JOURNAL OF SCIENTIFIC PERSPECTIVES

E-ISSN: 2587-3008

July 2018, Vol:3, Issue:3

http://ratingacademy.com.tr/journals/index.php/jsp/

STUDENTS' UNDERSTANDING OF GAS CONCEPTS[*]

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ARTICLE INFO

Article History:
Received: *19 June 2018*
Accepted: *05 July 2018*

Keywords: *chemistry, gas, misconception, pre-service, teacher education.*

DOI:

ABSTRACT

The main purpose of the present study was to investigate second year classroom teacher education students' misconceptions and learning difficulties related to gas concepts. The study was carried out during the last academic year at a state university in Turkey. About 100 second year students were the participants of the study. Gas Concept Test developed by Yalçınkaya (2010) was administered to the students to determine the students' misconceptions and their understanding of gas concepts. The results revealed that the students had misconceptions, such as gas particles expand when heated, shrink when cooled; particles are unevenly scattered in any enclosed space; particles rise and stay away from heat, etc. The misconceptions and learning difficulties of the classroom teacher students should be remedied by suitable conceptual change strategies. So, these erroneous ideas cannot pass on primary pupils.

1. INTRODUCTION

Misconceptions or misunderstandings are information that have evolved from the personal experience of the individual, are far from science, prevents the teaching of concepts verified scientifically (Yürük, Çakır, & Geban, 2000). In order for a student's knowledge to be counted as a misconception, it is necessary for the idea to have three conditions; the knowledge of the student is not scientifically appropriate, the student tries to search for scientific evidence to defend this false idea, and the student is confident in her/his own answer (Eryılmaz & Sürmeli, 2002).

The source of the misconceptions arising from experiential and instructional reasons (Skelly & Hall, 1993 as cited in Nakiboğlu, 2006, 200) are the preliminary information, spoken language, analogies and metaphors, models and symbols, and textbooks and teachers (Nakiboğlu, 2006, 201-202). The misunderstanding that comes from teacher involves all these factors that lead to the misconception, because the language of the teacher, the textbook the teacher used inadequacy of teacher's subject knowledge and if the teacher ignores the pre-knowledge and misconceptions of their students result with misconception (Nakiboğlu, 2006, 202-203).

Misconceptions are the greatest obstacle in learning. Failure to intervene in these obstacles will lead to erroneous learning. Demir and Sezek (2009) stated that misconceptions

[*] This study is the revised version of the same name paper presented in the "2nd International Rating Academy Congress: Hope" held in Kepez / Çanakkale on April 19-21, 2018.

that were not taken care of were transferred to upper classes, and if the mistakes of teacher candidates could not be resolved, they would be passed on to the students. Dikici, Türker and Özdemir (2010) stated that the factors such as psychology, environment, socio-cultural structure are the obstacles in front of the meaningful learning of the students. These factors indicate that misconceptions can also arise from students. In order for meaningful learning to take place, it is necessary to establish links between newly learned concepts and old concepts. Elimination of misconceptions at elementary level facilitates meaningful learning (Bal & Koray, 2002).

Chemistry is a science that examines the matter and relations between matters. In relation to this discipline, students need to correctly structure the concept of "matter" and especially the properties of solid, liquid and gas in their minds in order to because they constitute a base for other concepts as well (Birinci Konur and Ayas 2010).

Lawrenz, Lin, and Cheng (2000 as cited in Morgil et al, 2003) investigated the misconceptions existed in students and teachers after Boyle, Charles, and ideal gas laws have been processed and found that half of students and teachers made incorrect comments on the problem of volume-temperature, and 80 % of the students gave inadequate and incorrect answers to the solution of conceptual problems. Boyle's law describes the relationship between the pressure and volume of a gas under relatively normal conditions (close to room temperature and pressure). Boyle's law states that, when holding temperature constant, the pressure of a gas is inversely proportional to its volume (Maeng & Randy Bell, 2013). Charles's law is the direct relationship between the temperature and volume of a gas (Maeng & Randy Bell, 2013). Ideal gas law describes the relationship between pressure, volume, moles, and temperature of a gas or PV=nRT (Maeng & Randy Bell, 2013).

One of the concepts of abstract science that students have difficulty in understanding is the concept of gas pressure (Şahin & Çepni, 2012). It has also been revealed in the literature that prospective teachers have difficulty in establishing relations between the concepts that constitute the factors affecting the state of gases such as temperature, volume and pressure in gas, and they have inadequate meaning and some misconceptions (Birinci Konur & Ayas 2010; Nakiboğlu & Özkılıç Arik, 2006).

Although there are studies in the literature about classroom teacher education students' understanding of the particulate nature of the material, such studies are mostly in the level of secondary education. It becomes important to determine what gases mean to candidate teachers who will become classroom teacher when they graduate (Birinci Konur & Ayas, 2010).

Chemistry has three basic components; the macrochemistry of the tangible, edible, visible; the submicrochemistry of the molecular, atomic and kinetic and the representational chemistry of symbols, equations, stoichiometry, and mathematics (Johnstone, 1983 as cited in Johnstone, 1993). The correct understanding between these dimensions makes it easier for students to understand chemistry. The fact that students have great mental gaps between micro- and macro-dimensions makes it difficult for them to correlate macroscopic events with microscopic events and to bridge these gaps (Çavdar, Okumuş, Alyar, & Doymuş, 2016). The fact that the particulate nature of matter is first taught in the primary school (Çavdar et al., 2016) by the classroom teachers, the education of the classroom teacher candidates on these misconceptions becomes important in terms of not moving these errors to future generations**.**

2. MATERIAL AND METHODS

In this study, which is aimed to determine the conceptions of pre-service classroom teachers about gases, a survey model was used. The survey model is a research approach aimed at describing the existing situation (Karasar, 2009, p.77).

The participants were 107 freshmen students attending to classroom teacher education department at Niğde Ömer Halisdemir University in Turkey. Since the sample can be accessed and selected from the group in which the application can be performed, appropriate sampling is used for non-arbitrary sampling methods (Büyüköztürk, 2012).

