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# THE EFFECTS OF MODEL-BASED COOPERATIVE AND INDIVIDUAL LEARNING METHODS ON PRE-SERVICE SCIENCE TEACHERS' CONCEPTUAL UNDERSTANDING OF GASES

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**Abstract:** The aim of this study was to determine the effect of model-based cooperative (Reading Writing Application) and individual learning methods on conceptual understandings of pre-service science teachers and to eliminate their misconceptions related to gases. For this reason, a pre-test/post-test non-equivalent comparison group design was applied across two experimental groups. The sample consisted of 42 pre-service science teachers; one of the research groups was a Reading Writing Application- Model Group (n=22) and the other group was an Individual Learning- Model Group (n=20). The Gases Concept Test (GCT) was used for pre- and post-test as the data collection instrument. For analysing data, descriptive statistics were determined, and the Mann-Whitney U test was performed. There was not a significant difference between groups with respect to their development of their conceptual understanding of gases. In addition, some pre-service science teachers from both groups had various misconceptions about the topic after the application.

**Key words:** Cooperative learning, Reading writing application, Individual learning, Models, Gases

## 1. Introduction

Many studies have described learning as a process of cognitive construction, which shows a wide variation from person to person (Greca & Moreira, 2000). For this reason, learning processes and the resulting understanding of concepts vary among individuals. Understanding abstract concepts and visualizing them in science can be challenging for learners, which adds further complexity to learning. A major difficulty of understanding certain science topics is that students cannot construct a meaningful correlation between sub-microscopic (sub-micro) and macro levels. These correlations are very important to developing an understanding of abstract concepts (Papageorgiou et al, 2010; Smith & Villarreal, 2015). While the macro level includes concrete and observable events, the sub-micro level includes invisible, abstract phenomena or situations (Johnstone, 1991).

Various researchers have emphasized that students have problems in understanding specific topics in physics, chemistry and biology content because they are unable to envision events fully in the sub-micro level (Smith & Villarreal, 2015; Talanquer, 2011). Chemistry, being one of the most abstract fields of the sciences, often presents students with such challenges as demonstrated by several studies that have been conducted on the conceptual understanding of chemistry by secondary and high school students and pre-service science and chemistry teachers (Belge Can & Boz, 2016; Kimberlin & Yezierski, 2016; Privat et al., 2016; Talanquer, 2011). Taken together, these studies have identified several related conclusions, including that students have learning difficulties related to chemistry subjects are (e.g., Griffiths & Preston, 1992), these learning difficulties may be related to misconceptions that the learners have in these topics (e.g., Smothers & Goldstone, 2010), and there are strategies that can be suggested to eliminate these misconceptions (e.g., Kimberlin & Yezierski, 2016). However, despite the guidance offered by prior research and the implementation of different methods

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and techniques for supporting student learning, some misconceptions still exist (Smith & Villareal, 2015; Tsai, 1999).

### 1.1. Review of Relevant Literature: Gases

Gases are one of the most abstract subjects in chemistry, and students often have difficulty in understanding this topic (Stavy, 1988). Because most gases are colourless and have a structure that cannot be observed at macro level, students are not able to imagine the behaviour of the gas molecules in a container (Şenocak et al., 2007). A meaningful understanding of the concept of gases can eventually provide a more effective understanding of the additional, inter-related concepts, such as the mole, change of state, chemical reactions, and others. Therefore, misconceptions hinder conceptual development along several lines. Misconceptions about is given at Table 1 gases.

**Table 1.** *Misconceptions about Gases*

| Misconceptions | Author(s) | Participants |
|---|---|---|
| -Cannot understand sub-microscopic behaviour of gases | Adadan & Oner, 2014<br><br>Aydeniz et al., 2012<br>Correia et al., 2018<br>Çalık et al., 2007<br>Griffiths & Preston, 1992<br>Papageorgiou et al., 2010<br>Samon & Levy, 2020 | Pre-service chemistry teachers (PCT)<br>Undergraduate Students (US)<br>Secondary school students (SSS)<br>High school students (HSS)<br>HSS<br>Primary teachers (PT)<br>SSS |
| -Cannot understand distribution of gas molecules and kinetic theory | Adadan & Oner, 2014<br>Aydeniz et al., 2012<br>Bak Kibar et al., 2013 | PCT<br>US<br>PCT |
| -Cannot understand ideal gas concept | Bak Kibar, et al., 2013<br>Kautz et al., 2005<br>Yoshikawa & Kaga, 2016 | PCT<br>US<br>US |
| -Cannot understand vapour pressure | Kautz et al., 2005<br>Yoshikawa & Koga, 2016 | US<br>US |
| -Cannot understand gas laws | Abdullah & Shariff, 2008<br>Karslı et al., 2019 | US<br>Pre-service science teachers (PST) |
| -Cannot understand particulate nature of gases | Aydeniz et al., 2012<br>Benson et al., 1993<br>Griffiths & Preston, 1992<br>Mamombe et al., 2020<br>Papageorgiou et al., 2010 | US<br>US<br>HSS<br>Primary school students (PSS)<br>PT |
| -Think that inert gases form a reaction | Authors, 2016 | PST |
| -Cannot perceive the behaviours of dissolved gases in the liquids | Çalık et al., 2007 | HSS |
| -Cannot understand evaporation occurs at every temperature | Yoshikawa & Koga, 2016 | US |
| -Cannot understand the liquid-vapour balance | Yoshikawa & Koga, 2016 | US |
| -Gases have no mass | Adadan & Oner, 2014<br>Aydeniz et al., 2012<br>Çetin et al., 2009 | PCT<br>US<br>HSS |
| -Spaces between particles and speed of particles decrease when a gas is condensed | Aydeniz et al., 2012 | US |
| -The attraction force between gas particles increases with an increase in the temperature | Aydeniz et al., 2012 | US |
| -Heavy gases occupy more space than the lighter ones | Aydeniz et al., 2012 | US |
| -The gases are not distributed homogeneously | Aydeniz et al., 2012<br>Authors, 2016 | US<br>PST |

Several methods such as argumentation, simulations have been attempted to eliminate misunderstandings related to gases (Abdullah & Shariff, 2008; Correia et al., 2018; Papuçcu & Erduran, 2016; Yoshikawa & Kaga, 2016). Some studies on this subject have been successful and some have not. This inconsistency is potentially problematic for the future of chemistry education. The present study builds on this knowledge base, but also takes the perspective that an effective approach to addressing student misconceptions would be to determine the misconceptions of pre-service teachers (PSTs) while they are in the process of teacher education and to correct them with appropriate teaching methods. This is because it is the misconceptions they have during their in-service teaching can affect the conceptual development of secondary school students. This study, therefore, aims to enhance the conceptual understanding and eliminate the misconceptions of PSTs related to gases by using different methods, focusing specifically at concepts that call for understanding at the sub-micro level. The specific approach being tested in this study is a comparison of cooperative and individual learning models, which are discussed in detail below.

