Determining the Effect of Cooperative Learning and Models on the Conceptual Understanding of the Chemical Reactions[1]

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Abstract

The aim of this study was to determine the effects of cooperative learning and models on the conceptual understanding of the chemical reactions. The sample of study was comprised of 71 preservice science teachers from the first grade of science teacher education program. Quasi-experimental method with pre-and post-test of quantitative research was used. This study was carried out at General Chemistry Laboratory I course and was applied to two experimental and one control group. At the first experimental group (CMG, n=25), cooperative learning and models were implemented together, and cooperative learning was implemented on the second group (COG, n=23). On the other hand, there was no intervention on the control group (CG, n=23), in which traditional laboratory model was used. To collect data, Chemical Reactions Concept Test (CRCT) was utilized. It was found that cooperative learning with models increased the conceptual understanding about chemical reactions in this study.

Keywords: Cooperative learning; model; chemical reactions; particulate nature of matter.

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Introduction

Science is a difficult course for students since it is comprehensible and the phenomena, situations or concepts in abstract and micro level are involved in all of the branches of physics, chemistry and biology (Adadan, 2013; Mumba, Chabalengula & Banda, 2014). Chemistry which is one of the branches of science can be said to be more abstract than other fields because it focuses on atoms, molecules, and compounds. This situation can make it difficult for the students to understand chemistry (Kingir & Geban, 2014) and cause the students to have negative attitudes towards learning chemistry (Ercan, Ural & Ozates, 2015).

Micro, macro, and symbolic levels are correctly correlated in order to learn chemistry effectively (Jaber & Boujaoude, 2012; Johnstone, 1982). Micro level includes invisible relations of events, phenomena, situations, or concepts and is the most difficult level for students to learn (Jaber & Boujaoude, 2012; Talanquer, 2011). Macro level refers to visible and sensate phenomena and situations. The symbolic level implies that concepts or concept relations are represented by symbols and formulas (Jaber & Boujaoude, 2012; Philipp et al., 2014; Talanquer, 2011). Literature has indicated that students have misconceptions and misunderstanding resulting from the fact that they cannot correctly associate these three levels (Adadan, 2013, Talanquer, 2011). Research on the association of the three levels have been carried out with the aim of increasing the conceptual meaning of the students through dismissing misconceptions and misunderstandings (Adadan, 2013; Jaber & Boujaoude, 2012; Okumus, Cavdar, Alyar & Doymus, 2017a; Smith & Villarreal, 2015; Talanquer, 2011). In these studies, it has been revealed that the conceptual understandings increase through associating micro, macro, and symbolic levels effectively (Okumus et al., 2017a). In this vein, Jaber and Boujaoude (2012) applied a teaching by associating micro, macro, and symbolic levels to increase 10th grade students' conceptual understanding of chemical reactions in their research. The findings have reported that conceptual understanding of students increased and they started to establish more accurate relations among the concepts.

Chemical reactions, which is one of the basic subjects of the chemistry, are a comprehensive issue because they involve many reactions such as analysis, synthesis, combustion, acid-base, and redox reactions. In this regard, learning chemical reactions may allow students to understand other chemistry subjects better. Therefore, various investigations have been carried out on the understanding of chemical reactions (Ahtee & Varjola, 1998; Andersson, 1986; Barker & Millar, 1999; Boo, 1998; Chandrasegaran, Treagust, & Mocerino, 2009; Chang, Quintana, & Krajcik, 2014; Griffiths & Preston, 1992; Novick & Nussbaum, 1978; Okumus et al., 2017a; Yan & Talanquer, 2015). In these studies, it has been reported that students have many misconceptions about the subject (Jaber & Boujaoude, 2012). These misconceptions are based on changes of the subject in the micro level. Misconceptions take place at students who are unable to relate micro and macro levels effectively (Johnstone, 1982). It

has been determined such misconceptions on the subject as "*explaining chemical reaction as the effect of the active phase on the passive substance*" (Andersson, 1986), "*disappearance of the chemical reaction-causing substance*" (Barker & Millar, 1999; Okumus et al., 2017a), "*little or no mass of chemical reaction-causing gases*" (Griffiths & Preston, 1992; Okumus et al., 2017a), "*chemical reactions will always occur with external factors such as heating*" (Boo, 1998; Novick & Nussbaum, 1978), "*the tendency to describe physical changes like change of state as chemical changes*" (Ahtee & Varjola, 1998). In addition, research has revealed that not only secondary school and high school students but also preservice science and chemistry teachers, and science and chemistry teachers have various misconceptions about the chemical reactions (Chang et al., 2014; Yan & Talanquer, 2015). The fact that teachers have misconceptions reveals the importance of in-service training given to teachers because these teachers mislead students, as well. Another important issue is that preservice teachers have misconceptions. It is important to eliminate and reduce these misconceptions in their undergraduate education with the aim of preventing preservice teachers from misinforming their students when they start to practice their professions.

