Educational Policy Analysis and Strategic Research, V 15, N 3, 2020

The Effect of Cooperative Learning Methods and Individual Learning Method on Pre-Service Science Teachers' Sub-Micro Level Conceptual Understanding at Equilibrium Chemistry

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Abstract

The purpose of the study is to investigate the effect of cooperative and individual learning methods on the conceptual understanding at sub-micro level of pre-service science teachers (PST) in equilibrium chemistry. The study was conducted on 52 PSTs. A pre-test/posttest non-equivalent quasi-experimental design was used in this study. Data collection instruments used as pre- and posttest as a Module Test (MT) consisted of seven open-ended questions developed by the researchers. Although, participants were identified with a convenience sampling method, each group were randomly assigned. For this reason, three study groups were selected, and each implementation was randomly assigned. Groups was determined as Cooperative Student Teams-Achievement Divisions (STAD, E1) and Reading-Writing-Application (RWA, E2) methods, and Individual Learning (IL, E3) method. The data gathered with the MT were evaluated using content analysis. According to findings, there was not a significance difference among groups related to conceptual understandings at equilibrium chemistry. However, some misconceptions related to topic were decreased. Consequently, when three learning methods are used that it is more likely to misconceptions of the PSTs will be treated, while at the same time micro level understanding will improve.

Keywords: Cooperative learning, STAD, RWA, individual learning, equilibrium chemistry, conceptual understanding

DOI: 10.29329/epasr.2020.270.19

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Introduction

The study of the behavior of chemical equilibrium has been an essential part of the secondary and undergraduate education chemistry curriculum for many years (Cheung, Ma, & Yang, 2009; van Driel & Graber, 2002). The subject of chemical equilibrium is considered as one of the issues that the students have difficulty in learning due to its complex structure as it includes various abstract concepts (Aydeniz & Doğan, 2016; Banerjee, 1995; Ceylan & Seçken, 2019; Özmen & Naseriazar, 2018). The concept of chemical equilibrium involves the synthesis of most general chemistry concepts and principles (Bilgin, Uzuntiryaki & Geban, 2003). The concept of chemical equilibrium is a basis for students to understand other chemical subjects such as acids and base behaviors, oxidation / reduction reactions and solubility (Bergquist & Heikkinen, 1990; Bilgin & Geban, 2006; Eilks, Gulacar, & Sandoval, 2018; Piquette & Heikkinen, 2005).

Some studies have shown that there are some difficulties about the problematic aspects of understanding the concepts of chemical equilibrium. There are misconceptions regarding the chemical equilibrium at the following points: (a) mass vs. concentration (b) characteristics of chemical equilibrium, (c) changing equilibrium conditions, (d) rate vs. extent, and (e) misconceptions about K. The misconceptions identified by previous research summarized according to these themes in Table 1.

Table 1. Some Common Misconceptions about Chemical Equilibrium

Theme	Misconceptions	Studies
Mass vs. concentration	The concentrations of reactants and products are equal at equilibrium.	Atasoy, Akkuş & Kadayıfçı, 2009; Bilgin & Geban, 2006; Erdemir Özdemir, Geban & Uzuntiryaki, 2000; Hackling & Garnett, 1985; Karpudewan, Treagust, Mocerino, Won & Chandrasegaran, 2015; Okumuş, Çavdar, Alyar & Doymuş, 2017
	Confusion regarding amount and concentration.	Bilgin & Geban, 2006; Bergquist & Heikkinen, 1990; Doymuş, 2008; Mensah & Morabe, 2018
	Inability to appreciate that certain substances display fixed or constant concentration in certain chemical reaction.	Wheeler & Kass, 1978
	The bigger the mole number of the products, the bigger the equilibrium constant.	Atasoy et. al., 2009
Characteristics of chemical equilibrium	Each side of the chemical equation is independent.	Wheeldon, Atkinson, Dawes & Levinson, 2012
	If a substance is added to products which are on stable a temperature, reaction will favor the products.	Mutlu & Acar Şeşen, 2016
	Not to understand the Le Chatelier's Principle (LCP) in equilibrium systems.	Cheung et.al., 2009; Hackling & Garnett, 1985; Mutlu & Acar Şeşen, 2016; Voska & Heikkinen, 2000
	Fewer particles (per unit of volume) would lead to fewer collisions (per unit of time)	Van Driel & Graber, 2002
	Confusing the balance concepts in physics and chemical equilibrium	Bergquist & Heikkinen, 1990
	Inability to understand the dynamic structure of equilibrium	Bilgin & Geban, 2006