Based on General Chemistry is the name of the course classroom teacher candidates take for one semester. The course is a theoretic lesson and takes two lesson hours. Properties of matter, elements and compounds, chemical reactions, reaction stoichiometry, states of matter, solid and gas state structure of matter, mineral forms, changes in form of matter; solutes and mixtures, acids and bases, carbon compounds, solubility and precipitation, oxidation and reduction, and chemistry of life are the subjects taught at this course.

The Gas Concept Test developed by Yalçınkaya (2010) was used as a data collection instrument in the study in order to explore first grade classroom teacher candidates' conceptions about gases. This test included 26 multiple choice items with five alternatives. Possible misconceptions were included in the alternatives of the multiple-choice test items. The test forms were administered during one lesson hour to the classroom teacher education students.

Students' responses to the test form were saved in the SPSS data file and frequency analyses for each item were performed. The proportion of incorrect responses given to an alternative was used to determine misconception. This means that when more than 20% of the teacher candidates chose the incorrect alternative, this alternative was considered as a misconception held by these students. If the proportion is less than 20 %, it was not taken as a misconception.

3. RESULTS

1. Which of the following is true about the gases?

Item 1 was about the general properties of gases. As seen from the Table 1, majority of students (69%) was aware that there are almost non-existing forces between gas particles. When Birinci Konur and Ayas (2010) studied the gas molecule drawings of classroom teacher education students in order to determine how the students constructed the gas concept in their minds, they realized that 34% of the students made accurate explanations about gas molecules and drawings supporting these explanations. In the explanations made about these drawings, students used the expression "the distance between molecules is less than that of solid and liquid".

Table 1. Students' Selection of Alternatives for Item 1

Alternatives	f	%
A) Gas pressure is downward.	5	4,8
B) Gas particles are getting smaller during the transition from the state of gas to liquid or liquid to solid.	6	5,8
C) There are almost non-existing forces between gas particles (*Correct Alternative)	72	69,2
D) Gases occupy different volumes according to their molecular weights.	14	13,5
E) Gas pressure depends on type of the gas particles and number of atoms contained in the gas.	7	6,7
Total	104	100

2. Which one of the following is not true about a substance in a closed container with gas remaining?

Table 2. Students' Selection of Alternatives for Item 2

Alternatives	f	%
A) The unit number of particles per square centimeter of container surface at the time of unit is the same.	5	4,8
B) The pressure of the gas is the same all over the walls of the container.	13	12,5
C) The pressure measured at any point in the vessel is the pressure of this gas.	5	4,8
D) The pressure inside the container is higher than the pressure made on the side surfaces of the pressure (*Correct Alternative)	75	72,1
E) The total number of collisions the particles have made with each other is equal to the total number of collisions they have made with the walls.	6	5,8
Total	104	100,0

72% of the students gave correct responses to this question and there was no misconception.

3. If a balloon inflated with a little puffing and mouth is connected to the balloon by taking it from its environment and putting it in the following media, it is expected to decrease the volume of the balloon?

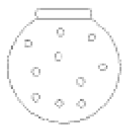
Table 3. Students' Selection of Alternatives for Item 3

Alternatives	f	%
A) At the same pressure, colder (*Correct Alternative)	60	57,7
B) At the same pressure, warmer	28	26,9
C) At the same temperature, the temperature is higher	1	1,0
D) At the same temperature, the air is discharged	8	7,7
E) At the same altitude, warmer	4	3,8
No answer	3	2,9
Total	104	100,0

58% of the students gave correct responses to this question but 27% of the students had a misconception. In the category of temperature-gas volume, students hold the misconception of "In gas, volume and temperature are inversely proportional".

Birinci Konur and Ayas (2010) asked "Describe the change that can be observed at a normal inflated balloon, first in a cold environment, then in a warm environment by drawing" 14% of the students answered this question correctly by making drawings and explanations. 50% of the students made drawings and tried to explain this question only with pressure or by volume. 18% of the students briefly explained the situation without drawing at all. 15% of the students answered this question with misleading and conflicting expressions:

- In a cold environment the balloon remains swollen. It expands and shrinks in hot weather.
- When the balloon is warm, it becomes thicker and heavier. That's why it swells.
- In cold conditions the air molecules condenses and the balloon becomes bigger. In the hot air, it shrinks.
- When the balloon is in a warm environment, the volume decreases and the pressure increases.



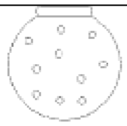
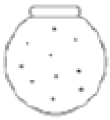
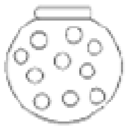
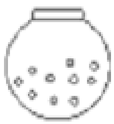
4. The distribution of hydrogen gas molecules in a closed container at 25°C and 1 atm pressure was given in the picture (The circles (o) represent the distribution of hydrogen molecules). Which of the following diagrams illustrate the distribution of H_2 molecules when the temperature of the container is lowered to -15 ^{0}C? (Note: Before responding to this problem students were told that at -15 ^{0}C hydrogen is still gas.)

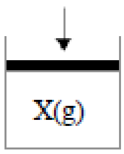
Item 4 was a conceptual problem and measured whether the gas particles expand when heated, and shrink when cooled. It is based on the knowledge that whatever the temperature, a gas will always occupy all the space available (Niaz, 2000).

The percentages of students' selection of alternatives for item 4 were represented in Table 5. As seen from this table, only 1% of the students answered this question correctly.

However, 30 % of students chose the alternative B as a correct answer, indicating that they still had the misconception that when the gas in the container is cooled, each of the gas particles shrinks or gets smaller (Brook et al., 1984; Novick & Nussbaum, 1981; Sanger et al., 2000). Moreover 29 % selected alternatives D and E representing when the gas is cooled, gas particles started to accumulate at the bottom of the container like liquids. This misconception is in the category of temperature-gas molecule relationship, students hold the misconception of "As the temperature increases, the volume of gas molecules expands for volume increase" (Karslı & Ayas, 2013).