### 1.2. Theoretical Framework: Cooperative Learning, Individual Learning and Models

Cooperative learning is a model in which learners are actively involved in processes that give them responsibility for learning within heterogeneous groups (Belge Can & Boz, 2016; Johnson & Johnson, 2014; Jones & Jones, 2008; Slavin, 1996). As there is no competition among the group members, cooperative learning differs from traditional group work (Belge Can & Boz, 2016). Instead of being competitors, students encourage and help each other (Authors, 2018). Cooperative learning also increases the face-to-face interaction, as well as interpersonal and small group skills (Slavin, 1996). Research has shown that cooperative learning has a positive effect on students' academic achievement (Author, 2007), conceptual understanding (Belge Can & Boz, 2016; Eymur & Geban, 2017; Warfa et al., 2014), and social/communication skills (Wang et al., 2017; Woods-McConney et al., 2016).

Cooperative learning has a wide range of learning methods and techniques that basically differ in the implementation process (Author, 2013) such as the Student Teams Achievement Division (STAD) method (Slavin, 1978), co-learning, group research, and the jigsaw classroom (Aronson & Patnoe, 1997) as well as less-known methods such as the Reading Writing Application (RWA) method (Authors, 2018). In this study, the RWA method of cooperative learning was used. The RWA method is adapted to all school levels, with the combined cooperative literacy and composition technique used in the lower levels of education (Authors, 2018). In this method, the students read about the given topic in a way that provides a positive commitment to the cooperative groups, then they put aside the reading material and summarize the topic as a group report and apply what they understand from the topic in various ways, such as an experiment, a role play, or presentation (Authors, 2018). Research has demonstrated that the RWA method increased conceptual understandings and academic achievement (Authors, 2018). The reason for choosing this method is that PSTs are given the opportunity to read, write, and practice during the learning process. In this way, it is intended that the PSTs understand the topic by reading, repeat it by writing and make it permanent by doing something with the knowledge.

In distinction from cooperative learning, individual learning (IL) is a learning approach that varies from person to person and allows each student to work in a way that suits their own learning style (Ifinedo, 2018). Different methods and techniques, therefore, are used in instruction because of individual differences. For example, while visual materials are used for some students, others may be provided with auditory or tactile materials. For some students, activities aiming at reading and writing are carried out, while for others, activities such as experiments and observations are used to be provide different sensory stimuli. The goal of IL is to reach every student using their individual learning strengths so that each of them can learn effectively. The point to be considered in IL is to take into account the individual needs of the students (Ginsburg, Jamalian & Creighan 2013).

Looking at the studies on IL, many recent studies, include studies in the use of electronic formats, such as on e-learning (Bahiraey, 2010; Ifinedo, 2018; Wang, 2018; Zhang et al., 2018) and games (Kjällander & Frankenberg, 2018). The effectiveness of IL versus cooperative learning has been compared in some studies, especially in the electronic learning domain (Bahiraey, 2010; Morice et al., 2015; Wang, 2018; Zhang et al., 2018). For example, Bahiraey (2010) examined the quality of cooperative and IL in a virtual learning environment and he determined factors that enhance or hinder the quality of students' learning. According to that study, the quality of IL was superior to that of cooperative learning. However, the number of studies using IL in science education is limited. In these studies, the effectiveness of team-based, peer-assisted learning (Morice et al., 2015) is compared to IL. In science education, research on IL has generally been conducted through studies of computer-assisted learning (Morice et al., 2015), which aim to develop various skills in the computer environment. Studying each student with respect to his/her own style and speed allows first-hand and permanent learning. Because the learning styles of people differ, some people might be better able to learn in her/his own learning style and speed. In the present study, cooperative learning and IL were compared in combination with the use of models to support the visualization of abstract concepts.

Models are defined as "a simplified representation of complex phenomenon or process" (Harrison, 2001, p. 401) that are used in the learning process to increase the conceptual understanding of the students (Develaki, 2017; Kimberlin & Yezierski, 2016). Models are categorised as pedagogical-analogical models, scale models, iconic and symbolic models, mathematical models, theoretical models, maps, diagrams and tables, simulations, mental models, concept-process models, and synthetic models (Harrison & Treagust, 2000). Of those, pedagogical-analogical models, concept-process models and simulations are the types most often used in the teaching chemistry. Pedagogical-analogical models are often used to describe entities or events in microscopic dimensions, such as atoms and molecules, and to facilitate their visualization in students' minds. Here, the aim is to generate a better understanding of the situation or event that modelled. Illustrating molecules with ball-and-stick structures in a molecular model, and comparing DNA to a helical rope are two examples of pedagogical-analogical models. Different types of models, present different challenges to students. For example, concept-process models, are the most complex and abstract models. Therefore, it is quite difficult for students to understand them. Examples of concept-process models include models of acids and bases, the photoelectric effect, redox reactions, and chemical equilibrium. In this study, pedagogical-analogical models were used.

It has long been recognized that student misconceptions can present obstacles in acquiring scientific knowledge (e.g., Correia et al., 2018). It has been proposed that science instruction be approached as a process of conceptual change. Posner, Strike, Hewson and Gertzog (1982) state that conceptual change can be brought about by providing students information in multiple modes such as verbal, mathematical, pictorial, and concrete-practical, thus helping the students translate from one mode of representation to another. This highlights the value of the use of models can be effective in the process of conceptual change. The use of pedagogical- analogical models, concept-process models, theoretical models and simulations in teaching helps students developing conceptual understanding, such as by assisting students to learn about concepts they cannot observe, touch, taste, or smell, providing students with internalizations that support correct understanding of the concepts (Demir et al., 2017; Oliva et al., 2015). In particular, the use of model has been found to be effective in helping students understand the concepts of chemistry (Cheng & Gilbert, 2017; Johnstone, 1991; Kimberlin & Yezierski, 2016; Smith & Villareal, 2015). Studies also suggests that model-based reasoning can be enhance conceptual learning about some of the more difficult areas of chemistry (Cheng & Gilbert, 2017; Develaki, 2017). For example, Cheng & Gilbert (2017) investigated model-based reasoning on sub-micro representations of chemical reactions. They analysed how students mentally visualised the reaction between magnesium and hydrochloric acid. After the students were taught the reactions of acids and redox, they could form more sophisticated models.

Models are not a learning technique per se, so they must be used in conjunction with a learning method or technique. Models can be more effective when integrated with a compatible teaching method that supports a better understanding of abstract situations (Smith & Villareal, 2015). However, there are not enough studies in literature related to model-based learning to provide strong guidance about effective methods for using models, especially with respect to using student-centred approaches (Becker et al., 2013; Karaçöp, 2016; Wade-Jaimes et al., 2018; Shim & Kim, 2018; Warfa et al., 2014). In recent years, some studies on model-based implementation of cooperative learning have been carried out to investigate the effect of those methods on student learning (Shim & Kim, 2018; Wang et al., 2017; Warfa et al., 2014). For example, Abdullah and Shariff (2008) stated that inquiry-based computer simulation with cooperative learning has a positive effect on scientific thinking and conceptual understanding of gas laws. Similarly, Warfa et al. (2014) investigated the impact of physical 3-dimensional magnetic molecular modelling by employing a cooperative inquiry-based activity. The researchers found that cooperative learning and models increased the conceptual understanding of students about the subject and ensured correct explanations with respect to the particle size. As stated above, some studies related to visualization-supported IL determined that IL is more effective than group working (Bahiraey, 2010; Morice et al., 2015), suggesting that IL was superior to cooperative learning (Bahiraey, 2010). However, there are not enough studies related to model-based IL to support a conclusion regarding the effect IL versus cooperative learning in model-based instruction. Therefore, the present study examine instruction intended to develop conceptual understanding of gases, comparing model-based IL and model-based cooperative learning activities.