	No reaction takes place while the system is in equilibrium.	Doymuş, 2008
Changing equilibrium conditions	When catalyst is added to a system in equilibrium, the concentration of reactants and products increases.	Bilgin & Geban, 2006; Voska & Heikkinen 2000
	Forward and reverse reaction rate does not change or increase depending on whether the catalyst is suitable for forward or reverse reaction.	Bilgin & Geban, 2006
	In a system, the equilibrium constant does not change with temperature or any effect.	Mutlu & Acar Şeşen, 2016
	If the temperature of a system in chemical equilibrium increases, the reaction moves forward.	Atasoy et. al., 2009; Bilgin & Geban, 2006; Mutlu & Acar Şeşen, 2016
Rate vs. extent	The rate of forward reaction increases with time until equilibrium is established and forward and reverse reaction rates are not equal at an equilibrium system.	Demircioğlu, Demircioğlu & Yadigaroğlu, 2013
	Failure to distinguish between rate and extent of reaction.	Atasoy et. al., 2009; Banerjee & Power, 1991; Gussarksy & Gorodetsky, 1990; Hackling & Garnett, 1985; Wheeler & Kass, 1978
	When a catalyst is added for both the forward and reverse reactions by the same amount.	Karpudewan et. al., 2015
	When a reaction approaches to equilibrium forward reaction rate increases.	Erdemir Özdemir et. al., 2000; Hackling & Garnett, 1985; Niaz, 1998
	Not to distinguish the difference between rate and equilibrium.	Koretsky, 2020
Misconceptions about K	The value of K does not depend on temperature.	Bilgin & Geban, 2006; Voska & Heikkinen, 2000
	The value of K always decreases as temperature decreases.	Voska & Heikkinen, 2000
	When more products are added to an equilibrium system at constant temperature, K_c will increase.	Voska & Heikkinen, 2000
	Confusion regarding the meaning of K.	Bergquist & Heikkinen, 1990; Bilgin, 2006; Doymuş, 2008; Karpudewan et. al., 2015; Okumuş et. al., 2017

Van Driel and Graber (2012) explained the difficulty of understanding this subject by students because of the chemical reactions is usually presented with observable events in introductory chemistry courses, on the other hand chemical equilibrium at a later stage presents reversibility of chemical reactions and the possibility of chemical reactions to continue to be completed. Furthermore, though this cannot be deduced from observation, the dynamic nature of chemical equilibrium requires students to assume that two opposite chemical reactions take place. Nakhleh (1992) stated that students were not able to develop more advanced concepts based on the foundations because they could not understand the basic concepts of chemistry. Additionally, Huddle and Pillay (1996) denote that the most important reasons for this difficulty are that the subjects are abstract and contain words from the daily language that have different meanings. In this regard, many studies and projects have been carried out to enable students to understand scientific concepts (Ültay, Durukan, & Ültay, 2015). Özmen and Naseriazar (2018) investigated the effect of computer simulations enhanced with conceptual change texts (CS-CCT) on first year university students' understanding of chemical equilibrium. They found that this method has been effective on students conceptual understanding of the topic.

Cooperative Learning

Today, human beings have started to live in societies based on knowledge rather than power. Creating the information is usually done through cooperative studies in the social environment. In this case, the question of "How can the most effective learning design be realized in the process of creating knowledge needs to be answered (Hong, Chai & Tsai, 2015). Learning outcomes covering knowledge, attitudes and abilities are dependent on effective learning. The effectiveness of the teaching and learning process can be facilitated by appropriate strategies or models adopted in a learning environment (Adesoji, Omilani & Nyinebi, 2015). Cooperative learning was created to increase cognitive, social and emotional learning outcomes. Cooperative learning has gained popularity among student-centered teaching methods in recent years (Herrmann, 2013; Tran, 2014). Since science includes understanding the essence of the universe and learning the information that will shape the world, it is very important in the process of creating information. In this context, cooperative learning practices should be adequately involved in science education. Student-centered cooperative learning is recommended as an alternative to reduce the difficulties that students face while learning science (Adesoji et. al., 2015). Studies on cooperative learning have shown that when students work together, they learn more than they work alone (Johnson & Johnson, 2014; Slavin, 2014). Cooperative learning, which takes place through the interaction of an individual's environment and peers, is based on the idea that students learn through social contexts (Tsay & Brady, 2010).

Chemistry education, which is one of the most abstract areas of science education, is an area that is difficult to understand by students. In this context, it is thought that the use of cooperative learning in chemistry education will have a positive effect on conceptual meanings. There have some studies investigating the impact of cooperative learning on the teaching of various chemistry subjects. Joel, Kamji and Godiya (2016) found that cooperative learning strategy enhanced pre-degree chemistry students' conceptual understanding of the rate of chemical reactions than the IL. Some studies have explored how cooperative learning could facilitate students' learning of chemical equilibrium.

There are different cooperative learning methods and techniques applied in various educational areas and different subject areas in many parts of the world. At the same time, the pursuit of both increasing the impact of these existing methods and developing more effective classroom applications continues (Sharan, 2015; Slavin, 2015). Student Teams-Achievement Divisions (STAD) method was developed by Slavin (1994) in which students work together in heterogeneous groups of 4-5 people selected from students at high-low and average -grade levels. In the implementation of this method, there are five important factors: presentation, teams, exams, individual progress points and team award. The reason for the selection of STAD is to improve positive attitude towards subject, increase interpersonal skills good interaction among students. STAD also add an extra source of learning with in the groups because some high achievers act as a role of tutor (Khan & Inamullah 2011). The detailed information about the implementation of the method is given in the method section. STAD has been used in such a wide variety of subjects (Karaçöp, 2016). Many studies have shown that the STAD method of cooperative learning has positive effects on academic achievements of high school students (Nurhayati &Hartono, 2016) and PSTs. Karaçöp (2016) compared the three different learning method in teaching of the electrochemical cells. The researcher found that the STAD method along with the models is more effective in increasing student achievements when compared STAD method alone and the traditional teaching method.