Table 4. Students' Selection of Alternatives for Item 4

Alternatives	f	%
A  *Correct Alternative	1	1,0
B 	31	29,8
C 	12	11,5
D 	30	28,8
E 	30	28,8
Total	104	100,0



5. At constant temperature, the ideal gas X is placed in a piston chamber and the piston is compressed. Which of the following judgments about this gas at the end of the compression process is wrong?

Table 5. Students' Selection of Alternatives for Item 5

Alternatives	f	%
A) Pressure increases.	13	12,5
B) The distance between the particles decreases.	5	4,8
C) Increase the number of particles in the unit volume.	51	49,0
D) The mean velocity of the particles decreases (*Correct Alternative)	23	22,1
E) The number of particles does not change	12	11,5
Total	104	100,0

22% of the students gave correct response to the item 5. On the other hand 49 % of the students chose the alternative C because they thought that when the gases compressed, the number of gas particles in the unit volume increases.

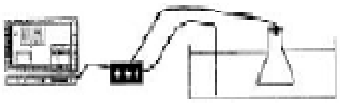
6. When a constant-volume closed container filled with a gas is heated, increase in pressure is observed. In which of following alternative explains the reason of this event most accurately?

Item 6 was asked to explain the reason for the increasing pressure of gas when the gas is heated in a constant-volume container. It refers to the internal properties of the gases namely the relationship between molecular collisions and the pressure exerted by the gas (Niaz, 2000). As Table 7 indicates, 37% of the students selected the scientifically correct response as stating that when the gas is heated in a constant-volume container, the number of collisions increase so do the pressure. However, 23% of the students considered that when the gas is heated, the size of the of gas particles increases (Alternative A). In addition, 21 % of students believed that when the gas is heated in a constant-volume container, gas particles condense in the wall of the container (Alternative E). These students conceptualize the increase in pressure of a gas as a product of both the expansion of the molecules (leading to repulsive forces) and the faster speed (Niaz, 2000) that make the molecules hit the walls of the container and condense in there.

Table 6. Students' Selection of Alternatives for Item 6

Alternatives	f	%
A) Increase the size of gas particles	24	23,1
B) Increase in the numbers of particles when the gas is heated	11	10,6
C) Becoming heavier of the gas when it is heated	9	8,7
D) Increase in the number of the collisions when the gas is heated (*Correct Alternative)	38	36,5
E) When the gas is heated, gas particles condense in the wall of the container.	22	21,2
Total	104	100,0

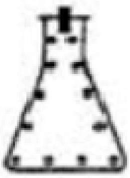
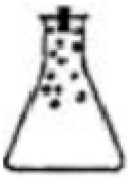
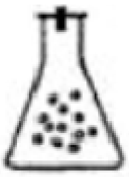
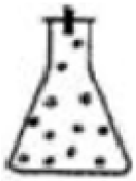
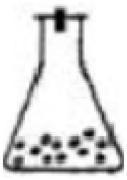
7-9



A constant-volume container filled with air is placed into a bath and connected to a computer. Temperature changes are followed by a thermometer placed. Moreover, container is connected to device for measuring pressure and pressure can be read on the computer. The temperature of the bath is 25 °C and the pressure is 1 atm.

7. Which of the following diagrams shows the distribution of molecules that form the air at 25 °C within the container the best?

Table 7. Students' Selection of Alternatives for Items 7-8

Alternatives	Item 7		Item 8		Item 9	
	f	%	f	%	f	%
A 	6	5,8	7	6,7	46	44,2
B 	1	1,0	9	8,7	34	32,7
C 	7	6,7	36	34,6	2	1,9
D  *Correct Alternative	89	85,6	2	1,9	14	13,5
E 	1	1,0	50	48,1	8	7,7
Total	104	100,0	104	100,0	104	100,0

About 86% of the students gave correct responses to this question. There was no misconception

8. The temperature of the container is reduced to 0 °C by adding ice into bath. After waiting to affect the temperature change on air particles, which of the following diagrams shows the distribution of molecules within the container the best? (Note: Before responding to this problem students were told that at 0 ^{o}C air is stil gas.)

Similar to item 4, item 8 was a conceptual problem measuring the distribution of air in a constant-volume closed container when decreasing the temperature of the container. In addition, before responding to this problem, students were informed that at 0 ^{o}C air is still gas. The percentages of experimental and control group students' selection of alternatives for item 8 was presented in Table 9. Results indicated that only 2% of the students selected this scientifically correct answer, which represents the homogeneous distribution of air with decreasing temperature. On the other hand, 83% of the students believed that gas particles are unevenly scattered in any enclosed space and (35% thinks air molecules accumulated at the bottom of the container while 35% thinks the particles accumulate in the middle of the Erlenmeyer with decreasing temperature as figured out in alternatives E and C.

9. The temperature of the container containing gas is increased to 60 °C by heating the water bath with the help of heater. In this case, which of the following diagrams shows the distribution of molecules within container the best?

Item 8 and item 9 were the sequential questions having the same question root. Item 9 was asked to measure the distribution of air molecules in a constant volume container with increasing temperature. The percentages of students' selection of alternatives for item 9 was provided in Table 10. Scientifically correct answer, figured in alternative D, was the homogeneous distribution of air molecules even if the temperature is increased, and only 14% of the students gave correct responses to this question. When the students' responses were examined for each alternative, the frequency of selecting alternative A draws the attention. In other words, 44% of the students believed that gas particles are unevenly scattered in any enclosed space and air molecules accumulates on the walls of the container with increasing temperature. Similarly, 33% of the students thought that with increasing temperature air molecules rises and accumulates at the top of the Erlenmeyer. This misconception is in the category of temperature-gas volume, students hold the misconception of "As the gas molecules in the closed container are heated, the molecules are collected above the container" or "When gas molecules in a container are heated, they move up the container to reduce the density" (Karslı & Ayas, 2013

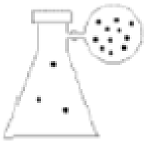
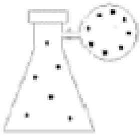
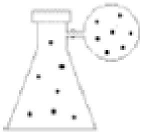
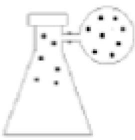
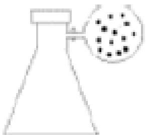
Birinci Konur & Ayas (2010), when asked 'what do you think about the movement and distribution of gas molecules in the closed syringe when it is heated? What do you think about the movement and distribution of gas molecules in the closed syringe when it is heated? To the classroom teacher education students, 24% of the students made incorrect drawings and misleading statements. According to these students, "The gas molecules on the side where the heat is applied slide to the other side, so they move to the right side" and "Gas molecules rise and shrink under the influence of heat".