### 1.3. Aim and Research Questions

The aim of this study is to determine the effects of model-based cooperative and IL methods on conceptual understandings of PSTs and to address the PSTs misconceptions related to gases. According to this aim, the research questions are:

1. Are there any differences in the learning achieved using the model-based cooperative learning methods versus the model-based IL methods on the PSTs' conceptual understanding on gases?

2. Are misconceptions of the PSTs reduced about gases after the application of either model-based cooperative learning or model-based IL?

## 2. Method

### 2. 1. Research Design

Use of a quasi-experimental research design is convenient to analyse the effects of learning materials or learning methods in different learning settings (McMillan & Schumacher, 2010). A pre-test/post-test non-equivalent comparison group design was used in this study. Accordingly, participants for two experimental groups were selected with convenience sampling method. Because researchers are working in this university. One group was assigned as model-based RWA group (RWA-M; n=22; 18 females, 4 males) and the other was assigned as model-based IL group (IL-M; n=20; 14 females, 6 males). The participants were randomly selected into research groups

### 2. 2. Participants

The sample consisted of 42 (32 females and 10 males) PSTs from two groups enrolled in the General Chemistry course in Ataturk University from Erzurum, Turkey. Participants were first-year PSTs. In the previous semester the PSTs had taken General Chemistry I and General Chemistry Laboratory I courses. Also, they were enrolled in General Chemistry II and General Chemistry Laboratory II courses during the study was conducted. All the PSTs had taken Chemistry courses for four years at high school (i.e. grades 9-12) before being enrolled into the science teacher education program. The PSTs were admitted to these groups after the pre-test of Gases Concept Test (GCT) results. Participants did not have any problems in adapting to the process since they had previously carried out different activities on cooperative learning, individual learning, and models in General Chemistry Laboratory II course.

### 2. 3. Data Collecting Tool

While multiple-choice tests are often used to determine how the methods applied in research change academic achievement, various measurement tools such as two-tier diagnostic tests, open-ended questions, semi-structured interviews, and drawings are used in defining conceptual understandings (Schmidt, 1997). The common features of these tools are that they are designed to reveal misconceptions or misunderstandings that exist in individuals. To verify the effects of learning methods on the conceptual understanding of the PSTs on gases, each group of the PSTs was given the GCT at the beginning and at the end of the study.

**2.3.1. Gases Concept Test (GCT).** The GCT consisted of six drawing questions, which measured the PSTs' understandings of gases at particulate level. Common conceptual misconceptions by PSTs about the subtopics of gases, as documented by previous literature, were considered in the selection and preparation of the questions. The GCT questions included subjects: (a) the understanding of gas reactions in a particle size (gases), (b) the understanding of the volume-pressure relationship of gases (gas laws), (c) inert gases, the mixing of gases with liquids in a particulate form (kinetic theory), and (d) the effect of temperature on gas distribution (diffusion). The PSTs were expected to make the most appropriate drawings for the questions in the GCT. Two chemistry experts were consulted to check the content validity of the GCT and certain questions were clarified or reconstructed. In addition, authors established consensus about the difficulty level of each question, and the language used in the questions. Each question in the test were 10 points and the maximum score to be obtained from the GCT was 60. The pilot study was done with PSTs before the implementation. KR-20 analyses were used to determine the reliability of the GCT and the reliability coefficient was found as .68.

## 2. 4. Procedure

Firstly, the GCT was applied as pre-test in both experimental groups for a period (50 minutes). Then, each group studied the gases topic according to their own learning method. Both experimental groups studied on “gases”, “gas laws”, “inert gases”, “kinetic theory”, and “diffusion” in their learning method (RWA and IL by integrating models). Implementations for both groups continued for two weeks as of two hours per week. After the implementation, the GCT was applied as post- test in both groups for a period. Totally, this study continued as four weeks. Researchers carried out the applications in both groups. The role of researchers is to assist PSTs in the process. The process of the study is given in Table 2.

**Table 2.** *The Process of the Study*

| Applications/ Groups | RWA-M | IL-M |
|---|---|---|
| GCT (pre) | 1 period* (1 week) | 1 period (1 week) |
| Implementation process | 2 + 2 periods (2 weeks) | 2 + 2 periods (2 weeks) |
| GCT (post) | 1 period (1 week) | 1 period (1 week) |
| Total | 6 periods (4 weeks) | 6 periods (4 weeks) |

* 1 period = 50 minutes

**2.4.1. Implementation of the RWA Method with Models.** Working groups of cooperative learning can be 2-6 members according to the classroom size. Cooperative groups are formed as heterogeneously with respect to the scores of the GCT. Since there were 22 PSTs in the RWA-M group, the individuals were divided into five sub-groups heterogeneously. Three groups had four members and two groups had five members. The main features of the RWA are presented in three phases for each group as; 1) reading, 2) writing, and 3) application. In the first phase of implementation, all the groups read the gases topic for 50 minutes from the course books or other resources in the classroom. In the second phase, books and resources were taken from groups and group members wrote their understanding about what they read as a report for 50 minutes. The reports were then evaluated by the researchers and groups with unsatisfactory content related to the topic were sent back to repeat the first phase. In the application phase, the PSTs made modelling activities with molecular models and "play dough" for 50 + 50 minutes in their groups. In this part, modelling activities related to the particulate structure of gases, inert gases and liquid-vapour balance were designed by the PSTs via group study. During this phase, the PSTs were asked to consider the atomic masses in the representative models they created. This was ensured by modelling large atomic mass substances with large beads and modelling each atom with a different colour. After constructing the models, the GCT was applied as post-test to the RWA-M group for a period.

**2.4.2. Implementation of the Individual Learning with Models.** In IL-M group, the PSTs worked individually. In application, firstly the PSTs were transferred to their worktables. Then, the PSTs were informed about the particle model of the matter, and the worksheets about gases were distributed by the researchers. Necessary explanations were given to the PSTs by the researchers after studied the worksheets (totally 50 + 50 minutes). Then, molecular models and play dough were assigned to each individual. During researchers visited the working tables of the PSTs and provided assistance if required. The PSTs created modelling activities as individually by molecular models and play doughs for 50 + 50 minutes. In this part, modelling activities related to the particulate structure of gases, inert gases and liquid-vapour balance were designed by the PSTs individually. During this phase, the PSTs were asked to consider the atomic masses in the representative models they created. This was ensured by modelling large atomic mass substances with large beads and modelling each atom with a different colour. After constructing models, the GCT was applied as post-test to the IL-M group for a period. Some models prepared by the PSTs are presented in Figure 1.