One of the other techniques used in the implementation of the cooperative learning model is the Reading-Writing- Application (RWA). The application of this method is carried out in three stages: reading, writing and presentation /application. In the process of application of the method, the class is divided into groups of 4-5 students and then the group head and the name of the group are determined. In the reading stage, the groups read the topic given to them by group. The main aim here is to increase the time spent by students to think about the subject by reading texts presented to students. At the writing stage, the resources related to the subject are eliminated and the students write about what they understand about the subject. The instructor of the course examines the student reports and if there is a missing group, it will redirect the group to the reading stage; otherwise, the presentation will be started. In the presentation/application phase, the students present the subject in the class or apply the subject. The lecturer completes the missing parts during the group presentations (Okumuş & Doymuş, 2018). In some studies, the effect of RWA method on academic achievement was investigated and found to be more effective than the IL in various subjects such as 6th grade material and temperature (Gürbüz, Aksoy & Töman, 2013), undergraduate level force and motion (Okur Akçay & Doymuş, 2014).

Individual Learning

The individualization of teaching has been one of the most debated subjects in education. The discussion that students should progress according to their own levels and individual speeds led to the development of many programmed instructional models in which students work individually (Slavin, Leavey & Madden, 1984). When students reach their goal in a cooperative learning environment, all students reach their goals and in an individualistic environment, the achievement goal is independent. The achievement of a student's target is not related to the success of other students (Johnson, Johnson, & Scott, 1978). Bangert, Kulik and Kulik (1983) stated that individualized systems in secondary education give the same results as traditional teaching, and that students' achievements and critical thinking and self-confidence in the typical individualized classroom are similar to those in traditional classroom. Today, the focus of individualization has shifted towards the personalization, emphasizing the social dimension of learning. The aim of personalized instruction is to provide a holistic learning environment with frequent and close personal relationships between students and teachers, with emphasis on collaborative groups and authentic assessment (Molenda, 2012).

Research Hypothesis

In this study, the hypothesis that cooperative learning methods can be more effective than individual learning in terms of conceptual understanding of chemical equilibrium is advocated. Some studies in the literature support this hypothesis. For example, Johnson et al. (1978) stated that cooperative learning resulted in more positive attitudes and higher achievement compared to individualized learning in their study. Tran, Nguyen, Van De, Soryaly & Doan (2019) found that students who were instructed using lecture-based teaching had lower scores on the posttest of resource management and cognitive - metacognitive strategies than did the students who were instructed using cooperative learning. However, there are some studies showing that there is no significant difference between individual learning and cooperative learning. For example, Chang and Mao (1999) found no significant differences between participants who used cooperative and individual learning strategies on comprehension-level scores on the earth science achievement in secondary schools. More recently, Özdilek, Okumuş and Doymuş (2018) found that there was no significant effect of applied methods (RWA and STAD of cooperative learning and IL) with respect to the achievement level of PSTs' conceptual understanding level at the particulate nature of matter in solution chemistry.

Purpose of the Study

The aim of this study is to determine the effect of Student Teams-Achievement Divisions (STAD) and Reading-Writing- Application (RWA) of cooperative learning and individual learning (IL) methods on the PSTs' conceptual understanding of chemical equilibrium at sub-micro level. Research questions are given as follows:

(1) Is there a significant difference among the research groups in terms of conceptual understanding in the pre and post application of the MT?

(2) Does the STAD, RWA, and IL methods affect PSTs' conceptual understanding of chemical equilibrium after the implementation?

Method

Research Design

A mix method sequential explanatory research design that consists of two distinct stage was used in the study. In this design, researchers first collect and analyze quantitative data. Qualitative (text) data is collected and analyzed in the sequence and helps explain or elaborate the quantitative results obtained in the first stage (Creswell, Clark & Garrett, 2003). This study, therefore, combines both quantitative and qualitative approaches in two phases. Firstly, a 7-item Module Test (MT) were carried out on the PSTs in order to determine the level of conceptual understanding. Data were analyzed using descriptive statistics namely Kruskall Wallis and Wilcoxon Signed Ranks Tests. In the second phase, content analysis was performed in order to determine the comprehensive level and misconceptions of the PSTs.

Sample

This study was carried out with the 52 PSTs (42 females, 10 males) of a state university located in the east of Turkey. The PSTs were in the second semester of their science teacher education program enrolled in General Chemistry II and General Chemistry Laboratory II courses at the time in a laboratory application setting. In addition, the PSTs took the General Chemistry I and General Chemistry Laboratory I courses at the previous semester. Although all participants had taken chemistry courses in high school (i.e. grades 9-12) for four years before entering the Science Teacher Education Program, they first met with the subject of chemical equilibrium in the 11th grade. Convenience sampling method was used as the study was carried out in the university where the researchers took part. Three groups were randomly assigned to the Students Teams Achievement Divisions method of cooperative learning (STAD) [E1, (n=19, 16 females, 3 males], Reading Writing Application method of cooperative learning (RWA) [E2, (n=15, 12 females, 3 males)], and Individual Learning (IL) [E3, (n=18, 14 females, 4 males)]. All of the participants were voluntarily participated in the study.