Much research has been conducted to eliminate misconceptions about chemical reactions (Chandrasegaran et al., 2009; Chang et al., 2014; Cheng & Gilbert, 2017; Chiu & Lin, 2014; Jaber & Boujaoude, 2012; Okumuş et al, 2017a; Ryoo, Bedell & Swearingen, 2018). In these studies, methods and techniques such as animation, computer assisted teaching and modeling which allow the visualization of the subject of chemical reactions are utilized. Therefore, micro, macro and symbolic levels are tried to be associated by students. In that regard, correlating micro, macro, and symbolic levels in their research using multiple presentations Chandrasegaran et al. (2009) enhanced the conceptual understanding of the formation of chemical reactions at ninth grade students. Chang et al. (2014) studied with seventh grade students, in there students learn about the subject of chemical reactions with a computer-aided chemistry teaching program (Chemation), and then they have learned through the interviews conducted with students to find out about their understanding of the subject. According to this, there is a relationship between drawings and conceptual understanding, and the use of drawings has been found to be effective in the understanding of subject. Chiu & Lin (2014) determined the effect of inquiry-oriented on-line curriculum to improve high school students' understanding of chemical reactions. This curriculum was taken advantage of dynamic molecular visualizations. They found that visualization-enhanced inquiry designed increased students' understandings. Cheng & Gilbert (2017) investigated the effect of model-based notion to understanding the sub-micro representations of chemical reactions of 10-11 grade students. They suggested two models of reactions: simple rearrangements of particles and interactions of chemical species with electrons and protons. They analyzed the students' visualizing the reaction between magnesium and hydrochloric acid. It was found that students progressed from the simple model to the more sophisticated model with visualizations.

Research reveals that students gain experiences from the first hand by participating in their learning process, leading their own learning, and establishing a relationship between prior knowledges and new information which have positive effects on providing effective chemistry learning (Ultay, Durukan & Ultay, 2015). However, it is stated that the misconceptions of the students cannot be dismissed completely and that they are resistant to change (Adadan, 2014, Ozmen, 2011). This situation is considered to cause from preliminary learning. In literature, various methods and techniques which supports constructivist approach and provides active learning such as problem-based learning, cooperative learning, computer-assisted learning, predicting-observing-explaining with the aim of providing effective chemistry teaching, dismissing misconceptions, and increasing students' academic achievements and conceptual understandings have been applied (Wang, Cheng, Chen, Mercer & Kirschner, 2017; Ultay et al., 2015).

Cooperative learning is one of the models which provides active learning and appropriate for the constructivist approach. In the cooperative learning process, students work together in heterogeneous groups. In this respect, cooperative learning is an effective way that can be applied together with other methods. Because, in most countries, the class sizes are above 20 students in primary, secondary and high school levels. Likewise, the number of preservice teachers studying in the same classes at university level is generally crowded. Cooperative learning can be more effective for students to work together to ensure active learning. Because, through cooperative learning, students participate actively in their learning process by working in collaboration with each other in a way to help each other to learn. Cooperative learning aims at allowing students to achieve their social and academic success with face-to-face interaction by studying cooperatively with heterogeneous groups, being responsible for their own and group's learning (Doymus, 2007; Karacop & Doymus, 2013; Okumus et al., 2017a). In this regard, cooperative learning aiming to increase both individual and group achievement can be effective to ease the understanding of chemistry course. It is stated in the literature that cooperative learning has a positive effect on the conceptual understanding of the chemistry course and enhances academic achievement (Belge Can & Boz, 2016; Doymus, 2007; Eymur & Geban, 2017; Karacop & Doymus, 2013; Warfa, 2016). In their research on determining the effects of cooperative jigsaw technique through animations on the understanding of the particulate nature of matter, Karacop and Doymus (2013) found that the implementation of cooperative learning method through animations improved the conceptual understandings of preservice science teachers (PSTs) on the target subject. The use of cooperative learning in understanding the concepts of chemistry is an effective way in the crowded classrooms. Because it is time consuming to follow an individual teaching path for each student and can be boring for successful students. However, in cooperative learning, it is ensured that the students who are successful in heterogeneous groups provide guidance to the less successful students, and also peer learning takes place. In this regard,

cooperative learning will be utilized in the conceptual understanding of chemical reactions in this research.

Chemistry concepts are abstract and difficult for students to understand correctly. In this regard, using such techniques that enable the concretization and visualization of abstract situations together with active learning methods will be effective. The first strategy when thinking about visualizations is the modelling. This includes models, simulations, three-dimensional models, pedagogical-analogical models, and it has a wide range. Okumus (2017) reports that models applied to enhance the effectiveness of learning through embodying abstract concepts can be defined as "*a simplified representation of a complex object or process*" (Harrison, 2001), "*a simplified representation of the system that draws attention to the typical characteristics of the system*" (Ingham & Gilbert, 1991), and "*mental constructs that individuals shape in their minds and question through mental components*" (Johnson-Laird, 1983). Models help embody and visualize abstract situations in mind (Gobert & Buckley, 2000; Okumus, 2017). Various studies have been carried out to determine the effects of models on the understanding of chemical concepts. These studies revealed that the models had a positive effect on the learning process since they provided students the opportunity to experience from the firsthand, allowed the students to visualize the events more accurately in their minds (Develaki, 2017; Okumus et al., 2017a; Wang, Chi, Hu & Chen, 2014). It also stated that the models provide solution to problems, allow to fill the information gaps in mind, facilitate constructing and transferring of information (Evagorou, Erduran & Mantyla, 2015).

