- iii. If the gas is heated, the gas molecule will move faster and faster, resulting in greater inner energy.
- iv. If heated, large-volume gas will have a higher temperature than a gas that has a small volume.
- v. The internal energy depends on the type of gas and does not depend on the temperature or volume of the gas.
- vi. Tube A and tube B are at the same pressure.
- vii.

Are you sure about your answer?

- a. Sure
- b. Not sure

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