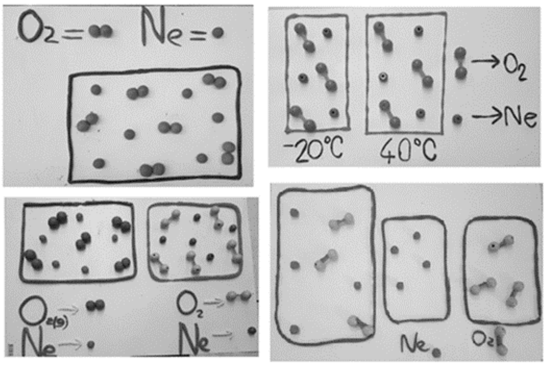


**Figure 1.** *Some models prepared by the PSTs*

## 2. 4. Data Analyses

Firstly, the data obtained from the GCT were classified as "correct drawing", "incorrect drawing" and "blank". The points that all the PSTs have received from the GCT were determined as 10 points for correct drawings, 5 points for incorrect drawings and 0 points for blank answers. The situations considered in the "correct", "incorrect" and "blank" categories are summarized in Table 3.

**Table 3.** *Analysing Categories of the GCT*

| Categories | Explanation | Point |
|---|---|---|
| Correct drawing | Particulate structure is shown in full and correctly with all aspects; does not contain any misconceptions | 10 |
| Incorrect drawing | Particulate structure is not shown completely and correctly with all aspects; it contains misconceptions | 5 |
| Blank | No answer is given to the question | 0 |

Two researchers scored the GCT according to the answer key. Then, consistency between the researchers was examined and the consistency was found in the scoring. To answer the first research question, descriptive statistics and Mann-Whitney U test were used to determine whether there was a statistically significant difference between the research groups on pre- and post-test scores. For the second research question, correct and incorrect drawings of the PSTs were analysed descriptively.

# 3. Findings

## 3. 1. Findings from Quantitative Data

As the sample size was lower than 30, Shapiro Wilk test of normality was performed to determine whether the distribution of the data was normal. The results (for RWA-M ($p_{pre}$=.00, $p<.05$; $p_{post}$=.02, p<.05) and for IL-M ($p_{pre}$=.00, p<.05; $p_{post}$=.03, p<.05) showed that the data did not have a normal distribution. Therefore, Mann-Whitney U test was used to compare the average mean scores of the groups. Table 4 presents descriptive statistics and Mann- Whitney U test results of the data obtained from the implementation of the GCT as pre- and post-test.

**Table 4.** *Mann-Whitney U Test related to the Pre- and Post-GCT Scores*

| GCT | Groups | n | Mean Rank | Sum of Ranks | U | p |
|---|---|---|---|---|---|---|
| **Pre** | RWA-M | 22 | 23.41 | 515 | 178 | .28 |
| | IL-M | 20 | 19.40 | 388 | | |
| **Post** | RWA-M | 22 | 23.05 | 507 | 186 | .38 |
| | IL-M | 20 | 19.80 | 396 | | |

Table 4 shows that there is not a statistically significant difference between the groups on pre- and post-test scores ($U_{pre}$=178, p>.05; $U_{post}$=186, p>.05).

Data obtained from the GCT were evaluated separately on a question-based basis. Mann-Whitney U test was performed to determine whether there was a significant difference between the groups in each question. Table 5 shows a question-based analysis of the data obtained from the administration of the GCT as a pre-test.

**Table 5.** *Question-Based Analysis of the Pre-GCT Scores*

| Questions | Groups | n | Mean Rank | Sum of Ranks | U | p |
|---|---|---|---|---|---|---|
| **Q1** | RWA-M | 22 | 23.45 | 516 | 177 | .21 |
| | IL-M | 20 | 19.35 | 387 | | |
| **Q2** | RWA-M | 22 | 22.18 | 488 | 205 | .63 |
| | IL-M | 20 | 20.75 | 415 | | |
| **Q3** | RWA-M | 22 | 21.55 | 474 | 219 | .98 |
| | IL-M | 20 | 21.45 | 429 | | |
| **Q4** | RWA-M | 22 | 24.05 | 529 | 164 | .08 |
| | IL-M | 20 | 18.70 | 374 | | |
| **Q5** | RWA-M | 22 | 21.64 | 476 | 217 | .93 |
| | IL-M | 20 | 21.35 | 427 | | |
| **Q6** | RWA-M | 22 | 21.05 | 463 | 210 | .77 |
| | IL-M | 20 | 22.00 | 440 | | |

While the mean scores of RWA-M tended to be higher than the mean scores of IL-M in the first five questions, the superiority of this method could not be substantiated statistically. But, there was not a significant difference between groups in all questions (p>.05).

Question-based analysis of the data obtained from the application of the GCT as a post-test was given in Table 6.

**Table 6.** *Question-Based Analysis of the Post-GCT Scores*

| Questions | Groups | n | Mean Rank | Sum of Ranks | U | p |
|---|---|---|---|---|---|---|
| **Q1** | RWA-M | 22 | 24.73 | 544 | 149 | **.03** |
| | IL-M | 20 | 17.95 | 359 | | |
| **Q2** | RWA-M | 22 | 23.45 | 516 | 177 | .23 |
| | IL-M | 20 | 19.35 | 387 | | |
| **Q3** | RWA-M | 22 | 22.59 | 497 | 196 | .32 |
| | IL-M | 20 | 20.30 | 406 | | |
| **Q4** | RWA-M | 22 | 24.41 | 537 | 156 | .06 |
| | IL-M | 20 | 18.30 | 366 | | |
| **Q5** | RWA-M | 22 | 19.50 | 429 | 176 | .19 |
| | IL-M | 20 | 23.70 | 474 | | |
| **Q6** | RWA-M | 22 | 19.73 | 434 | 181 | .11 |
| | IL-M | 20 | 23.45 | 469 | | |

According to Table 6, there was a significant difference between groups only in the first question in favour of RWA-M (p <.05).

### 3. 2. Findings from Qualitative Data

First question of the GCT required the PSTs to demonstrate the $NH_3$ formation reaction of the $H_2$ and $N_2$ gases in a particulate nature form. In the second question, the PSTs were asked to draw the particle size of the last state (HCl gas) of $H_2$ and $Cl_2$ gases which were present in different piston cups and then entered the reaction at the third cup. The frequency and percentage values of the answers of the PSTs to the first and the second question are given in Table 7.

