

Analyzing Students' Level of Understanding on Kinetic Theory of Gases

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Abstract. The purpose of this research is to analysis students' level of understanding on gas kinetic theory. The method used is descriptive analytic with 32 students at the 11th grade of one high school in Bandung city as a sample. The sample was taken using random sampling technique. Data collection tool used is an essay test with 23 questions. The instrument was used to identify students' level of understanding and was judged by four expert judges before it was employed, from 27 questions become to 23 questions, for data collection. Questions used are the conceptual understanding including the competence to explain, extrapolate, translate and interpret. Kinetic theory of gases section that was tested includes ideal gas law, kinetic molecular theory and equipartition of energy. The result shows from 0-4 level of understanding, 19% of the students have partial understanding on the 3th level and 81% of them have partial understanding with a specific misconception on 2th level. For the future research, it is suggested to overcome these conceptual understanding with an Interactive Lecture Demonstrations teaching model and coupled with some teaching materials based on multi-visualization because kinetic theory of gases is a microscopic concept.

1. Introductions

In a teaching learning process, teachers always expect instructional goals that have been set can be achieved. Each of them sometimes feels that they have struggled in teaching students, but in fact many students are not able to achieve the expected instructional goals. During the teaching process, sometimes teachers are difficult to determine how many students have achieved the objectives and how many students have learning difficulties. The students' difficulties need to be detected as early as possible by the teachers and the results of this difficulty analysis are further used as a consideration in planning the next instructional programs. Students' learning difficulties are indeed varied, either in terms of scope or cause. Some of the indications that show a student with learning difficulties are, for example: acquisitions show lower educational outcomes, unequal results to the efforts that have been made and tardiness in performing tasks and learning activities. Based on these indications, an effective way to detect students' learning difficulties, especially in large lecture classes, is by measuring learning outcomes, for example, by employing diagnostic tests. A diagnostic test need to be valid, that is, able to measure what is being measured, and consistent when it is used to measure on another occasion. However, in a case with the need for accountability in higher education, standardized outcome assessments have been widely used to evaluate learning and inform policy ^[1].

The instructional process of physics should facilitate the students to discover concepts by themselves. Considering this situation, exploring and developing students' ability to understand concepts should become the teachers' commitment. Comprehension is the ability to understand or



comprehend anything once they are known and remembered ^[2]. Students are supposed to get a lot of opportunities to use their logical reasoning abilities, practice, formulate concepts, and participate in solving complex problems that require their great effort. Then, the students are encouraged to reflect their thoughts in drawing an accurate conclusion.

Kinetic Theory of Gases is one of the key concepts used to understand other scientific concepts. In this research comprehension ability is divided into explaining, interpreting, inferring, exemplifying and comparing ^[3]. This concept is important to be understood by the students beforehand to explain other laws of thermodynamics. Besides, the most important is that this theory specifically discusses the behavior of gas particles microscopically and its relation to macroscopic quantities. This study is focused on the exposure profile of students' concept understanding, which is further broken down into the level of student understanding ^[4]. The results of this study can be used for further research to determine the appropriate treatment for improving students' concept understanding of the topic of gas kinetic theory.

2. Methodology

This research uses descriptive analysis to describe the level of students' understanding of the gas kinetic theory. The test instrument used was an essay test that had been content-validated by 4 experts, and this validated instrument was tested on 32 eleventh grade students of one senior high school in Bandung. The results of the test were then processed and analysed to see the validity, reliability, discriminating power, and level of difficulties ^[5]. Reliability was defined by researchers and statisticians as an indicator that provides information about the uniformity of a test when repeated measures are conducted. Reliability is also defined as the consistency of measurements used to measure the same thing ^[6]. Based on these criteria, the instrument is reduced to the one that can be trusted to describe the level of students' understanding which are categorized in Table 1 ^[4]

Table 1. Evaluation Scheme for Concept Test Items

Numerical score and degree of understanding	Criteria for scoring
0-No Understanding (NU)	Blank, repeats question, irrelevant or unclear response, no explanation given for choice answer
1-Specific misconception (SM)	Scientifically incorrect responses
2-Partial understanding with a specific misconception (PUSM)	Responses that show understanding of the concept, but that also contain a misconception
3-P3-Partial Understanding (PU)	Responses that contain a part of the scientifically accepted concept
4-Sound Understanding (SU)	Responses that contain all parts of the scientifically accepted concept