10. A container filled with air is connected to a balloon as shown in the figure. When the tap of the container is opened and the container is heated, it is observed that balloon is swelling. Which of the following illustrate the distribution of air the best after swelling the balloon? (Dots (.) represent the molecules within air.)

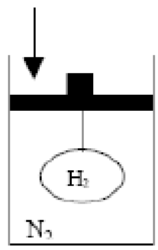
Related to item 9, item 10 aimed to investigate the distribution of air molecules when the constant-volume container connected to a balloon as shown in the figure in Table 11 is heated. The percentages of students' selection of alternatives for item 10 were indicated in Table 11. Scientifically correct answer was given in alternative C showing the homogeneous distribution of air within the container and the balloon even if the container was heated. Results indicated that only 20 % of the students were aware of the homogeneous distribution of gases when the tap of the container connected to balloon is opened and the container is heated simultaneously.

On the other hand, 70 % of the students though that Gas particles are unevenly scattered in any enclosed space and Gas particles rise and stay away from heat (alternatives B, D, and E). 30% selected alternative D repeating the misconception that hot air increases. These results of Item 10 supported the results of the item 9 in terms of raised hot air towards the top of the container and the accumulation of gas molecules on the walls of the container with increasing temperature. Additionally, 18 % of the students selected the figure given in alternative B, which means they believed that some of the heated air accumulated on the walls of the balloon. Furthermore, 25 % of students thought that when the tap between the container and balloon is opened, most of the air molecules or all of them are transferred to the balloon. This misconception is in the category of temperature-gas volume, students hold the misconception of "As the gas molecules in the closed containers are heated, the molecules are collected above the container" (D and E) (Karslı & Ayas, 2013). A similar question was asked to science teacher education students and although at least 5% of the students drawed the same number of particles in the both parts correctly; at least 18% of the students drawed more particles in the second part and less particles in the first part (Çavdar et al., 2016). Since the students drawed more particles in the second part, they thought that the number of particles increases with the temperature increase and when the particles increase in the number so does the volume (Çavdar et al., 2016).

Table 8. Students' Selection of Alternatives for Item 10

Alternatives	f	%
A 	9	8,7
B 	19	18,3
C  ***Correct Alternative**	21	20,2
D 	29	27,9
E 	26	25,0
Total	104	100,0

11. As shown in the figure, nitrogen gas is found in the cylindrical container with movable frictionless piston. Hydrogen gas is found in the elastic balloon connected to cylinder by a steel rope. If the cylinder is pushed downward without touching of elastic balloon to the surface of the vessel, what will be the shape of balloon?



Item 11 was about the effect of changing pressure on an elastic balloon, the related figure was given in the Table 12. Scientifically correct answer was the increasing of pressure inside the non-constant volume container when movable frictionless piston is pushed towards the downward. Since the gases distributes homogenously wherever they are placed, the balloon inside the container shrinks from everywhere by the effect of increased pressure on it. The percentages of students' selection of alternatives for item 11 were represented in Table 12. 46 % of students answered this question correctly. However, 20 % of students' selected alternative A and thought that when movable frictionless piston is pushed towards the downward, the elastic balloon explodes. In fact, they may think that when the pressure drops on the balloon, its volume increases and so it explodes. One of the reasons of selecting this alternative might be the daily life experiences because if someone compresses the balloon from one or two sides, it generally explodes.

Table 9. Students' Selection of Alternatives for Item 11

Alternatives	**f**	**%**
A) Balloon explodes.	21	20,2
B) Balloon shrinks only from both sides.	10	9,6
C) Only upper part of the balloon shrinks.	16	15,4
D) Only the bottom of the balloon shrinks.	8	7,7
E) Balloon shrinks from everywhere. (*Correct Alternative)	48	46,2
No answer	1	1,0
Total	104	100,0

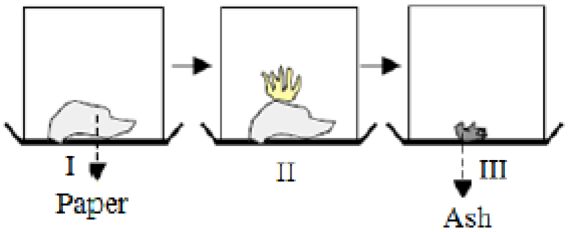
12. What exists between the particles of a gas?

Item 12 was intended to ask what the students think about what exists among the particles of a gas. Since gas particles cannot be seen by naked eyes, two responses came from students. Scientifically correct answer should be "nothing" is found between the particles of a gas. The percentages of students' selection of alternatives for this item were given in Table 10. Only 14% of the students believed that there was nothing between the particles of a gas. On the other hand, 64% of the students believed that Matter, especially air, exists between the particles/atoms of a gas (Novick & Nussbaum, 1978, 1981) and chose the alternative A. One of the reason for choosing this option could be the finding of air in everywhere of the world. Therefore, they might think that air was found even within gas particles.

Table 10. Students' Selection of Alternatives for Item 12

Alternatives	f	%
A) Air	67	64,4
B) Water vapor	5	4,8
C) Other gases	13	12,5
D) Nothing (*Correct Alternative)	15	14,4
E) Foreign substances (dust, dirt, etc.)	4	3,8
Total	104	100,0

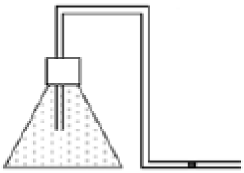
13. As shown in following figure, a piece of paper is put in a glass container in condition I. In condition II paper is burning and in condition III ash is formed. In all three cases, glass container is weighted. Accordingly, which one of the following is true?