Table 7. Frequency Distribution and Percentages of the Answers to Q1 and Q2

| | **Drawings** | **RWA-M** | | | | **IL-M** | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Pre-test | | Post-test | | Pre-test | | Post-test | |
| | | f | % | f | % | f | % | f | % |
| **Q1** | Correct drawing | 14 | 63.6 | 19 | 86.4 | 13 | 65 | 15 | 75 |
| | Incorrect drawing | 8 | 36.4 | 3 | 13.6 | 7 | 35 | 5 | 25 |
| **Q2** | Correct drawing | 3 | 13.6 | 9 | 40.9 | 1 | 5 | 5 | 25 |
| | Incorrect drawing | 18 | 81.8 | 13 | 59.1 | 18 | 90 | 15 | 75 |
| | Blank | 1 | 4.5 | 0 | 0 | 1 | 5 | 0 | 0 |

Table 7 shows that the conceptual understanding related to the first question in both groups increased in the post-test. In this question, the most important misconceptions in the PSTs' drawings were as follows: (a) not knowing exactly the equation between the given gases, (b) being unable to realize that the given gases were reacting, and (c) being unable to demonstrate the particulate nature of the product obtained from the reaction. According to Table 7, the rate of correct response to the second question was lower than the incorrect drawings both in pre- and post-tests. Also, RWA-M scores were higher than IL-M scores. In this question, the most important misconceptions obtained from the PSTs' drawings were as follows: (a) being unable to realize that the given gases are reacting, (b) incorrect formation of molecular geometry of HCl and (c) the idea that gases are a heterogeneous mixture.

Sample drawings from the answers given by the PSTs to the first and the second questions are given in Figure 2.

According to Figure 2, the PST in row 1 did not pay attention to the law of conservation of matter in the first question. This PST had drawn eight NH3 molecules in the products while there were six $H_2$ and two $N_2$ molecules in the reactants. However, the PST who made the drawing in row 2 had thought that the matters would form a mixture after the reaction, and the PST in row 3 had drawn heterogeneous molecules. The PST in row 4 had formed products without considering the particulate amounts. According to the drawings made for the second question; the PST in row 1 had formed a wrong reaction between $H_2$ and $Cl_2$. The second drawing of the PST in row 2 showed heterogeneous gases of $H_2$ and $Cl_2$ as the final product. The PSTs in row 3 and 4 formed an incorrect molecular geometry. Besides, the PST in row 3 incorrectly showed the volume of the product.

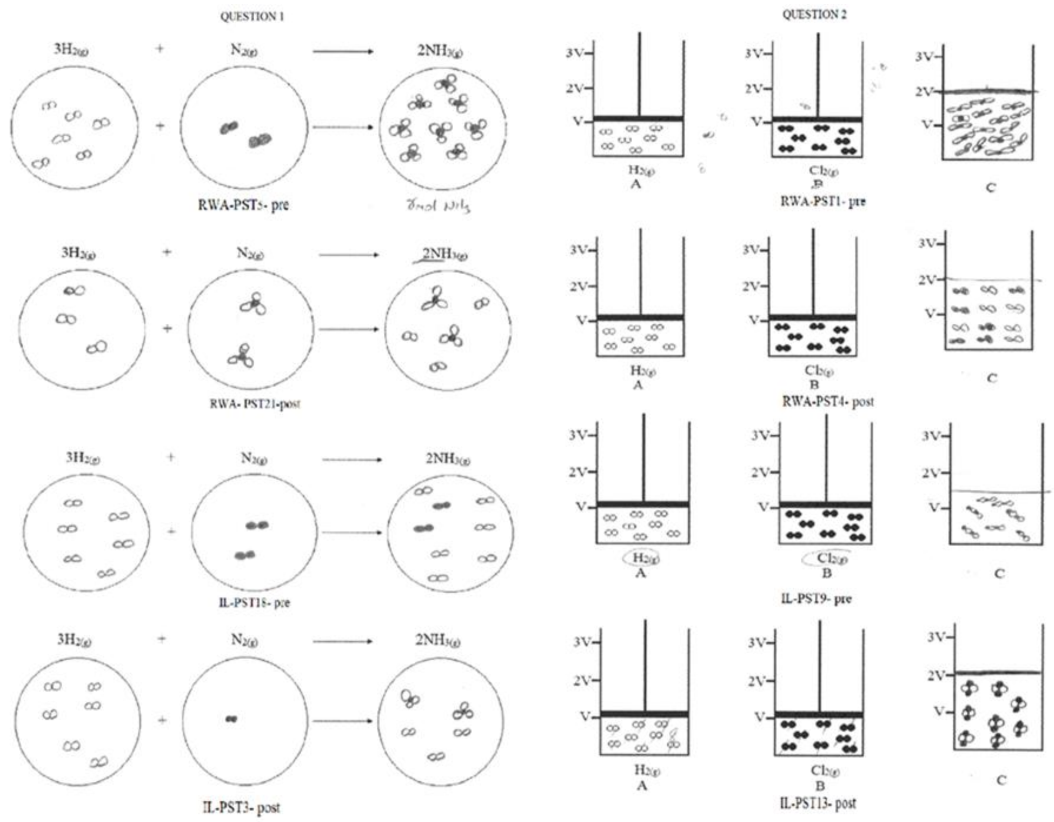

**Figure 2.** *Some PSTs' drawings related to "incorrect" category in Q1 and Q2 of the GCT*

In the third question, the PSTs were asked to show the two gases ($N_2$ and Ar) which are not reacting and mixed in a different container in a particle nature form. The PSTs were asked to show the liquid-vapour balance of the water in particulate nature form at different temperatures in the fourth question. The frequency and percentage values of the PSTs' drawings to the third and the fourth question are given in Table 8.

**Table 8.** *Frequency Distribution and Percentages of the Answers to the Q3 and Q4*

| | **Drawings** | **RWA-M** | | | | **IL-M** | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Pre-test | | Post-test | | Pre-test | | Post-test | |
| | | f | % | f | % | f | % | f | % |
| **Q3** | Correct drawing | 7 | 31.8 | 18 | 81.8 | 10 | 50 | 14 | 70 |
| | Incorrect drawing | 15 | 68.2 | 4 | 18.2 | 9 | 45 | 6 | 30 |
| | Blank | 0 | 0 | 0 | 0 | 1 | 5 | 0 | 0 |
| **Q4** | Correct drawing | 6 | 27.3 | 6 | 27.3 | 3 | 15 | 3 | 15 |
| | Incorrect drawing | 16 | 72.7 | 16 | 72.7 | 17 | 85 | 17 | 85 |

Table 8 shows that the conceptual understandings of the PSTs have increased in the post test and the PSTs in RWA-M were more successful in this question. The most common misconception was "inert gases react with each other and they form a heterogeneous mixture". According to Table 8, the rate of correct response of the fourth question was low in both groups in the pre- and post-tests and also, the rate of correct response did not change in post-test. Drawings showed that the PSTs did not know that the evaporation increases in parallel to the increase in temperature and vaporization occurs at every temperature. The PSTs' sample drawings about the third and the fourth questions are given in Figure 3.