Data Collection Tool

The Module Test (MT) was developed by the researchers in order to determine the conceptual understanding levels of the PSTs on the chemical equilibrium. When the MT was first created, it contained 10 open-ended questions. In these questions, the PSTs were asked to draw several chemical equilibrium issues in particle size. Two experts of chemistry education were independently examined the test for validity. For reliability, the MT was applied to three PSTs. According to this, three low-comprehension questions were excluded from the test. The MT contains seven open-ended questions in the last case. The PST's responses were evaluated with 10 points for correct drawings and 0 for false drawings. The maximum score for the questions was 70. The average of each question was calculated by dividing the total correct answer score by the number of PSTs. In addition, two different scorers have read the PSTs' MT papers and the consistency between the scorers is examined as 90%. For this, Miles and Huberman’s (1994) formulas [Reliability=agreement/ (agreement + disagreement) x 100] was used. The MT were applied to all experimental groups as pre-and posttest.

Implementation

Prior to the study, the MT was applied as pre-test to the all groups. Three of the groups were randomly assigned to the STAD (E1), RWA (E2), and IL (E3) groups. All of the groups studied two weeks on the subject. The MT was re-applied to the groups after the implementation as posttest. The same researcher taught the lessons to the STAD, RWA, and IL groups. The same course content was used in all of the groups.

Implementation of students team achievement divisions (STAD) method

The group in which the implementation was performed according to the STAD method was called as E1. As there were 19 PSTs in the practice group five sub-groups were formed, (one group has three people and four groups have four people). The PSTs were informed that the subject of chemical equilibrium would be processed according to STAD method. At the stage of presentation of STAD technique, work sheets containing explanations, drawings and questions of events occurring in the chemical equilibrium were distributed to each group and the subjects and concepts related to chemical equilibrium were expressed by forming a discussion environment in the classroom by the researcher. In the second stage, the study groups worked on the work sheets given, discussed within the groups and fulfilled the tasks given. In the last stage of the application, groups made an experiment and modelling activity related to equilibrium chemistry.

Implementation of reading-writing-application (RWA) technique

RWA of cooperative learning technique was implemented for two weeks in the second study group called as E2. According to the cooperative learning where the number of members to be assigned to the groups by class size is determined, the working groups can be 2-6 members (Okumuş & Doymuş, 2018). The PSTs (n=15) were randomly divided into five sub-groups, each with three PSTs. In the first phase of the RWA technique consisting of reading, the PSTs read the explanations about chemical equilibrium using textbook and other written sources for 40 minutes in the classroom setting. In the second stage of the application, the sources were removed and the groups wrote their understanding about what they read. Then the researcher evaluated the tasks and groups with unsatisfactory results were returned to repeat the reading phase. In the third stage, the groups made an experiment and modelling activity related to equilibrium chemistry.

Implementation of individual learning (IL) method

The subjects and concepts related to chemical equilibrium was learning through individual activities in the third study group called as E3 (n=18). Prior to each lesson, the PSTs studied the subject as individually. During the process, the researcher helped the whole of the classroom environment and the learning process. The PSTs asked questions to the researcher related to subjects and concepts, which they did not understand, or they were curious in the learning process and researcher informed the PSTs by answering questions, sometimes repeatedly, also sometimes using different viewpoints. At the end of the lesson, the PSTs made an experiment and modelling activity related to equilibrium chemistry as individually.

Data Analysis

For the analysis of the data, firstly, it was examined whether the scores of each experimental group in the pre and posttest were suitable for normal distribution. Since the number of the PSTs in each experimental group was less than 30, the data were checked for normality with the Shapiro-Wilk normality test. Accordingly, it was determined in the pre-test that E2 data were suitable for normal distribution ($E2_{pre}$, $p=.088$; $p> .05$), other data (pre-and post) did not show normal distribution ($E1_{pre}$ and $E1_{post}$, $p=.003$; $E3_{pre}$, $p=.001$; $E2_{post}$, $p=.032$; $E3_{post}$, $p=.015$; $p <.05$). In addition, it was determined that the skewness-kurtosis values of the data are not suitable for normal distribution. In addition, the suitability of the pre- and posttest data of the MT for normal distribution on a question basis was examined. Accordingly, it is seen that all the data obtained from the pre- and posttest of MT of all groups are not suitable for normal distribution ($p=.00$; $p <.05$). For this reason, (Can, 2017), Kruskall-Wallis Test, one of the nonparametric tests, was applied to the pre and posttest data for significance analysis. In addition, to compare pre- MT scores with post-MT scores of each groups Wilcoxon Signed Ranks Test Analysis was employed. Then, content analysis was made for each question. In the content analysis of PSTs' drawings, conceptual understanding levels, difficulties and misconceptions were tried to be determined. PST_1, PST_2, PST_3 etc. represent PST codes given under the figures.

Results

Findings Relating to the First Research Question

In the pre-and posttest of the MT, Kruskall Wallis, one of the nonparametric tests, was used to evaluate whether there was a significant difference among the groups for the data to be suitable for normal distribution. The results of Kruskall Wallis test are given in Table 2.

Table 2. Kruskall Wallis Results of Pre-and Post-MT

MT	Groups	n	Mean Rank	df	X^2	p
Pre-MT	E1	19	24.37	2	.932	.627
	E2	15	29.33			
	E3	18	26.39			
Post-MT	E1	19	27.45	2	.907	.636
	E2	15	28.47			
	E3	18	23.86			

According to Table 2, no statistically significant difference was determined among the groups in the pre- and posttest ($p> .05$). It can be said that all three methods affect PSTs' conceptual understanding of chemical equilibrium in a similar way. Accordingly, it has been observed that the application of individual learning with cooperative methods does not show very different results in terms of conceptual understanding. Table 3 presents the descriptive statistics and Kruskall Wallis Test results of the data obtained from the implementation of the pre-MT on the question basis.