3. Results and Discussions

Table 2 shows content validity results of the instrument validated by 4 judges. On average, the judges decide that 98% of instrument can be used. From 27 validated items, the questions are reduced to 23 items that fit the criteria, including the suitability of the questions with learning indicators, aspects of concept understanding, and with the answers. The reduced questions are those which do not meet all of the three criteria. Of the 23 questions, there are 15 questions that were revised in terms of indicators. Most of the revised sub-sections are about gas kinetic energy and average speed of gases.

Table 2. Validation content result

Judges	Percentage	Criteria
Judge I	92%	Excellent
Judge II	88%	Good
Judge III	92%	Excellent
Judge IV	85 %	Good

Table 3 shows the results of the instrument validation after being content-validated that has been reduced to 23 questions. Based on the instrument validation, the instrument (23 essay test questions) can measure what is being measured and is consistent when tested in different samples. George and Mallery (2003) provide the following rules of thumb: “_ > .9 – Excellent, _ > .8 – Good, _ > .7 – Acceptable, _ > .6 – Questionable, _ > .5 – Poor, and _ < .5 – Unacceptable” [8]. Based on the 23 questions, an overview of students’ level of understanding of the topic about the kinetic theory of gases can be seen, as shown in Table 4.

Table 3 Results of Instrument Validation

Results	Value	Criteria
Validity	0,73	Acceptable
Reliability	0,85	Good
Average	52,94	
Standard deviation	7,87	

Table 4 shows an overview of students’ level of understanding on each sub material. The highest level of understanding, that is at level 4, occurs at ‘the ideal gas law’ section (33%), while the lowest level of understanding or not understanding, that is at level 0, occurs at ‘pressure’ and ‘kinetic energy of gases’ section (14%).

Table 4 Percentage of understanding levels on kinetic theory of gases

Level of understanding	Ideal gas law (%)	Pressure gas and kinetic energy gases (%)	Equipartition theorem (%)
SU	33%	4%	27%
PU	36%	26%	40%
PUSM	17%	35%	12%
SM	6%	21%	8 %
NU	8%	14%	13%

From further analysis, it is found that a few students have misconceptions in a specific way. The greatest misconception is on the question number 19 and 20, in the aspect of interpreting the questions from verbal words into mathematical equations on the 2nd level of understanding. The question number 19 is “A gas cylinder with a certain volume contains ideal gas with the pressure P , the square root of the average squared-speed of the gas molecules is called v_{RMS} . If the tube is pumped with the similar gas, so the pressure becomes $2P$, while the temperature is made constant, determine v_{RMS} now!” In this case, most of the students answer $v_{RMS} = \sqrt{\frac{2P}{\rho}}$, which is supposed to be

$RMS = \sqrt{\frac{3RT}{M}} v$; therefore, $v_{RMS} \sim \sqrt{T}$ and because the temperature is constant, then v_{rms} is also

constant. Hence, the present v_{rms} is the same as the original v_{rms} .

At the question number 20 some students answered on the 3rd level of understanding. The question is "the effective speed or root mean square (RMS) of ideal gas molecules at a particular temperature is C , then the temperature of the gas is converted at the constant volume, so that the pressure becomes a quarter of the original. Estimate effective speed after the gas temperature is changed!" Most students answered directly using $v_{RMS} = \sqrt{\frac{3P}{\rho}}$ and $v_{RMS} = \sqrt{\frac{3RT}{M}}$ equations. Whereas, they actually need to use Gay-Lussac equation first