According to the Figure 3, the PSTs think that gases were heterogeneous mixtures as seen in the first and the third-row drawings. The PST in the second-row decreased the particulate number. The PST in fourth row did not understand that Ar and $N_2$ are inert gases. Results of the fourth question showed that the PSTs did not understand the number of the vapour particles, which is balanced with vapour at 25ºC, increase when the water is heated to 70ºC. They also think that the vapour in the upper level of the container would also freeze since the water is in ice form at -40ºC. These findings revealed that the PSTs did not understand the evaporation which takes place at every temperature.

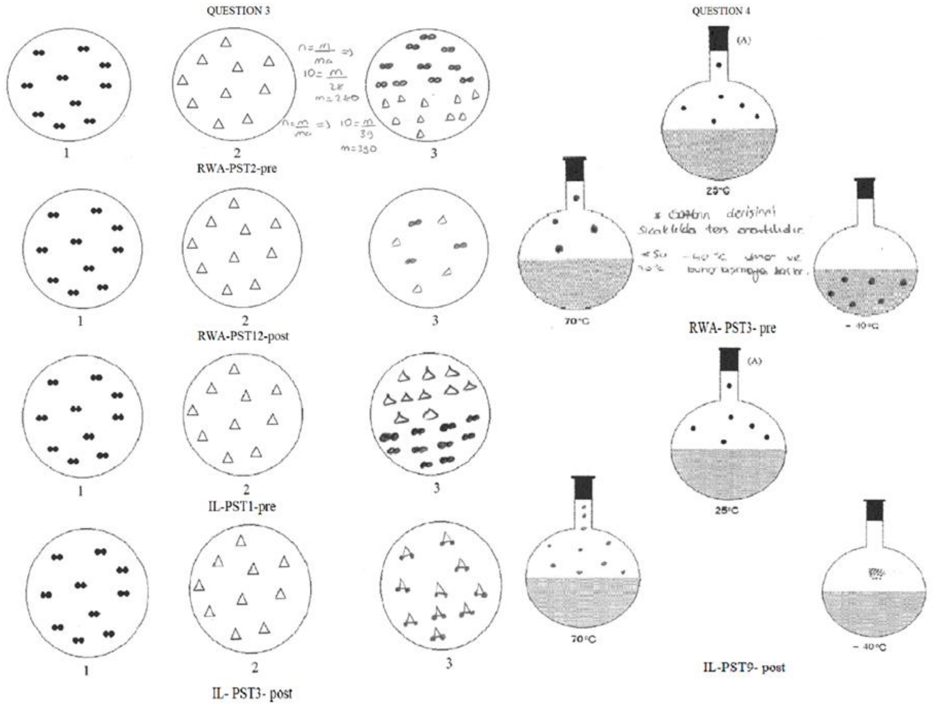


**Figure 3.** *Some PSTs' drawings related to "incorrect" category of Q3 and Q4 of the GCT*

In the fifth question, the PSTs were asked to draw the liquid-vapour balance of the ethyl alcohol solution in particulate nature form at different temperatures. In the sixth question, the PSTs were asked to show the oxygen gas in the particle structure at different temperatures. The frequency and percentage values of the answers of the PSTs to the fifth and the sixth question are given in Table 9.

**Table 9.** *Frequency Distribution and Percentages of the Answers to the Q5 and Q6*

| | **Drawings** | **RWA-M** | | | | **IL-M** | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Pre-test | | Post-test | | Pre-test | | Post-test | |
| | | f | % | f | % | f | % | f | % |
| **Q5** | Correct drawing | 5 | 22.7 | 10 | 45.5 | 4 | 20 | 11 | 55 |
| | Incorrect drawing | 17 | 77.3 | 12 | 54.5 | 16 | 80 | 9 | 45 |
| **Q6** | Correct drawing | 3 | 13.6 | 6 | 27.3 | 7 | 35 | 15 | 75 |
| | Incorrect drawing | 19 | 86.4 | 16 | 72.7 | 13 | 65 | 5 | 25 |

The correct answer rate increased in both groups as shown in Table 11. According to the fifth question, some of the PSTs had no idea that the gases were homogeneously distributed in the container and gases could evaporate at any temperature. (See Figure 4). According to Table 9, the correct answer percentage was lower in the pre-test in both groups, whereas the correct answer levels of the PSTs in IL-M were higher than the RWA-M in the post-test. In this question, the most important misconceptions obtained from the PSTs' drawings were as follows: "the amount of the substance changes at different temperatures" and "the gases are not homogeneously distributed in the container". Sample drawings from the answers given by the PSTs in the fifth and the sixth questions are shown in Figure 4.

First drawing showed that the PST in the first-row thought that the gas in the heated container will only be located at the top of the container and that the particulates will accumulate at the liquid surface if the container is cooled down. The drawing at the second-row showed that the vapour molecules will decrease as the vessel warms and the vapour molecules will only be located at the top of the container. The sixth question findings revealed that the PSTs did not understand that the gases were homogeneous. The PST at the first-row increased the number of gas molecules when the temperature decreased and she decreased the number of gas molecules when the temperature increased without considering the conservation of matter. The PST at the row 2 thought that as the temperature increases, the gases will accumulate at the upper part of the container and vice versa, the gases will gather at the bottom of the container when the temperature decreases.