Regarding the studies conducted through models, models are implemented in various parts of the lesson as an aid to a teaching approach, method, or technique (Kimberlin & Yezierski, 2016; Warfa, Roehrig, Schneider & Nyachwaya, 2014). In this vein, it is considered that the implementation of models, which help embody abstract situations, together with active learning methods encourages learners not only to be active in their learning process but to construct accurate relations between micro and macro levels, as well. Cooperative learning, which helps to provide active learning in crowded groups and which is appropriate to different learning levels, can be effective with the models. Various studies on applying cooperative learning from the active learning methods together with models exist in the literature (Cavdar & Doymus, 2016, 2018; Cavdar, Okumus, Alyar & Doymus, 2017a; Okumus et al., 2017a; Wang et al., 2017; Warfa et al., 2014). Accordingly, it has been reported that model studies conducted with cooperative learning offer students the opportunity to better associate macro-micro and symbolic dimensions. In this study, the effect of application of cooperative learning alone and with models on the conceptual understanding of the subject of chemical reactions will be examined. It is known that models alone are generally not sufficient in learning and are recommended to be applied together with active learning methods. Therefore, this study was conducted with two experimental groups as cooperative learning group and cooperative-model group.

In addition, the combined use of different methods and techniques helped students with different learning styles. For this reason, cooperative learning was chosen as an active learning method that supports models. Unlike other studies, this study attempts to determine the effects of cooperative learning together with models on conceptual understanding of gas discharge in chemical reactions in laboratory environment. In this way, the conceptual understanding of the PSTs before and after the implementation and the effectiveness of the research were determined. The research problem of the study is as follows:

- What is the effect of cooperative learning method and models on conceptual understanding of the subject of gas discharge in chemical reactions?

Sub-Problems:

o What is the understandings of the PSTs in regard to the subject of gas discharge in chemical reactions before the implementation?

o What is the understandings of the PSTs in regard to the subject of gas discharge in chemical reactions after the implementation?

Regarding the research problems and sub-problems, the study aims to determine the effects of cooperative learning and models on conceptual understanding of gas discharge in chemical reactions.

Methods

A quasi-experimental design with pre-test post-test, which is one of the quantitative designs, was utilized in this research. Quasi-experimental design is implemented in situations where all patterns of the experimental design cannot be applied (Buyukozturk, Kilic Cakmak, Akgun, Karadeniz & Demirel, 2012). The quasi-experimental design is preferred, especially because the educational studies deal with human factor and cannot be intervened with all variables. It cannot be intervened in research groups beforehand in quasi-experimental design, but it can be randomly determined which groups will be the control and which groups will be the experimental group (Cepni, 2009). In this study, regarding the fact that all patterns of experimental design cannot be applied, a quasi-experimental design was utilized.

Sample

71 freshman PSTs who were studying at the Department of Science Teacher Education Program of Ataturk University were participated in the study. The study was conducted with two experimental groups and a control group. Cooperative learning together with model was applied in the first experimental group, The Cooperative Model Group (CMG, n = 25, 6 male, 19 female). Cooperative learning method was applied in the second experimental group, Cooperative Group (COG, n=23, 2 male, 21 female). Traditional laboratory teaching method was implemented to control

group, the Control Group (CG, n=23, 7 male, 16 female). The research was carried out at General Chemistry Laboratory-I course. Student teams achievement divisions (STAD) of cooperative learning method was used. In the random sampling method, the probability of the selection of groups participating in the study as experimental and control groups is equal. Research groups were assigned randomly as experimental and control groups.

Data Collection Tool

Chemical Reactions Concept Test (CRCT) was implemented as the data collection tool in the research. The CRCT was implemented as a pre-test to determine levels of groups and to present alternative concepts that already exist before the implementation, and as a post-test to determine if there were any significant differences among the groups and whether alternative concepts persisted after the implementation.

The CRCT was developed to be understood the gas discharge during chemical reactions involving acid and base titrations and contains two open-ended drawing questions. In order to ensure the validity of the questions, three experts working at the department of science education were consulted. The necessary changes had been made in line with the opinions of the experts and the clarity of the questions had been increased. For the reliability of the questions, the consistency of experts' answers to the questions were examined and found as .92. The implementations conducted in the research groups and sampling are given in Table 1.

Table 1. The Sampling of the Research and the Implementations

Groups	CRCT	Implementations
CMG (n = 25)	Pre-test	Cooperative STAD + Model
COG (n = 23)	Pre-test	Cooperative STAD
CG (n = 23)	Pre-test	Traditional Laboratory Teaching Method
Total (N = 71)		

Implementation

The CRCT was implemented as a pre-test to all groups before the implementation. After each group was taught to chemical reactions through its own method, all groups did the experiment of acid-bas reaction with gas discharge. The application was implemented for two weeks. At the last stage, the CRCT was applied as a post-test to all groups. In both of the experimental groups, the STAD method from the cooperative learning methods was applied as a main teaching method. In the experiment done in this research, a chemical reaction takes place between an acid (CH_3COOH) and a base ($NaHCO_3$). In this experiment, it is aimed to understand whether the amount of the reactant in the experiment affects the amount of product formed. Accordingly, the PSTs were asked to compare the amount of CO_2 gas in the reaction between 10mL CH_3COOH and 5g $NaHCO_3$ and the amount of CO_2

gas in the reaction between 10mL CH_3COOH and 10g $NaHCO_3$. A plastic balloon is attached to the end of the reaction containers to monitor the amount of gas formed. The experiment of acid-bas reaction with gas discharge was given at Figure 1.