$$\frac{P_2 V_2}{T_2} = \frac{P_1 V_1}{T_1} \quad (1)$$

$$\frac{\frac{1}{4} P_1}{T_2} = \frac{P_1}{T_1}$$

$$T_2 = \frac{1}{4} T_1$$

$$v_{RMS} = \sqrt{\frac{3RT}{M}} \quad (2)$$

$$v_{RMS} \sim \sqrt{T}$$

$$\frac{v_2}{v_1} = \sqrt{\frac{T_2}{T_1}}$$

$$\frac{v_2}{v_1} = \sqrt{\frac{\frac{1}{4} T_1}{T_1}}$$

$$\frac{v_2}{v_1} = \frac{1}{2}$$

$$v_2 = \frac{1}{2} v_1$$

At the question number 9, in the sub-material 'ideal gas law', most students answered with the 1st level of understanding. The question is "If the volume of gas that is located in a closed vessel is kept constant 0.001 m^3 , there is a relationship between gas pressure (P) and the absolute temperature (T), as presented in the following table^[9]:"

Table 5. Question number 9

Experiment	T (K)	P(N/m ²)
1	170	8,5
2	190	9,5
3	210	10,5

Draw a pattern graph of the relationship between pressure (P) and temperature (T), if the volume is more than $0,001 \text{ m}^3$ and less than $(V) = 0,001 \text{ m}^3$ ". Most students answered by directly modifying the table into a graphic form of temperature (T) against the volume by using a linear chart $V = 0.001$

m^3 and the pressure (T) against the volume (V) = 0,001 m^3 , so the pattern graphs are constant. Whereas, there should be three chart pattern lines, namely $V_1 < 0,001 \text{ m}^3$, $V_2 = 0,001 \text{ m}^3$, and $V_3 > 0,001 \text{ m}^3$, as shown in **Figure 1**.

$$PV = nRT$$

$$V = \frac{nRT}{P}$$

$$V \sim \frac{T}{P}$$

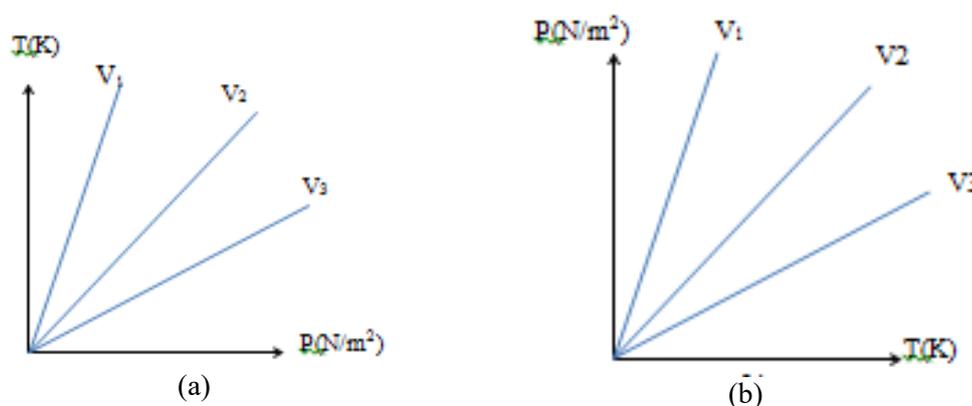


Figure 1. Graph of pressure (P) and temperature (T)

Furthermore, at the question number 5 most students answered on the 4th level of understanding. The question is "During the summer, children are playing football and the ball is made of plastic. However, the ball gets dented. How do you fix this dented ball? Explain using the relationship between volume and temperature." Most of the students answered correctly that the dented ball will return to its normal state when it is heated by putting it into a container of boiling water. This happens because when the ball is heated along with water, the temperature of the ball will increase, therefore the volume on the ball will expand and the pressure will be constant. This is in relation to *Charles' law* which states that if the gas pressure is constant, the gas volume (V) is directly proportional to its absolute temperature (T). The longer the surface of the ball is heated, the flatter it becomes because the volume inside the gas increases until the ball is restored to its original state.

4. Conclusions

Based on the elaborated discussion, it can be concluded that at the 'ideal gas law' section, 33% of the students have understood fully. However, 14 % of them have a lot of misunderstanding on the sub-material 'pressure and kinetic energy of gas'. Essentially, the concept of gas pressure and gas kinetic energy is a microscopic concept and cannot be directly observed. It is also associated with Newton's laws of motion; considered from its microscopic aspects, those are speed, collisions, pressure gas, kinetic energy and density.

5. References

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