Table 3. Descriptive Statistics and Kruskal Wallis Test Results of Pre-MT on the Question Basis

Question	Group	n	Mean Rank	SD	df	χ^2	p
Q1	E1	19	3.68	4.956	2	1.236	.539
	E2	15	4.67	5.164			
	E3	18	2.78	4.609			
Q2	E1	19	1.05	3.153	2	5.876	.053
	E2	15	4.67	5.164			
	E3	18	3.89	5.016			
Q3	E1	19	2.11	4.189	2	1.004	.605
	E2	15	1.33	3.519			
	E3	18	2.78	4.609			
Q4	E1	19	6.84	4.776	2	1.106	.575
	E2	15	7.33	4.577			
	E3	18	8.33	3.835			
Q5	E1	19	2.11	4.189	2	.481	.786
	E2	15	2.67	4.577			
	E3	18	1.67	3.835			
Q6	E1	19	1.58	3.746	2	.110	.947
	E2	15	2.00	4.140			
	E3	18	1.67	3.835			
Q7	E1	19	4.74	5.130	2	4.058	.131
	E2	15	7.33	4.577			
	E3	18	3.89	5.016			

As can be seen in Table 3, Kruskall Wallis test analysis did not show a meaningful difference among the PSTs' conceptual level on the chemical equilibrium at the beginning of the study when study groups were compared according to their mean scores on all of the questions. However, mean scores of E1 in Q2 and Q6, E2 in Q3 and E3 in Q1 and Q5 are lower than the other groups. This result is clearly seen in the graph in Figure 1.

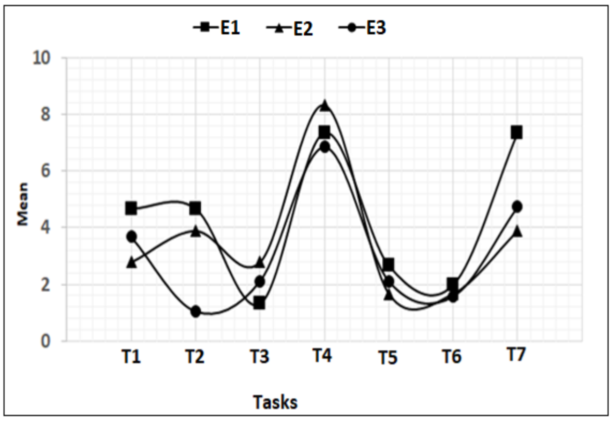


Figure 1. Means of Pre-Test Scores of Research Groups in terms of Questions

Table 4 shows that the descriptive statistics and Kruskall Wallis test results of the data revealed from the posttest of MT.

Table 4. Descriptive Statistics and Kruskall Wallis Test Results of Post- MT on the Question Basis

Question	Group	n	Mean Rank	SD	df	χ^2	p
Q1	E1	19	5.26	5.130	2	1.612	.447
	E2	15	6.67	4.880			
	E3	18	4.44	5.113			
Q2	E1	19	7.89	4.189	2	.471	.790
	E2	15	8.67	3.519			
	E3	18	7.78	4.278			
Q3	E1	19	6.32	4.956	2	4.264	.119
	E2	15	3.33	4.880			
	E3	18	3.33	4.851			
Q4	E1	19	6.84	4.776	2	5.923	.052
	E2	15	9.33	2.582			
	E3	18	9,44	2.357			
Q5	E1	19	5.79	5.073	2	2.923	.232
	E2	15	3.33	4.880			
	E3	18	3.33	4.851			
Q6	E1	19	3.16	4.776	2	.125	.939
	E2	15	3.33	4.880			
	E3	18	2.78	4.609			
Q7	E1	19	8.42	3.746	2	7.330	.026
	E2	15	9.33	2.582			
	E3	18	5.56	5.113			

Kruskal Wallis test results shows that while there was a significant difference in the Q7 (χ^2 =7.330, p <.05) in favor of E1 and E2 and there was no statistically significant difference among posttest results in the other questions of the research groups (E1, E2, & E3). However, when the mean averages are examined, it is seen that the success of E3 group is lower than the other groups except Q4. The same results are also shown in the graph in Figure 2.

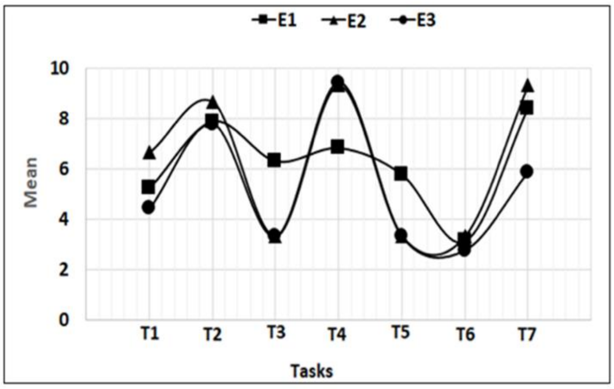


Figure 2. Means of Posttest Scores of Research Groups in terms of Questions

Findings Relating to the Second Research Question

The second research question aims to reveal that how the STAD, RWA, and IL methods affect the PSTs' conceptual understandings after the implementation. For the analysis of this research question, pre-test and posttest data were interpreted both quantitatively and qualitatively. Wilcoxon Signed Rank Test was used to determine the significance, if any, between pre- and posttest scores based on the questions in each experimental groups respectively. The significance of the difference between the scores was tested at the .05 level. Additionally, Figure 1 and Figure 2 shows that the means of pre- and posttest scores of research groups in terms of each question, respectively. After, content analyses were done to all questions. The PSTs’ misconceptions in drawings related to the subject of equilibrium were presented as Figure 3-9 with the examples according to questions.