Experiment: Gas Discharge

Aim: Understanding the relationship between the amount of the reactant and the amount of the product, comprehend the particulate nature of matter based on the change in balloon

Equipment/ Chemicals:

- Plastic balloon (2 pieces)
- Volumetric flask (100mL, 2 pieces)
- Spatula
- Pipet
- Analytical balance
- CH_3COOH
- $NaHCO_3$

Experimental Procedure:

- 10mL of acetic acid is filled into a 100mL volumetric flask, 5g of sodium bicarbonate are added.
- A plastic balloon is attached to the head of the volumetric flask. Wait a while. Changes in the balloon are observed.
- 10mL of acetic acid is filled into another 100mL volumetric flask, 10 g of sodium bicarbonate is added.
- A plastic balloon is attached to the head of the volumetric flask. Wait a while. Changes in the balloon are observed.
- The changes in plastic balloons attached to volumetric flask are compared.

The reaction between acetic acid and sodium bicarbonate is as follows:

$$CH_3COOH_{aq} + NaHCO_{3(s)} \longrightarrow NaCH_3COO_{(aq)} + H_2O + CO_{2(g)}$$

Questions:

1. Does adding different amounts of sodium bicarbonate to acetic acid cause a change in the amount of gas generated? How?
2. What kind of change did you observe in the plastic balloons? What would be the reason?
3. How do you relate the change in plastic balloons to the amount of matter?
4. Show the gas in the plastic balloons in particular form (CO_2: ◐●◑)

Figure 1. *The Experiment which Used the Research*

Before beginning the course at which COG was applied, the PSTs were assigned to study groups as to be heterogeneous regarding the scores obtained from the CRCT as a pre-test. Then, the researcher briefly described the chemical reactions and type of chemical reactions to whole class and the PSTs studied the target subject with their study groups. The PSTs worked together on the same paper during the group work. Thus, in addition to individual responsibility, "positive commitment" and "face-to-face interaction" were tried to be provided. Later, each cooperative group conducted a "gas discharge" experiment. After the implementation, the CRCT was implemented as the post-test. In traditional laboratory approaches, students conduct their experiments and note the results. In cooperative learning applications, there are learning from group members, questioning and discussion among the group members. In this way, group spirit is tried to be gained. In this respect, COG differs

from the traditional laboratory approach. The researcher has played a guiding role in the cooperative learning process and assisted them in the parts which the PSTs did not understand. In Figure 2, an example is given from experimental studies of the PSTs (this experiment was done in all studying groups- COG, CMG and CG).

Figure 2. *An Example from Experimental Studies*

In CMG, cooperative learning was implemented as in COG. In addition, after the experiment was completed, the PSTs were asked to model the phenomena they observed in the experiment with the help of play dough and molecular model sets given to them. During the learning process, each group member was given the opportunity to work in the process of conducting experiment and creating a model, thus the principle of "individual responsibility" was tried to be fulfilled. Following the model study, the CRCT was applied as the post-test. The conceptual understanding of the PSTs has been tried to be increased as the model practices and abstract situations are materialized with concrete materials. In this sense, applications in CMG differ from traditional laboratory practices. Figure 3 presents some examples of models designed by the PSTs.

Figure 3. *Examples of Models Designed by the PSTs*

The traditional laboratory teaching method was implemented in CG. In line with the traditional laboratory teaching method, the PSTs formed groups following the list order. It was not paid attention to forming groups homogeneously or heterogeneously. The PSTs carried out their

experiments by reading experimental sheet given about the chemical reactions. In the control group, the PSTs do not have to work together as in cooperative learning. Accordingly, there is no principle of "positive commitment". At the end of the experiment, the CRCT was applied as a post-test.

Data Analysis

For the analysis of the data, whether the data obtained from the pre-test and post-test of the CRCT were parametric was determined. Shapiro-Wilk test was implemented for this purpose. Then descriptive statistics and one-way ANOVA were implemented for the analysis of the data. In addition, descriptive analyzes were carried out to pre and post-tests in order to determine the understandings the PSTs had. In this regard, the answers of the PSTs were classified as *'Correct Drawings'*, *'Incorrect Drawings'* and *'No Drawings'*, frequency and percentage values were calculated, and incorrect drawings were exemplified.

Findings

Findings were presented in two parts as findings obtained from the implementation of the CRCT as a pre-test and post-test and descriptive analysis of the CRCT.

Findings Obtained from the Implementation of the CRCT as a Pre-test and Post-test

The normality test was applied to determine the appropriate test to be utilized in analyzing the data obtained from the implementation of the CRCT as a pre-test. The Shapiro-Wilk normality test was applied considering the fact that the number of samples was less than 30 in all groups participating in the study. The results of the Shapiro-Wilk test in regard to the CRCT are given in Table 2.

Table 2. The results of the Shapiro-Wilk test in regard to the CRCT

Groups	Statistic	SD	p
CMG	.96	25	.38
COG	.65	23	.25
CG	.97	23	.59

Regarding Table 2, it was determined that data had normal distribution in all groups [CMG (p=.38; p>.05); COG (p=.25; p> .05) and CG (p=.59; p>.05)] in the implementation of the CRCT as pre-test. Therefore, one-way ANOVA from the parametric tests was applied to data obtained from the implementation of the CRCT as a pre-test regarding the fact that the number of groups were three. The descriptive statistics of the data obtained from the implementation of the CRCT as a pre-test is presented in Table 3, and the ANOVA results are presented in Table 4.

Table 3. The Descriptive Statistics of the Data from the CRCT as Pre-Test

Groups	N	X	SD
CMG	25	37.40	18.15
COG	23	42.83	19.88
CG	23	32.83	15.06
Total	71	37.68	18.02

Considering Table 3, it is seen that the group with the highest mean is COG (X=42.83) and the group with the lowest mean is CG (X=32.83).