Item 13 was about the conservation of the mass of a gas. Law of conservation of matter was First clearly stated by 18th-century chemist Antoine Lavoisier. This law describes that in a closed system, matter is neither created nor destroyed. Atomic theory means that all matter is composed of elements made from indestructible particles called atoms. It explains why matter is conserved in chemical reactions (Maeng & Bell, 2013). As shown in Table 11, a piece of paper is put in a closed glass container and left to burn. Glass container is weighted before burning, during the burning and after burning. The total mass stays the same because of the closed container. Therefore, scientifically correct answer was the equality of mass of each container actually depending on the law of conservation of mass. The percentages of students' selection of alternatives for item 13 were presented in Table 11. 29 % of the students answered this question as correct. On the other hand, 64% of the students though that gases have no mass (Stayv, 1987 as cited in Morgil, Erdem, & Yılmaz, 2003); gases weight can be ignorable; conservation of matter applicable to solids and liquids but may be ignored for gaseous reactants or products; (27 % of students believed that container has the biggest mass in condition I and chose the alternative A whereas 24 % of students thought that the closed container has the biggest mass in condition II and chose the alternative B).

Table 11. Students' Selection of Alternatives for Item 13

Alternatives	f	%
A) Condition I has the biggest mass	28	26,9
B) Condition II has the biggest mass	25	24,0
C) Condition III has the biggest mass	11	10,6
D) I and II has the same weight and III is less	10	9,6
E) All of them have the same mass (*Correct Alternative)	30	28,8
Total	104	100,0



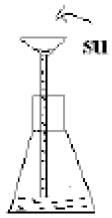
14. In the system, there is a drop of mercury in the glass container. The mercury drop moves to the right or left depending on the pressure and temperature change inside the glass container. If the apparatus of the room temperature (25 ^{o}C) is taken to an environment 5 ^{o}C, which of the following is correct regarding to the movement of the mercury?

In item 14, the pressure of glass container containing mercury was changed by changing the temperature of its environment. It was expected from students to predict the direction of the mercury drop depending on the pressure change of the given system. As seen from the Table 12, only 26% of the students gave correct answer by stating the way of movement as a result of decreasing pressure within the container with decreasing temperature. On the other hand, 34% of the students selected alternative D. They considered the direction of the mercury droplet to the right since pressure inside the container decreases due to decrease in temperature and increase in volume. Although the glass container was specified, these students considered the change in the volume of the system since the pressure inside the container decreases. To think "In a closed container, the volume of a gas decreases when the temperature decreases" is a Misuse of Charles's law (the direct relationship between the temperature and volume of a gas) ((Maeng & Randy Bell, 2013). This misconception is in the category of temperature-gas volume, students hold the misconception of "In gas, volume and temperature are inversely proportional" (Karslı & Ayas, 2013).

Table 12. Students' Selection of Alternatives for Item 14

Alternatives	f	%
A) Remain moveless because air pressure is constant.	21	20,2
B) First it moves to left, and then it moves to right.	3	2,9
C) Moves to the left, the pressure decreases within the container with decreasing temperature (*Correct Alternative)	27	26,0
D) Moves to the right, the pressure inside the container decreases with decreasing temperature and volume increases.	35	33,7
E) Moves to the right, with/in decreasing temperature volume decreases and pressure of the container increases.	17	16,3
No answer	1	1,0
Total	104	100,0

15. According to the figure given on the right, the container connected to a funnel is closed with a stopper preventing the gas leak from the container. Water is easily entered when poured to the container but when the water level in the container is reached to the bottom of the funnel, water input is becoming difficult. What is the reason of this event?

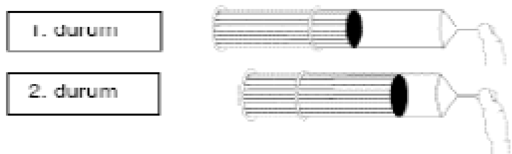


Nearly 57 % of the students gave correct responses to this question. On the other hand, 31% of the students though that The existence of the gas can be ignorable in a closed container when there is some amount of liquid in it (Misuse of Boyle's law) and chose the alternative D. Boyle's law describes the relationship between the pressure and volume of a gas under relatively normal conditions (close to room temperature and pressure). Boyle's law states that, when holding temperature constant, the pressure of a gas is inversely proportional to its volume (Maeng & Bell, 2013).

Table 13. Students' Selection of Alternatives for Item 15

Alternatives	f	%
A) The water inside the pot closes the inlet and no water can enter.	4	3,8
B) If the pot was bigger, it would get more water.	1	1,0
C) Increased internal pressure prevents water ingress (*Correct Alternative)	59	56,7
D) The water inside the pot is applying upward pushing force and water cannot enter.	32	30,8
E) The lifting force of the water has become unable to remove more water.	8	7,7
Total	104	100,0

16.



At constant temperature and pressure, the piston of the syringe containing an amount of air (condition 1) is pushed a bit and the air inside is compressed (condition 2). What is true about the gas particles forming air after compression?

About 79% of the students gave correct responses to this question. There is no misconception.

Table 14. Students' Selection of Alternatives for Item 16

Alternatives	f	%
A) The particles stick together.	3	2,9
B) All the particles are collected on the tip of the syringe.	10	9,6
C) The particles shrink.	3	2,9
D) The distance between the particles decreases. (*Correct Alternative)	82	78,8
E) Particles burst due to high pressure.	5	4,8
No answer	1	1,0
Total	104	100,0

17. At a constant temperature, during the transition of a pure matter in the phase of solid to liquid or liquid to gas, which of the following features of particles will change?