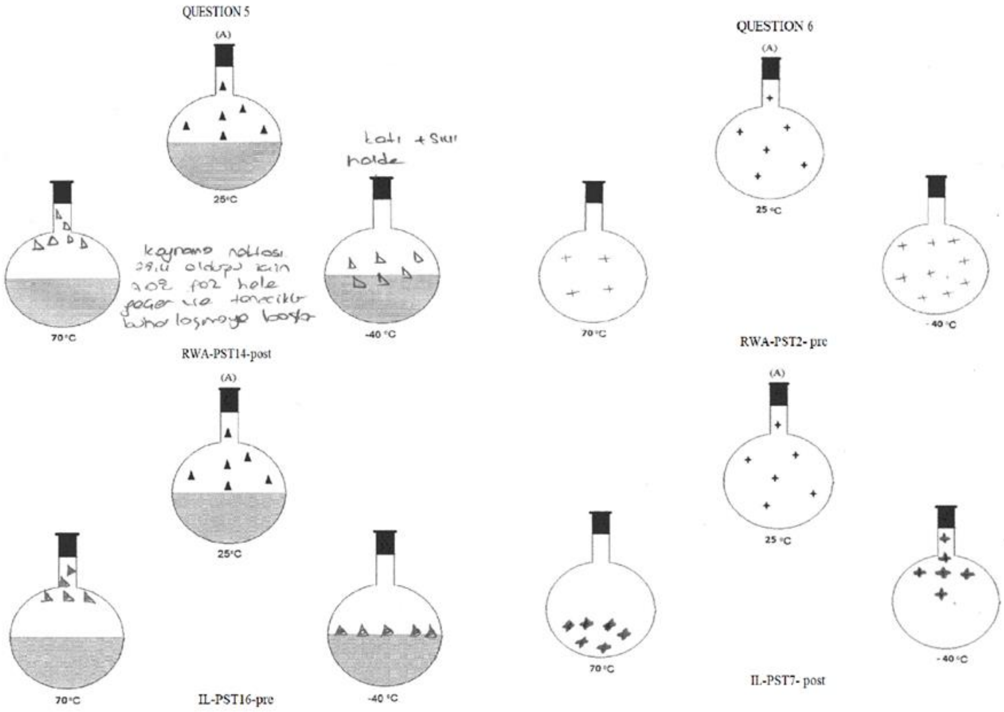


**Figure 4.** *Some PSTs' drawings related to "incorrect" category of Q5 and Q6 of the GCT*

## 4. Conclusion, Discussion and Suggestions

In this study, the effects of cooperative and individual learning methods supported by models on conceptual understanding of the PSTs and misconceptions related to the topic were investigated. There was not a statistically significant difference between the groups in pre- and post-test of the GCT. In question-based evaluations, a significant difference was found in favour of RWA-M only in the first question in the post-test. The model- based cooperative and IL methods had a close relation to the conceptual understanding in the subject of gases. However, although the scores of the RWA-M group were better in the first four questions, there was no statistically significant difference between the groups in the study. On the basis of the question, the correct answers of the PSTs in both experimental groups increased partially in the post-test. However, this increase was not at a level that makes a significant difference. This situation may be due to the process not being long enough. In fact, PSTs had model-based cooperative learning activities in previous courses. However, since the gases subject is a very abstract subject, it is thought that PSTs do not fully understand the subject. Also, models designed in practice are not sufficient to understand the subject efficiently. Besides, the small number of samples may also be effective in this result. Repeating the study with a larger sample may lead to the desired learning. In contrast to the results of this study, it was reported in some studies that model-supported cooperative learning practices are highly effective on conceptual understandings (Abdullah & Shariff, 2008; Authors, 2016; Karaçöp, 2016). Cooperative learning requires group working in which group members are responsible for each other's learning, and thus, group cooperation is thought to have a positive impact on conceptual learning. Nevertheless, in this study, lack of a significant difference between the research groups suggests that individual learning is also important in constructing the concepts. In the IL-M method, all learners are allowed to study on their own because each individual constructs knowledge (Bahiraey, 2010; Ifinedo, 2018) with models according to his/her own learning style. Therefore, IL-M activities were as effective as cooperative learning in this study. Similarly, Bahiraey (2010) investigated the effects of cooperative and IL methods on virtual learning and he determined that the IL method was more effective in providing virtual learning.

There were various misconceptions in the drawings related to the pre- and post-test of the GCT. Some PSTs did not understand reactions between the gases in desired level. There have been decreases in PSTs' misconceptions after the applications, but it has been observed that some PSTs have misconceptions about gases. As a consequence, the conceptual misconceptions identified in this study can be stated that the PSTs; (1) think that inert gases form a reaction, (2) do not understand the reaction equations which occur between gases, (3) cannot draw the product obtained from the reaction in particulate structure, (4) do not understand the molecular geometry, (5) think that gases form heterogeneous mixtures with each other, (6) are unable to perceive the behaviour of gases dissolved in liquids, (7) think that the volumes of the gases decrease as the temperature decreases, (8) cannot comprehend that evaporation increases as the temperature increases with respect to the liquid-vapour balance, (9) cannot comprehend that evaporation occurs at every temperature, (10) think that the amount of matter changes at different temperatures, (11) think that the gases are not homogeneously distributed in the container, and (12) cannot understand pressure-volume work in a piston cap. Similar results have been also found in previous research. According to these research, PSTs did not perceive the behaviours of dissolved gases in the liquids (Çalık et al., 2007), PSTs think that inert gases form a reaction and they do not stimulate in their mind the molecular geometry and reaction equations which occur between gases (Authors, 2016), and PSTs think that the amount of gas decreased as the temperature decreased. Also, they considered that the gases are not homogeneously distributed (Aydeniz et al., 2012); they cannot understand evaporation occurs at every temperature and cannot understand the liquid-vapour balance (Yoshikawa & Koga, 2016) and gas mixtures are not correctly understood correctly by PSTs (Aydeniz et al., 2012; Cho, Park & Choi, 2000). Similarly, studies conducted on the conceptual understanding of gases reported that students, PSTs and teachers had various misconceptions about the particulate nature of gases (Aydeniz et al., 2012; Benson et al., 1993; Griffiths & Preston, 1992; Papageorgiou et al., 2010), behaviour of gases (Çalık et al., 2007; Griffiths & Preston, 1992), gas laws (Abdullah & Shariff, 2008), and ideal gases (Privat et al., 2016; Yoshikawa & Koga, 2016).

This study showed that even after applying the treatment which includes CL-M and IL-M, the misconceptions did not completely resolve. This may be due to the preliminary misconception of the PSTs on gases. Given that the gases are the subject of the curriculum in elementary and high school, PSTs cannot easily change the misconceptions originating from their previous learning periods. Many studies have shown that pre-learnings can lead to the misconceptions (Hawsen et al., 1998) and these difficulties are resistant to change (Smith & Villareal, 2015). Many of the gases are colourless; therefore, they are not visible at the macro level and can be misconfigured in the minds of individuals who do not fully understand the sub-micro level (Papageorgiou et al., 2010). PSTs' misconceptions are resistant to change because they may be logical, sensible and valuable. Also, pre-existing beliefs influence how PSTs learn new scientific concepts and play an essential role in subsequent learning (Correira et al., 2018). In this regard, the correlation between sub-micro and macro levels is not fully achieved in this study. It has been stated that establishing an association between sub-micro and macro levels is highly effective on the complete and accurate understanding of chemical issues (Talanquer, 2011).

CL-M and IL-M methods were found to have a similar effect on the understanding of gas subjects. Participants did not have any problems in adapting to the process since they had previously carried out different activities on cooperative learning, individual learning, and models in General Chemistry Laboratory II course. However, the desired result could not be obtained in the study. In this case, the lack of implementation time or the lack of positive engagement among PSTs can be negatively affect. IL and CL methods can be applied in different contexts to increase the conceptual understandings within the framework of the results obtained from this study. IL and CL methods are also recommended in relation to the different chemistry issues to ensure that sub- micro and macro levels are significantly correlated and to minimize the misconceptions of PSTs. Since the application process was carried out for two weeks, the time given for the contextualization may not be sufficient. Therefore, the application of the research in a longer period may lead to a more positive result. In addition, since only forty-two PSTs participated in this study, the sample size is small. For this reason, the application of these methods with new populations can be suggested for similar research.