Table 4. The ANOVA results of the CRCT as Pre-Test

Groups	Sum of squares	df	Mean of squares	F	p
Between groups	1152.94	2	576.47	1.82	.17
Within groups	21588.61	68	317.48		
Total	22741.55	70			

Regarding the ANOVA results presented in Table 4, there was no significant difference among the groups in regard to the CRCT as a pre-test (p=.17; p>.05).

The normality test was applied to determine the test to be used in analyzing the data obtained from the implementation of the CRCT as a post-test. The Shapiro-Wilk normality test was applied regarding the fact that the number of samples was less than 30 in all groups participating in the study. Shapiro-Wilk test results regarding the CRCT are given in Table 5.

Table 5. Shapiro-Wilk test Results Regarding CRCT as Post-Test

Groups	Statistic	SD	p
CMG	.923	25	.06
COG	.915	23	.05
CG	.916	23	.06

Regarding Table 5, it was determined that the data had normal distribution in all groups [CMG (p=.06; p>.05); COG (p=.05; p>.05) and CG (p=.06; p>.05)] in the implementation of the CRCT as post-test. Therefore, one-way ANOVA from the parametric tests was applied to the data obtained from the implementation of the CRCT as a post-test. The descriptive statistics of the data obtained from the implementation of the CRCT as a post-test are presented in Table 6, and the ANOVA results are presented in Table 7.

Table 6. The Descriptive Statistics of the Data from the CRCT as Post-Test

Groups	N	X	SD
CMG	25	71.20	20.38
COG	23	44.57	18.64
CG	23	36.96	22.45
Total	71	51.48	25.18

Considering Table 6, it is seen that the group with the highest mean is CMG (X=71.20) and the group with the lowest mean is CG (X=36.96).

Table 7. The ANOVA results of the CRCT as Post-Test

Groups	Sum of squares	df	Mean of squares	F	p
Between groups	15673.11	2	7836.56	18.57	.00
Within groups	41596.61	68	422.01		
Total	57269.72	70			

Table 7 presented the results of ANOVA indicates that there was a significant difference among the groups in regard to the post-test (p =.00, p<.05). The Scheffe test from multiple comparisons test was utilized in order to determine which groups favored this difference since the variances were homogeneously distributed. The results of Scheffe test are shown in Table 8.

Table 8. The Results of Scheffe Test Regarding the Data from the CRCT as Post-Test

(I) Groups	(J) Groups	Mean difference (I-J)	Standard error	p
CMG	COG	26.64*	5.94	.00
	CG	34.24*	5.94	.00
COG	CMG	-26.64*	5.94	.00
	CG	7.61	6.06	.46
CG	CMG	-34.24*	5.94	.00
	COG	-7.61	6.06	.46

*Shows significance difference.

Table 8 shows that there was a significant difference between CMG and COG in favor of CMG, and between CMG and CG in favor of CMG (p<.05).

Findings of Descriptive Analysis in regards to the CRCT

The data obtained from the implementation of the CRCT as a pre- and post-test were conceptually analyzed. In that regard, the drawings containing the answers given to the pre- and post-test by the PSTs in the experimental and control groups were classified into three groups as *'Correct Drawings'*, *'Incorrect Drawings'* and *'No Drawings'*, and frequency and percentage values were calculated, and those findings were presented at tables for comparison between the pre-test and post-test. The first question of the CRCT is presented in Figure 4.

CHEMICAL REACTIONS CONCEPT TEST

1. A 250mL glass flask is taken and filled with 50 mL of CH_3COOH. Then, 25g of $NaHCO_3$ is added to the glass flask. Glass flask is covered with a plastic balloon.
a. **Before starting the reaction,** show the substances present in the figure on the particle size.

● = CH_3COOH; △ = $NaHCO_3$; ▲ = CO_2; O = H_2O ■ = $NaCH_3COO$
Neglect the air in the glass flask and plastic balloon.
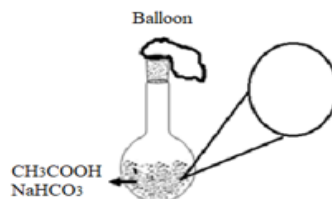
What causes the plastic balloon to swell after the reaction has started? The substances formed when the reaction is complete are given below.

$CH_3COOH_{(aq)} + NaHCO_{3(s)} \longrightarrow NaCH_3COO_{(aq)} + H_2O_{(l)} + CO_{2(g)}$

b. **After the reaction is completed,** draw the substances in the parts given with the question mark in the figures. *The reaction is carried out in 100% yield. Neglect the air in the glass flask and plastic balloon.*

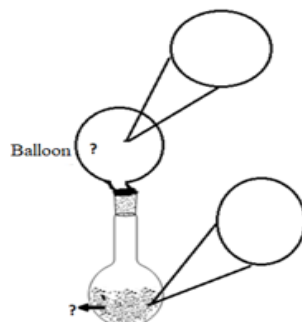● = CH_3COOH; △ = $NaHCO_3$; ▲ = CO_2; O = H_2O ■ = $NaCH_3COO$

Figure 4. *The First Question of the CRCT*

In the first question of the CRCT, a flask containing CH_3COOH and $NaHCO_3$ and attached with a plastic balloon at the head was given. Considering the symbols in part A of the problem, the PSTs were asked to represent the particles of the matter *before* the reaction starts. *The air in the plastic balloon and the volumetric flask has been ignored*. In this part, the PSTs were expected to leave CH_3COOH solution in the volumetric flask as liquid, draw $NaHCO_3$ as solid, and leave empty the plastic balloon. In part B of the question, after the reaction is completed, they were required to represent the matters which occurred after the reaction in the volumetric flask and plastic balloon in particulate level. *It has been stated that the reaction occurred at 100% efficiency*. In this part, CO_2 gas was expected to be drawn into the plastic balloon and $NaCH_3COO$ as liquid state and water (H_2O) were expected to be drawn into the volumetric flask. The second question of the CRCT is presented in Figure 5.