I. Size

II. Average Kinetic Energy

III. The distance between particles

Item 17 was related to the interpretation of what features of particles change during the transition of a pure matter in the phase of solid to liquid or liquid to gas at constant temperature. The correct answer was only the changing of distance between the particles during the transition of a pure matter in the phase of solid to liquid or liquid to gas. Size of the particles cannot change whether the temperature increased or decreased. In addition, average kinetic energy does not change unless there is any change in temperature. Results presented in Table 15 indicated that 22 % of students answered the question correctly by stating that the distance between particles will change during the phase transition. In contrary to this result, 65 % of the students thought that size of the particles, average kinetic energy and the distance between particles change in case of phase changes. This misconception is in the category of temperature-gas molecule relationship, students hold the misconception of "The kinetic energy between the gas molecules increases as the temperature decreases" (E) (Karslı & Ayas, 2013)

Table 15. Students' Selection of Alternatives for Item 17

Alternatives	f	%
A) Only I	0	0
B) Only II	2	3
C) Only III (*Correct Alternative)	3	23
D) I and III	4	10
E) I, II and III	5	68
Total	Total	104

18. Which of the following statements is wrong about gases?

Item 18 was also related with the properties of gases. Table 16 representing the percentages of students' selection of alternatives for this item indicates that 48% of students believed that diffusion rate of gases decreases with increasing molecular weight at the same temperature. On the other hand, a significant part of students (43%) thought that average kinetic energy of the all gases is not equal at the same temperature and chose the alternative D.

Table 16. Students' Selection of Alternatives for Item 18

Alternatives	f	%
A) They have a particulate structure.	3	2,9
B) Gases are distributed homogeneously in the container in which they are present.	1	1,0
C) Gas pressure depends on the number of particles in unit volume.	5	4,8
D) At the same temperature, average kinetic energy of all gas is the same.	45	43,3
E) At the same temperature, when the molecular weight of gases increases their rate of diffusion increases (*Correct Alternative)	50	48,1
Total	104	100,0

19. About the properties of cold and hot air which of the following statements is true?

Item 19 was related to the properties of cold and hot air. As presented in Table 17, 12% students selected the correct alternative stating that hot and cold air may have different volumes but they have equal masses. On the other hand, 75% of the students though that Air neither has mass nor can it occupy space and chose the alternatives A and E (50% students believed that while hot air particles expand, the cold air particles shrink; 25% students had the common misconception that hot air has little mass and is lighter than cold air). This misconception is in the category of temperature-gas molecule relationship, students hold the misconception of "As the temperature increases, the volume of gas molecules expands for volume increase" (Karslı & Ayas, 2013).

Table 17. Students' Selection of Alternatives for Item 19

Alternatives	f	%
A) Hot air is lighter than cold air.	26	25,0
B) Hot air is heavier than cold air.	9	8,7
C) Air has neither a mass nor a volume either hot or cold does not matter.	5	4,8
D) Hot and cold air may have different volumes but they have equal masses (*Correct Alternative)	12	11,5
E) Hot air gas particles expand while cold air particles shrink.	52	50,0
Total	104	100,0

20. The pressure of a balloon filled with air is measured as P_{full} in an environment where the pressure of atmosphere is P_{atm}. The balloon's mouth is opened and expected to shrink, and the pressure of collapsed balloon is measured as $P_{colllapsed}$. Which of the following is correctly related the pressures of P_{atm}, P_{full} and $P_{collapsed}$?

Table 18. Students' Selection of Alternatives for Item 20

Alternatives	f	%
A) $P_{collapsed} < P_{atm} < P_{full}$	40	38,5
B) $P_{collapsed} = P_{atm}$, $P_{atm} < P_{full}$	17	16,3
C) $P_{atm} = P_{full} = P_{collapsed}$ (*Correct Alternative)	4	3,8
D) $P_{atm} > P_{full}$, $P_{collapsed} = 0$	25	24,0
E) $P_{atm} < P_{full}$, $P_{collapsed} = 0$	15	14,4
No answer	3	2,9
Total	104	100,0

About 4% of the students gave correct responses to this question and stated that "hot or cold air has different volumes but same mass" is correct. On the other hand, 63 % of the students though that "Deflated balloon has less pressure inside than outside" and "The pressure of air inside the balloon is different from the pressure outside" and chose the alternatives A (39 %) and D (24 %).

21. Which of the following statements about the properties of gases is wrong?

Another question about the properties of the gases was the item 21. As seen from the Table 19 below, a large part of the students (97%) know that gases are not located at the bottom of the container when they are placed in a closed container and gave correct responses to this question. There is no misconception.

When Birinci Konur and Ayas (2010) studied the gas molecule drawings of classroom teacher education students in order to determine how the students constructed the gas concept in their minds, they realized that 34% of the students made accurate explanations about gas molecules and drawings supporting these explanations. In the explanations made about these drawings, students used the expression "The gas molecules are homogeneously dispersed evenly in the container".

Table 19. Students' Selection of Alternatives for Item 21

Alternatives	f	%
A) Gases can be liquefied.	1	1,0
B) Gas particles are constantly in motion.	0	0
C) When gases are placed in a container, gas particles are located at the bottom of the container as liquids (*Correct Alternative)	101	97,1
D) The forces between gas particles are weak as almost none existing.	2	1,9
E) Gas particles move randomly, there is no certain order of movement.	0	0
Total	104	100,0

22. A balloon made from rubber is filled with hydrogen gas and the mouth of it is tightly connected. However, after a few days later it is observed that balloon collapses. Which of the following best explains this situation?

In item 22, students were asked the reason to explain for collapsing of a balloon though its mouth was tightly connected. The scientifically correct answer is the escaping of gas from the pores of the balloon. As seen from Table 20 below, 14 % of students answered this question correctly. 32% students believed that increased external pressure was the reason of decreasing the volume of the balloon. However, in order to change the external pressure on balloon, it should be taken to a location having different altitude and in item 22 there was no information about change in external pressure. In addition, 34 % of students believed that weather is cooled and the molecules in balloon were clustered due to it. Cooling of weather might be the reason of shrinking or decreasing the volume of the balloon but the molecules in the balloon cannot be clustered somewhere upon cooling of weather which is the common misconception found in literature (Novick & Nussbaum, 1981).