Findings related to Q1

The first question was about the *changing equilibrium conditions* theme. In Q1, a small amount of product is added to a system in equilibrium. The PSTs are required to re-determine the number of reactants and products that represents in a particle size after the system is back into equilibrium again. It is seen that the pre-test mean average scores is in the range of 2.78-4.67 with a maximum score of 10 points on the Table 3. (See also Fig. 1-2). Table 4 shows that the mean average scores of research groups of the PSTs who answered the question correctly is 5.26 (E1), 6.67 (E2), and 4.44 (E3) after the implementation. These results indicate that the PSTs' understanding level of in Q1 is quite low. Table 5 shows that the Wilcoxon Signed Rank Test results of the groups on Q1.

Table 5. Wilcoxon Signed Rank Test Results on Pre- and Posttest Scores on Q1.

Groups		n	Mean Rank	Sum of Ranks	z	p
E1	Negative Ranks	0[a]	.00	.00	-1.732[b]	.083
	Positive Ranks	3[b]	2.00	6.00		
	Ties	16[c]				
	Total	19				
E2	Negative Ranks	0[a]	.00	.00	-1.732[b]	.083
	Positive Ranks	3[b]	2.00	6.00		
	Ties	12[c]				
	Total	15				
E3	Negative Ranks	0[a]	.00	.00	-1.732[b]	.083
	Positive Ranks	3[b]	2.00	6.00		
	Ties	15[c]				
	Total	18				

b. Based on negative ranks.

As can be seen in Table 5, there is no a statistically significant difference found between pre- and posttest mean scores of all the groups regarding conceptual understanding of concentration effect on the Le-Chatelier Principle (LCP) ($z = -1,732$; $p>.05$ for E1, E2, & E3). It was observed that all of the groups’ understandings average have increased and they made more accurate drawings at the particulate level. However, these results not showed that a statistically significant difference. Therefore, it is not possible to say that one of the teaching methods is more effective than to the others in Q1. Briefly, none of the teaching methods has been effective on the development of conceptual level on Q1. Table 6 shows that the PSTs' misconceptions were tried to be determined of the groups on Q1.

Table 6. Misconceptions about Q1.

	Frequency of misconceptions					
	Pre-test			Posttest		
	E1	E2	E3	E1	E2	E3
Misconceptions	12	8	13	9	5	10
1-The concentration on both reactants and products is reduced when a product is added to an equilibrium system	5	3	5	3	2	4
2-When the product is added to a system in equilibrium, the product concentration increases, the reactant concentration decreases	4	3	3	3	2	2
3-When the product is added to a system in equilibrium, the product concentration decreases, the reactant concentration increases	3	2	5	3	1	4

As can be seen in Table 6, PSTs have several misconceptions on the Le-Chatelier Principle before the implementation. Although, most of the PSTs in each research groups did not change these misconceptions after the application. The following drawing examples represent the misconceptions that PSTs have regarding the concentration effect (See Fig 3).

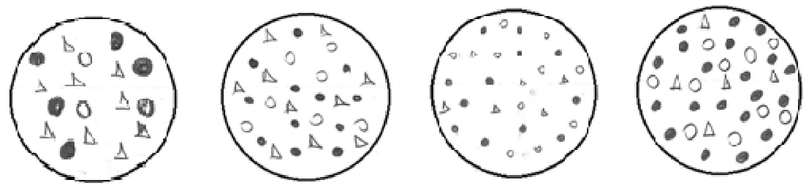


Figure 3. Examples of Misconceptions of PSTs in Q1

According to these drawings, PST_7 in $E1_{pre}$ group showed that both reactants and products were decreased despite the addition of SO_3 in the product side. PST_{16} in $E1_{post}$ believed that products are increased, and reactants are decreased in this condition. Some other PSTs thought that there would be a decrease on the side in which substance is added and an increase on the other side PST_5 in E_{2pre} and PST_2 in $E3_{post}$. According to the examples in Figure 3, the PSTs do not understand LCP on the effect of concentration.

Findings related to Q2

Q2 was about the *changing equilibrium conditions* in terms of effect of catalyst on chemical equilibrium according to LCP. As it is known, the catalysts have no effect on the chemical equilibrium and the numerical value of the equilibrium constant. The catalyst increases the speed of the reaction only in the forward or reverse direction, allowing for faster equilibrium. Addition of catalyst to a system in equilibrium does not affect the equilibrium. With Q2, the PSTs are asked to determine the number of reactants and products in particle size when the catalyst is added to a system in equilibrium and once the reaction is re-equilibrated at the same temperature. Table 7 shows that the Wilcoxon Signed Rank Test results of the groups on Q2.