2. A 250mL glass flask is taken and filled with 50 mL of CH_3COOH. Then, 25 g of $NaHCO_3$ is added to the glass flask. Glass flask is covered with a plastic balloon and waiting for a while. A 250mL another glass flask is taken and filled with 50 mL of CH_3COOH. Then, 5 g of $NaHCO_3$ is added to the glass flask. Glass flask is covered with a plastic balloon and waiting for a while. Plastic balloons appear swollen. In the last case, show the amount of matter in both plastic balloons in particulate form. *Neglect the air in the glass flask and plastic balloon.*
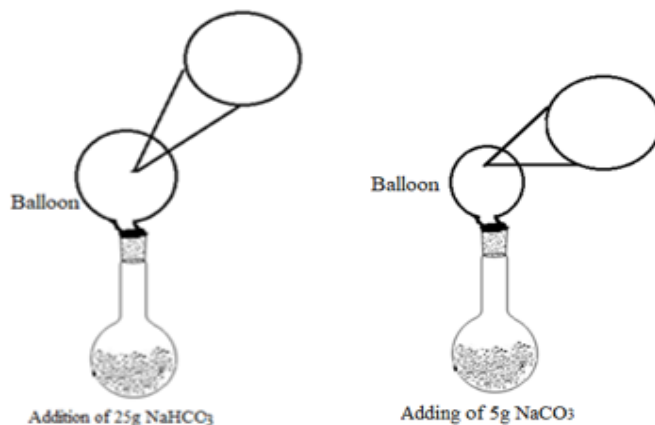
● = CH_3COOH;   △ = $NaHCO_3$;   ▲ = CO_2;   O = H_2O ■ = $NaCH_3COO$

$$CH_3COOH_{(aq)} + NaHCO_{3(s)} \longrightarrow NaCH_3COO_{(aq)} + H_2O_{(l)} + CO_{2(g)}$$

Balloon

Balloon

Addition of 25g $NaHCO_3$

Adding of 5g $NaCO_3$

Figure 5. *The Second Question of the CRCT*

In the second question of the CRCT, the amount of CO_2 which was formed as a result of the react CH_3COOH solution with 25g of $NaHCO_3$ and 5g of $NaHCO_3$ was required to be represented in particulate level. In that question, the PSTs were expected to know that the plastic balloon attached to the volumetric flask and containing 25g $NaHCO_3$ should be inflated more and accordingly draw more amount of the particles. Conceptual analysis of answers of the PSTs to the questions was presented. The frequency and percentage values of correct and incorrect drawings of the PSTs for the first question are presented in Table 9.

Table 9. Drawings of PSTs for the First Question

Answers		CMG (n=25)				COG (n=23)				CG (n=23)			
		Pre		Post		Pre		Post		Pre		Post	
		f	%	f	%	f	%	f	%	f	%	f	%
Correct drawing	Part A	3	12	13	52	-	-	4	17.4	1	4.3	1	4.3
	Part B	3	12	17	68	3	13	5	21.7	3	13	6	26.1
Incorrect drawing	Part A	22	88	12	48	23	100	19	82.6	21	91.3	21	91.3
	Part B	22	88	8	32	18	78.3	18	78.3	18	78.3	16	69.6
No drawing	Part A	-	-	-	-	-	-	-	-	1	4.3	1	4.3
	Part B	-	-	-	-	2	8.7	-	-	2	8.7	1	4.3

Table 9 represents that the rate of correct drawing is very low in all groups before the implementation. After the implementation, it was determined that the maximum increase in the correct drawing rate was in CMG whereas the rate of incorrect drawing was still high in the other groups.

Examples to incorrect drawings the PSTs did at the pre- and post-test to the part A of the first question are represented in Figure 6.
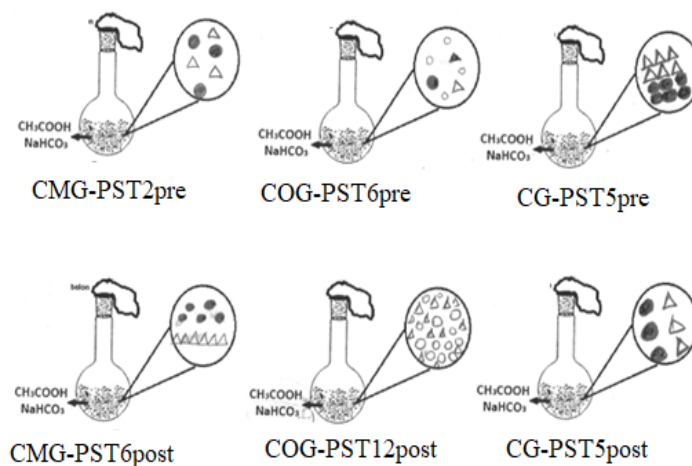

Figure 6. *Incorrect Drawings to the Part A of the First Question*

Figure 6 shows that CMG-PST$_2$ drawed the particles of CH$_3$COOH and NaHCO$_3$ in a highly porous form at pre-test. In the drawing of matters before the reaction, COG-PST$_6$ represented all matters in the flask including the matters formed after the reaction, as well. CG-PST$_5$ drawed particles at pre-and post-test in highly regular and ordered manner. At post-test, COG-PST$_{12}$ drawed the particles of water and NaHCO$_3$ as solution state at the first case. In that regard, it can be stated that some of the PSTs continued to do incorrect drawings at post-test.