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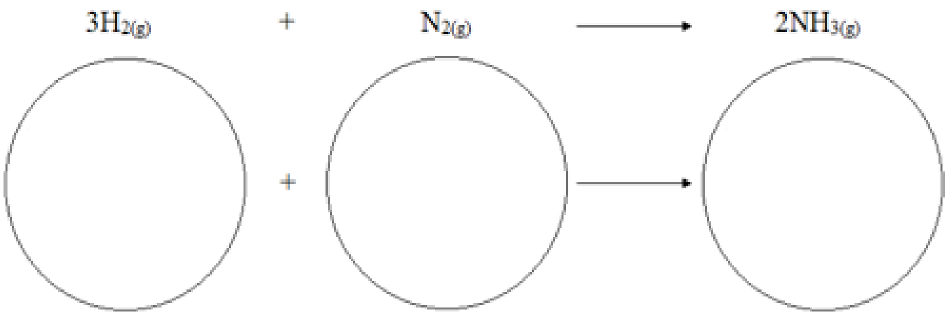
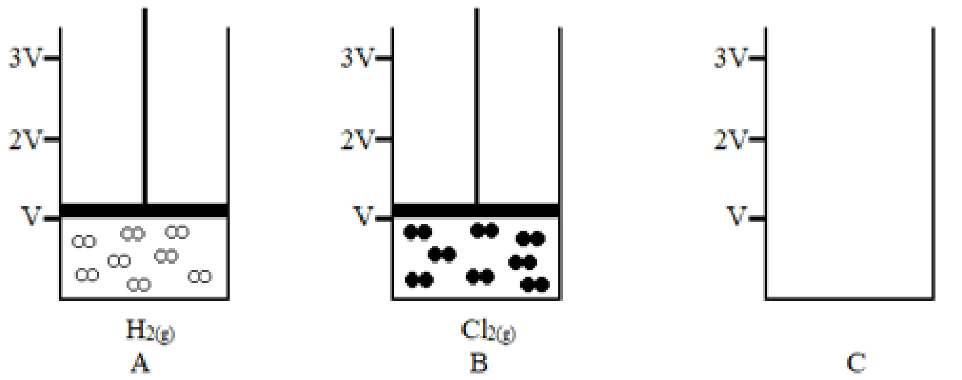
## Appendix: The Questions of the GCT

1. According to the reaction given below, 6 moles of hydrogen gas ($H_2$) and 2 moles of nitrogen ($N_2$) gas reacts to produce ammonia ($NH_3$). Draw the substances before and after the chemical reaction in particle size.

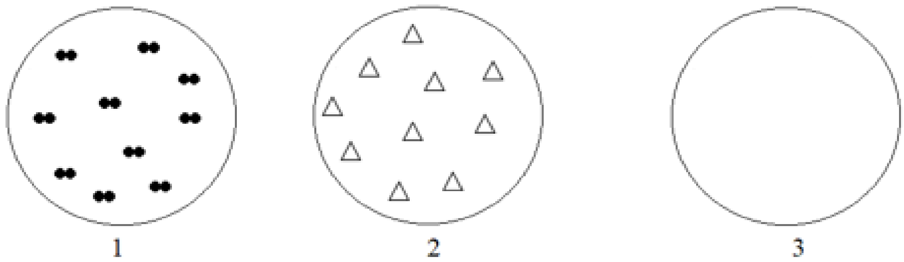
   ($H_2$: , $N_2$: , $NH_3$: , each particle represents 1 mole of substance.)



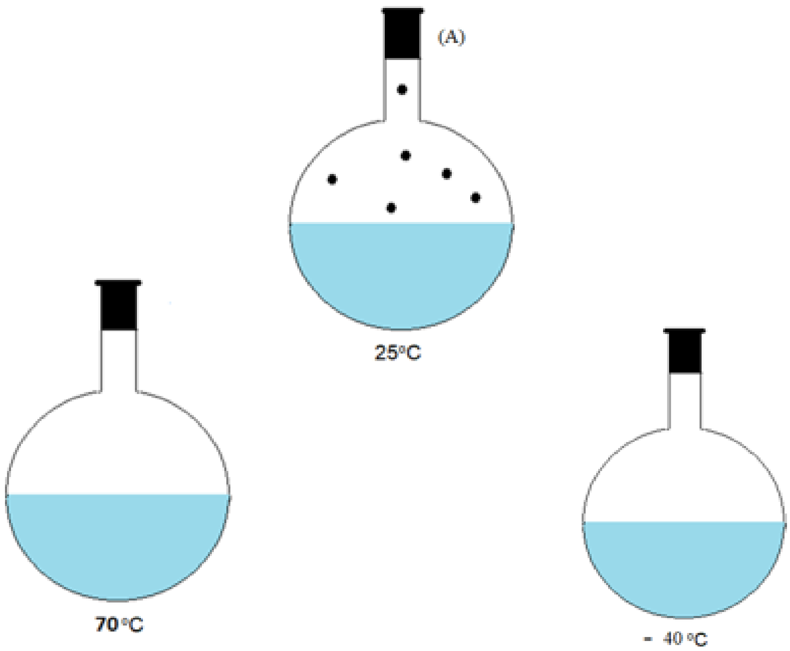

2. There are equal amounts of hydrogen ($H_2$) and chlorine ($Cl_2$) gases in the following A and B containers, having moveable pistons. These gases are reacted under suitable conditions in the C container.
   $H_{2(g)}+Cl_{2(g)} \rightarrow 2HCl_{(g)}$
   Demonstrate the product particles after the reaction in particle size. ($H_2$: , $Cl_2$: , Note that the container C has a moveable piston.)



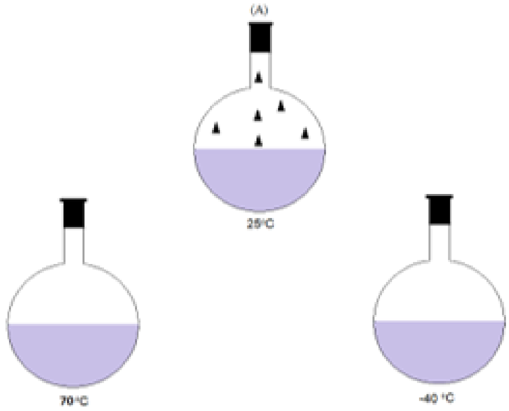
3. Containers 1 and 2 have nitrogen ($N_2$) and argon (Ar) gases in equal number of moles. It is known that these gases do not react with each other. If gases in containers 1 and 2 are placed in container 3, show the resulting gas mixture in particle size. ($N_2$: ●●, Ar:△ $N_2$: 28 g/mol, Ar: 39 g/mol)




4. In the following container A, the water-vapor balance of 25 °C is observed. If the same container is placed in an environment of 70 °C and then in an environment of - 40 °C, what is the distribution of water in the vapor phase after a certain period? Draw in particle size. (Freezing point of water = 0 °C, Boiling point = 100 °C)



**5.** In the following container A, the liquid-vapor balance of ethyl alcohol at 25 °C is observed. If the same container is placed in an environment of 70 °C and then in an environment of - 40 °C, how is the distribution of ethyl alcohol in the vapor phase. After a certain period? Draw in particle size. (Freezing point of Ethyl alcohol = -114,3 °C, Boiling point = 78,4 °C )




**6.** In the following container A, distribution of oxygen gas at 25 °C is observed. If the same container is placed in an environment of 70 °C and then in an environment of -40°C, how is the distribution of oxygen, after a certain period of time? Draw in particle size. (Boiling point of Oxygen = -183 °C)