Table 7. Wilcoxon Signed Rank Test Results on Pre- and Posttest Scores on Q2.

Groups		n	Mean Rank	Sum of Ranks	z	p
E1	Negative Ranks	0[a]	.00	.00	-3.606[bb]	.001
	Positive Ranks	3[b]	7.00	21.00		
	Ties	16[c]				
	Total	19				
E2	Negative Ranks	0[a]	.00	.00	-2.449[bb]	.014
	Positive Ranks	6[b]	3.50	21.00		
	Ties	9[c]				
	Total	15				
E3	Negative Ranks	0[a]	.00	.00		.008
	Positive Ranks	7[b]	4.00	28.00	-2.646[b]	
	Ties	11[c]				
	Total	18				

b. Based on negative ranks.

As Table 7 shows, there is a statistically significant difference between groups pre- and posttest scores relating effect of catalyst on chemical equilibrium ($z = -3.606$, $p < .05$ for E1; $z=-2.449$; $p < .05$ for E2; $z=-2.646$, $p < .05$ for E3). While the mean average scores of the groups were 1.05, 4.67 and 3.89 in pre-test (See Table 3); there were 7.89, 8.67 and 7.78 respectively in the posttest (See Table 4). It can be said that the all methods were effective on PSTs' conceptual understanding levels on Q2. According to this result, although the most successful group in the posttest seems to be E2, the greatest success increase occurred in the group E1 (STAD). Table 8 shows that the PSTs' misconceptions were tried to be determined of the groups on Q2.

Table 8. Misconceptions about Q2.

	Frequency of misconceptions					
	Pre-test			Posttest		
	E1	E2	E3	E1	E2	E3
Misconceptions	17	8	11	4	2	4
1-Catalyst increases the amount of substance	8	5	4	2	1	1
2-Catalyst decreases the amount of substances	5	1	4	1	-	1
3-Catalyst does not affect the concentration of some substances, while some of them increase	3	2	3	1	1	2

After the implementation, it was seen that there was a significant decrease in misconceptions in the E1, E2, and E3 (See Table 8). The following drawing examples represent the misconceptions that PSTs have regarding on Q2 (See Fig 4).

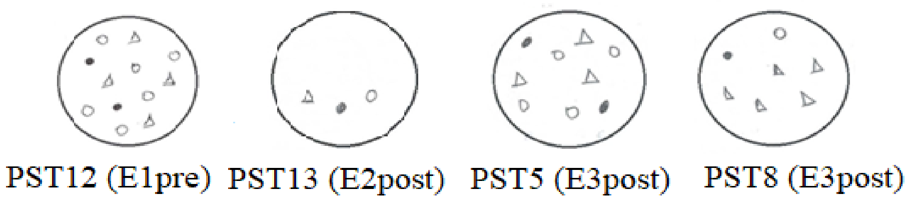


Figure 4. Examples of Misconceptions of PSTs in Q2

In Figure 4, some PSTs think that the use of catalyst increases the amount of substance PST_{12} from $E1_{pre}$ and PST_5 from $E3_{post}$, while some PSTs think that PST_{13} from $E2_{post}$ decreases the amount of substances present in the equilibrium reaction when the catalyst is used. On the other hand, some PSTs showed that some of the substances in the equilibrium reaction did not change and some showed an increase in PST_8 from $E3_{post}$.

Findings related to Q3

This question was about to equilibrium constant examined in the *misconceptions about K*. As shown in Table 3 and Table 4, the mean average success of the PSTs was between 1.33-2.78 in the pre-test and 3.33-6.32 in the posttest. The mean average success scores of all three groups who participated in the study were found to be quite low. The main reason for this is that PSTs do not have enough understanding of the position between the reactants and the products in the equilibrium reaction. Table 9 shows that the Wilcoxon Signed Rank Test results of the groups on Q3.

Table 9. Wilcoxon Signed Rank Test Results on Pre- and Posttest Scores on Q3

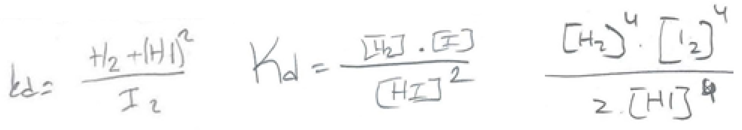
Groups		n	Mean Rank	Sum of Ranks	z	p
E1	Negative Ranks	0^a	.00	.00	-2.828^b	.005
	Positive Ranks	8^b	4.50	36.00		
	Ties	11^c				
	Total	19				
E2	Negative Ranks	0^a	.00	.00	-1.732^b	.083
	Positive Ranks	3^b	2.00	6.00		
	Ties	12^c				
	Total	15				
E3	Negative Ranks	0^a	.00	.00	-1.000^b	.317
	Positive Ranks	1^b	1.00	1.00		
	Ties	17^c				
	Total	18				

After the implementation, E1 was more successful than E2 and E3 (see Fig. 2). There is a significance difference between pre-and posttest scores of only E1 after the implementation. It can be said that the researcher explained the equilibrium constant and the PSTs did more examples have been more effective. Table 10 shows the frequency of PSTs who answered the question correctly and incorrectly.