Examples to the incorrect drawings the PSTs did at the pre- and post-test to the part B of the first question are presented in Figure 7.
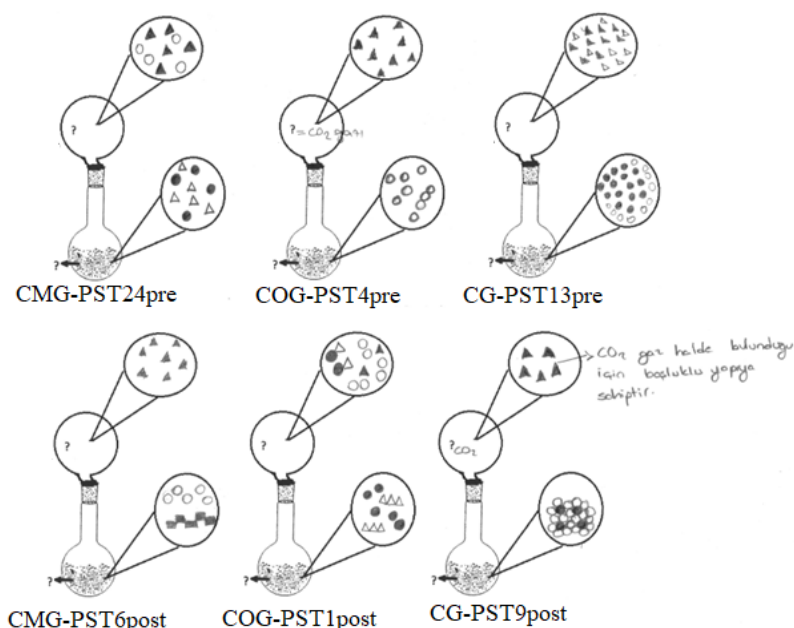
Figure 7. *Incorrect Drawings to the Part B of the First Question*

Figure 7 presents that CMG-PST$_{24}$ and CG-PST$_{13}$ represented other matters apart from CO_2 inside of the plastic balloon at pre-test as well as COG-PST$_1$ represented other matters apart from CO_2 inside of the plastic balloon at post-test. In the given examples, no PST drew $NaCH_3COO$ inside of the flask at post-test except the drawing of CMG-PST$_6$. COG-PST$_4$ represented only the particles of water inside of the flask at pre-test while CMG-PST$_{24}$ did not draw any particle of water at pre-test and COG-PST$_1$ did not draw any particle of water at PST$_{24}$ at post-test. Still, CMG-PST$_6$ and COG-PST$_1$ clearly distinguished the phases and make very regular drawings at the post-test. In Figure 7, it is observed incorrect drawings at post-test, and that students have difficulty in representing the matters formed in the reactions in the particles.

The frequency and percentage values of correct and incorrect drawings of the PSTs for the second question are presented in Table 10.

Table 10. Drawings of PSTs for the Second Question

Answers	CMG (n=25)				COG (n=23)				CG (n=23)			
	Pre		Post		Pre		Post		Pre		Post	
	f	%	f	%	f	%	f	%	f	%	f	%
Correct drawings	1	4	15	60	3	13	6	26.1	2	8.7	3	13
Incorrect drawings	24	96	10	40	18		17	73.9	19	82.6	19	82.6
No drawings	-	-	-	-	2	8.7	-		2	8.7	1	4.3

Regarding Table 10, parallel to the first question, it is seen that the rate of correct drawing is very low in all groups before the implementation. After the implementation, it is determined that the

maximum increase in the rate of correct drawing was in the CMG while the rate of incorrect drawing is still high in the other groups.

Examples to incorrect drawings the PSTs did at the pre- and post-test to the second question are presented in Figure 8.
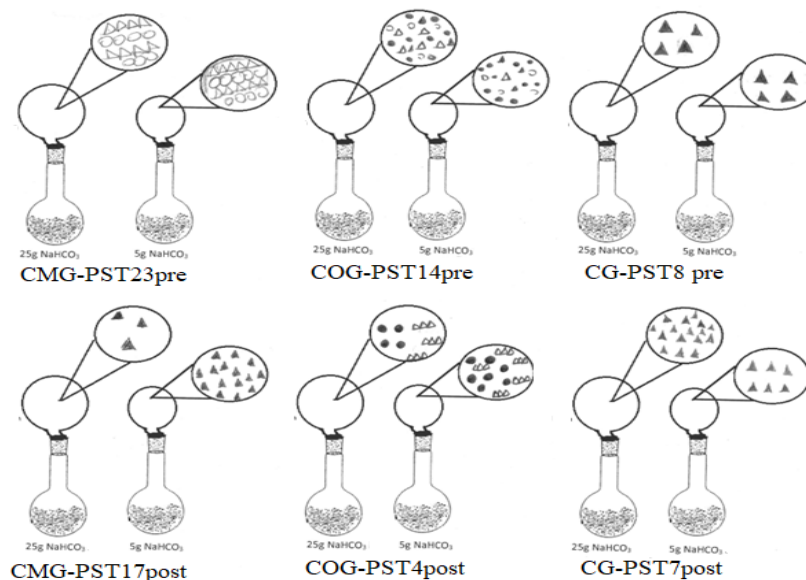

Figure 8. *Incorrect Drawing at the Second Question*

Figure 8 states that CMG-PST$_{23}$ and COG-PST$_{14}$ represented other matters apart from CO_2 inside of the plastic balloon at pre-test as well as COG-PST$_4$ represent other matters apart from CO_2 inside of the plastic balloon at post-test. It is observed that CG-PST$_8$ draw equal amount of particles inside of both plastic balloon at pre-test whereas CMG-PST$_{17}$ draw less number of particles inside of balloon at the first situation. CG-PST$_7$ is observed to represent particles at the second situation in a highly porous and ordered way.