Table 20. Students' Selection of Alternatives for Item 22

Alternatives	f	%
A) External pressure increases and the balloon gets smaller.	33	31,7
B) The molecules inside the balloon are getting smaller as a result of collisions.	6	5,8
C) The weather cools and the molecules in balloon are clustered.	35	33,7
D) Energy of molecules dissipated in time and their movements stop.	15	14,4
E) The gas escaped from the pores of the balloon (*Correct Alternative)	15	14,4
Total	104	100,0

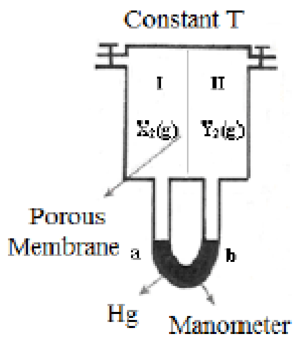
23. In the ideal behaviour of X_2 and X_3 gases' temperature, volume and number of molecules are equal. Which of the following comparison is wrong about these gases?

Item 23 was the one of the 1996 university entrance exam questions in the subject of chemistry in Turkey. This item aimed to make students use ideal gas law for two different gases containing the same kind of atoms. As seen from Table 21 below, 36 % students thought that pressures of X_2 and X_3 gases are equal. However, 43% of the students misused the ideal gas law: 23 % students selected alternative D and thought that these gases have different numbers of moles though the equality in number of molecules was mentioned in item 23. So, the problem with the mole concept was clearly seen in this question. What is more, 20 % of the students chose alternative E and considered the average kinetic energy of these two gases as being different. These students were not aware of the fact that average kinetic energy of the gases depends on the temperature and at the same temperature, the average kinetic energy of gases are the same.

Table 21. Students' Selection of Alternatives for Item 23

Alternatives	f	%
A) Pressures are different (*Correct Alternative)	37	35,6
B) Densities are different	12	11,5
C) Masses are different	10	9,6
D) The same number of moles	24	23,1
E) The same average kinetic	21	20,2
Total	104	100,0

24. As shown in figure, a container is separated into compartments I and II with a porous membrane and connected to a manometer. Being equal the levels of mercury in the arms of the manometer, compartment I is filled with X_2 gas and compartment II is filled with Y_2 gas. At the same temperature, after a short period of time it is observed that the level of mercury in arm "a" increases.



According to this observation, about the X_2 and Y_2 gases,

I. X_2 molecules are faster than Y_2 molecules.

II. Molar mass of Y_2 is more than that of X_2.

III. During the observation, total pressure of compartment II is increased.

Which of the above statements is true?

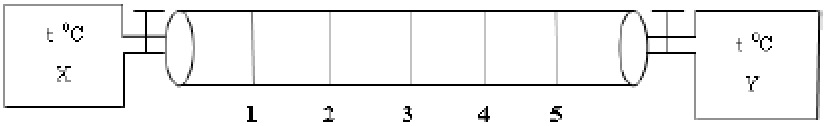
Item 24 aimed to make the students think about both diffusion of gases through a porous membrane and gas laws. The reason for increasing mercury level in arm "a" is due to the increase in pressure in compartment II. Since the volume and temperature are equal for compartment I and II, changes in the number of moles is the only reason for pressure change. Both X_2 and Y_2 gases passes through a porous membrane but X_2 gas should be faster than Y_2 gas in order to increase the pressure of compartment II. That is, diffusion rate of X_2 is bigger than the Y_2. Therefore, it can be concluded that since the temperature is equal, molecular weight of X_2 is smaller than Y_2. As the Table 22 below reveals, 14 % of students answered this question correctly.

On the other hand, 42% of the students selected alternative D, these students think that diffusion rate of gases increases with increasing molecular weight and did not think about the possibility of diffusion of the gases through the porous membrane.

Table 22. Students' Selection of Alternatives for Item 24

Alternatives	f	%
A) Only I	16	15,4
B) Only II	15	14,4
C) I and III	13	12,5
D) II and III	44	42,3
E) I, II and III (*Correct Alternative)	14	13,5
No answer	2	1,9
Total	104	100,0

25.



As shown in figure, X and Y gases are left to diffuse toward each other and as they come across at the 5th section of the tube,

I. The diffusion rate of X is more than Y.

II. Molecular weight of X is more than Y.

III. The container in which Y gas is found must be heated for encountering of both gases in the middle of the tube.

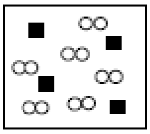
Which of the statement(s) is true?

Unlike item 24, item 25 was a kind of question often encountered in textbooks about the diffusion of gases. X and Y gases with same temperature were left to diffuse toward each other and met at the 5th section of the tube. As seen from the Table 23 below, 23 % of students did answer the question correctly. 59 % of the students could not establish the connection between molecular weight and diffusion rate (alternative E) and though that diffusion rate of gases increases with increasing molecular weight.

Table 23. Students' Selection of Alternatives for Item 25

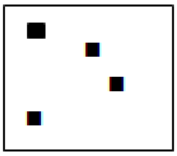
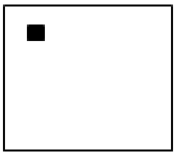
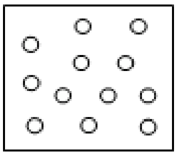
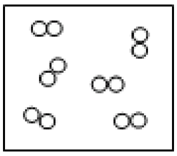
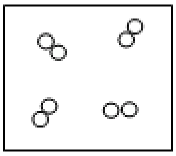
Alternatives	f	%
A) Only I	3	2,9
B) I and II	10	9,6
C) I and III (*Correct Alternative)	61	58,7
D) II and III	6	5,8
E) I, II, III	24	23,1
Total	104	100,0

26. The following closed container, as shown in picture, contains a mixture of oxygen (∞) and helium (■) gases at 25 ^{o}C. Which one of the following is the partial pressure of the oxygen gas?



Item 26 is related to the partial pressure concept of gases. A mixture of oxygen and helium gases was figured in a closed container and students are asked to select the figure that represents the partial pressure of oxygen gas. As Table 24 indicates, 60% of the students gave the correct response by selecting the container including only oxygen molecules (alternative D). However 21% of the students thought the partial pressure of oxygen gas as the homogenously distributed oxygen atoms, not the molecules and decided to choose the figure given in alternative C. This is a misconception that conceptual calculations are not obvious for students.