Discussion and Conclusion

Based on the CRCT which was implemented as a pre-test to determine the preliminary knowledge of the PSTs, there was no significant difference among the groups in regard to pre-knowledge before the application ($p>.05$). Thus, it can be concluded that the preliminary learnings of the PSTs are similar before the implementation.

The findings of the CRCT as a post-test implemented to determine the effects of the applied methods on the conceptual understanding after the cooperative and model studies were carried out indicates that there was a significant difference between CMG and COG in favor of CMG and CMG and CG in favor of CMG ($p<.05$). There was no significant difference between COG and CG ($p>.05$). In that regard, it can be inferred that model assisted cooperative learning has a positive effect on understanding gas discharge in chemical reactions. Similar results have been obtained in studies which

investigate the effect of models on chemical reactions in the literature (Chandrasegaran et al., 2009; Jaber & Boujaoude, 2012). Okumus, Cavdar, Alyar, and Doymus (2017b) reported that they did not observed a significant difference in their studies, while it was determined in studies in which various model types of cooperative learning were applied to different chemistry subjects that cooperative learning applied with models generally increase the conceptual understandings (Cavdar & Doymus, 2018; Cavdar et al., 2017a; Okumus et al., 2017a; Warfa et al., 2014). Concepts can be correctly structured in the mind by allowing models to offer first-hand experience of learning, enabling them to embody abstract concepts, and designing by seeing and touching (Adadan, 2014; Wang et al., 2014). This ensures more meaningful and correct understandings. In this respect, it can be stated that the visualizations through models have a positive effect on the PSTs' understanding gas discharge in chemical reactions in this study. Several studies (e.g. Adadan, 2014; Prins, Bulte & Pilot, 2016; Ryoo et al., 2018) have stated that models make the conceptual understandings easier.

However, applying only cooperative learning method alone did not make a meaningful difference in this respect. Unlike the result of this research, it is expressed in the literature that cooperative learning affects conceptual meaning positively on its own (Belge Can & Boz, 2016; Doymus, 2007; Eymur & Geban, 2017; Karacop & Doymus, 2013). The nature of cooperative learning makes it possible for a group to have a "group spirit" in the group where the individuals in the group are both responsible for their own learning as well as for the learning of their group members. Through this "group spirit" together with mutual cooperation, more meaningful learning takes place in a more social environment.

It has been determined that the rate of incorrect drawing is quite high in all groups before the implementation, and that these errors reduced after the implementation. It has been also determined that the most advancement was in CMG. However, based on the post-test data, incorrect drawings continued in all groups. Preliminary learning of PSTs can be the effective factor in this situation since correcting the wrong knowledge was already built in the mind is more difficult than making sense of new knowledge in the mind. This is an indication that the misconstructed concepts in mind are resistant to change. In this vein, many studies have been reported that it is difficult to promote students to change the pre-existing understanding of a subject (Cavdar et al., 2017; Okumus et al., 2017a; Tsai, 1999). The fact that misconstructed concepts in mind are resistant to change can be attributed to the fact that they do not embody abstract concepts in their minds precisely because of the preliminary learning of PSTs, the language they speak in everyday life, and the inability to correctly associate micro, macro, and symbolic levels (Kingir & Geban, 2014; Okumuş & Doymus, 2017; Ozmen, 2011). More meaningful learning can be taken place through using different model types as well as addressing different sense organs like seeing, hearing and feeling.

The most important alternative concepts that can be observed in the drawings of the PSTs related to chemical reactions are as follows: *not drawing the solid, liquid and gas particles correctly in the particle structure, drawing the particles of the liquid and gas matters as particles of the solid matters, not knowing the substances forming as a result of reaction even though the reaction equation is provided, not taking into account water molecules in aqueous solution, reactive matters of input at products.* The alternative concepts in this research overlap with the results of the studies in the literature. Accordingly, many relevant studies have been stated that students and PSTs are forced to think solid, liquid and gas materials as particles (Adadan, 2013; Aydeniz & Kotowski, 2012). In the study of Kimberlin and Yezierski (2016), it was also reported that students have difficulty in understanding the reaction stoichiometry in parallel with the above-identified conceptual error. The alternative concepts of the PSTs about chemical reactions can be continued at the end of the implementation since the application period is not long or different model types are not used together. Thus, the PSTs may not have been motivated to study for two weeks, or modeling studies conducted with molecular models and play-dough may not have made sense for some of the PSTs. In this respect, in the light of the results obtained from the research, it is considered that the applying different models for a longer period of time in order to enhance visually, such as simulation, animation, analogical models which embody abstract situations will be effective in order to provide a conceptual understanding of the chemistry course containing quite abstract concepts.

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