Table 24. Students' Selection of Alternatives for Item 26

Alternatives	f	%
A 	4	3,8
B 	0	0
C 	22	21,2
D  (*Correct Alternative)	62	59,6
E 	15	14,4
No answer	1	1,0
Total	104	100,0

4. DISCUSSION

In this study, classroom teacher education students' understanding of gas concepts was measured by a multiple-choice test. The proportions of correct responses in this test were determined by item analysis. It was found that students had misconceptions on some gas concepts:

Gas particles are able to "shrink", "condense", "sink", or "settle" (Novick & Nussbaum, 1981).

Air exists among the particles of a gas (Novick & Nussbaum, 1978 as cited in Yalçınkaya, 2010). In addition, most of them ignored the mass of gases (Lee et al., 1993 as cited in Yalçınkaya, 2010; Mas, Perez, & Harris, 1987; Stavy, 1988 and 1990 as cited in Yalçınkaya, 2010).

The size of the particles increases from the state of solid to liquid or liquid to gas.

In a closed container, when the gases are cooled, gas particles are accumulated in the middle of it.

The size of the gas particles decreases with increase in temperature.

Gas particles become heavier due to heat taken.

Students have difficulty in conceptual understanding of partial pressure.

In a closed container, gases do not exert the same pressure in different directions.

Gas particles are unevenly scattered in any enclosed space" (Novick & Nussbaum, 1981; Lee et al., 1993 as cited in Yalçınkaya, 2010; Cho, Park, & Choi, 2000),

Matter, especially air, exists between the particles/atoms of a gas" (Novick & Nussbaum, 1978 as cited in Yalçınkaya, 2010, Novick & Nussbaum, 1981; Lee et al., 1993 as cited in Yalçınkaya, 2010),

Conservation of matter is applicable to solids and liquids but may be ignored for gaseous reactants or products" (Mas, Perez, & Harris, 1987),

In a closed container, the volume of a gas decreases when the temperature decreases (Misuse of Charles's law)" (Lin, Cheng, & Lawrenz, 2000),

Conceptual calculations are not obvious for students" (Nurrenbern & Pickering, 1987; Sawrey, 1990; Nakhleh & Mitchell, 1993),

Molecules increase in size with change of state from solid to liquid to gas" (Haidar & Abraham, 1991 as cited in Yalçınkaya, 2010),

Gas particles sink to the bottom of the container when the temperature is lowered",

Gas particles may condense on the walls of the container" (Novick & Nussbaum, 1981), Heated or hot air weighs more than cold air or vice versa" (Lee et al., 1993 as cited in Yalçınkaya, 2010),

When the air is compressed, the particles stick to each other",

Misuse of ideal gas law" (Lin, Cheng, & Lawrenz, 2000),

If the volume decreases, the speed of the particles increases due to the increase in the number of collisions" (Kautz, Heron, Shaffer, & McDermott, 2005), and

Gases occupy different volumes according to their molecular weights" (Cho, Park, & Choi, 2000).

In students, the existence of alternative concepts in pressure-volume relationship and temperature-volume relation in gas is determined. In order for these alternative concepts to be formed, it is necessary that students do not fully understand the meaning of the PV = nRT formula and that this connection is used inappropriately (Bak et al., 2008; Kautz, Heron, Shaffer, & McDermott, 2005; Karsli, 2011; Lin, Cheng, & Lawrenz, 2000). However, it can be shown that students who are involved in temperature-changing, position, and movement of gas molecules in a trap under the temperature-gas molecule relationship category have alternative concepts, that preliminary learning about the properties of gases is inadequate and superficial, or that the invisibility of gases prevents students from forming a gas concept (Stavy, 1988 as cited in Yalçınkaya, 2010), or in other words, they may not be able to visually perceive gas behaviour. All of these reasons are a consequence of the students' inability to perceive the kinetic theory used to explain the behaviour of gases at the conceptual level.

Using simulation applets in comparison to traditional didactic, chalk-and-talk instruction facilitates understanding of gas pressure concepts as well as the positive attitudes ot the students towards the use of the simulation applets (Oh, Treagust, Koh, Phang, Ng, Sim, & Chandrasegaran, 2012).

For the students to understand the concept of gas pressure, it is necessary to know the properties of the molecular structure of gases and the behavior of these molecules in a molecular way. In other words, students need to know Kinetic Molecular Theory, which explains the properties of gases, such as pressure, temperature, volume, depending on their molecular composition and motion (Şahin & Çepni, 2012). According to Kinetic molecular theory, Matter consists of tiny particles in constant motion, whose speed is proportional to the absolute temperature. It Explains gas laws.for example, explains the relationship expressed by Boyle's law in terms of gas particle motion. It also explains Charles's law (the direct relationship between the temperature and volume of a gas) ((Maeng & Randy Bell, 2013).

5. IMPLICATIONS

This study has several important implications for classroom teachers, educators, and researchers:

Gas concepts are been used in daily life so there are many conceptions about gases in students' mind before instruction. While some of them are true, some of them conflict with scientific knowledge. Pre-service teachers have some misconceptions on gas concepts and these can be passed to their students when they become a teacher.

Teacher educators should take in consideration misconceptions while designing their lessons. Faculty of education should open more courses dealing with the misconceptions and these courses should include strategies help pre-service teachers to remedy them in their subject area.

Teacher educators should organize workshops organized by the University and the Ministry of National Education to primary or secondary school teachers about new teaching techniques. And teachers should be trained and be encouraged to use new teaching techniques in order to enrich their lessons.

Researchers should determine the misconceptions on the students and teachers and work for the effective methods of teaching to overcome those misconceptions. More importance should be given to conceptual change strategies in order to make student misconceptions appear. The gas concepts should be represented with using macroscopic, symbolic and microscopic states in harmony so that the concepts should be constructed easily by students. In this regard computer aided instruction and mobile technologies should be used to visualise these states.

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