Table 10. The Analyses of Drawings on Q3

Drawing	Frequency of drawings					
	Pre-test			Posttest		
	E1	E2	E3	E1	E2	E3
True	4	2	5	12	5	6
False	15	13	13	7	10	12

When Table 10 is examined, it is seen that the correct drawings of all groups regarding the writing of equilibrium constant show an increase. The highest increase in the number of true answer was in the E1 group. The increase in the E3 group was low. The following drawing examples represent the misconceptions that PSTs have regarding on Q3. While the PSTs are expected to write the equilibrium relation as $Kc = \frac{[HI]^2}{[I_2].[H_2]}$, it is seen that they make several misconceptions as it is shown in the Figure 5.



PST4 (E1pre) PST13 (E2post) PST16 (E3pre)

Figure 5. Examples of Misconceptions of PSTs in Q3

According to the Figure 5, PST_4 from $E1_{pre}$ did not write the reactant and products as a concentration. PST_{13} from $E2_{post}$ wrote reactant and products reversely in chemical equilibrium. PST_{16} from $E3_{pre}$ on the other hand, ignored the concentrations given in the equation and wrote the equilibrium incorrectly.

Findings related to Q4

This question was about to the equilibrium constant and the concentration relationship of the product and reactants in particle size that was examined in the *mass vs. concentration* theme. PSTs are expected to draw particles in the same way according to the equilibrium relation in Q4. Accordingly, they should show concentrations of C, B, A and D, respectively, from large to small. Table 11 shows that the Wilcoxon Signed Rank Test results of the groups on Q4.

Table 11. Wilcoxon Signed Rank Test Results on Pre- and Posttest Scores on Q4

Groups		n	Mean Rank	Sum of Ranks	z	p
E1	Negative Ranks	0[a]	.00	.00		1.000
	Positive Ranks	0[b]	0.00	.00	.000[c]	
	Ties	19[c]				
	Total	19				
E2	Negative Ranks	0[a]	.00	.00		.083
	Positive Ranks	3[b]	2.00	6.00	-1.732[b]	
	Ties	12[c]				
	Total	15				
E3	Negative Ranks	0[a]	.00	.00		.157
	Positive Ranks	2[b]	1.50	3.00	-1.414[b]	
	Ties	16[c]				
	Total	18				

Q4 is the question of the highest success rate of all the groups in the pre-test (see Table 3 and Fig. 1). However, there was no success increase in the first group, while the second and third groups increased their success average of 9.33 and 9.44, respectively after the study (see Table 4 and Fig. 2). However, none of the groups indicated a statistically significance difference after the implementation when comparing pre- and posttest mean scores. Table 12 shows the frequency of PSTs who answered the question correctly and incorrectly.

Table 12. The Analyses of Drawings on Q4

Drawings	Frequency of drawings					
	Pre-test			Posttest		
	E1	E2	E3	E1	E2	E3
True	13	11	15	13	14	17
False	6	4	3	6	1	1

According to Table 12, after the implementation, the levels of performing the question correctly regarding the representation of equilibrium constant and concentration relationship by drawing on particle level increased, but the level of correct response in the E1 group did not change. A few in some PSTs' drawing misconceptions related to this question is seen in Figure 6.

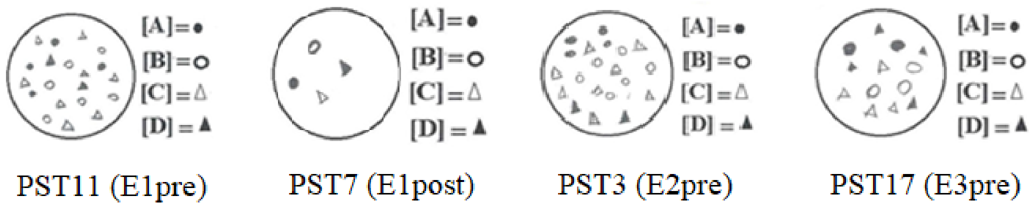


Figure 6. Examples of Misconceptions of PSTs in Q4

According to Figure 6, the concentrations are wrong in all the drawings. The PSTs made drawings without paying attention to the concentrations.

Findings related to Q5

This question relates to the relationship between equilibrium constant size and product-reactant concentrations that is examined in the *Characteristics of Chemical Equilibrium* theme. Table 13 shows that the Wilcoxon Signed Rank Test results of the groups on Q5.

Table 13. Wilcoxon Signed Rank Test Results on Pre- and Posttest Scores on Q5

Groups		n	Mean Rank	Sum of Ranks	z	p
E1	Negative Ranks	0[a]	.00	.00	-2.646[b]	.008
	Positive Ranks	7[b]	4.00	28.00		
	Ties	12[c]				
	Total	19				
E2	Negative Ranks	0[a]	.00	.00	-1.000[b]	.317
	Positive Ranks	1[b]	1.00	1.00		
	Ties	14[c]				
	Total	15				
E3	Negative Ranks	0[a]	.00	00	-1.732[b]	.083
	Positive Ranks	3[b]	2.00	6.00		
	Ties	15[c]				
	Total	18				

In Q5, it was the first group that increased its success largely (z=-2,646, p< .05). This finding showed that the PSTs had difficulty in adjusting the reactant and product concentrations according to the size of the Kc correlation for the same reaction. In Q5, it is expected from PSTs that when the Kc becomes smaller, the concentration of the reactant will be larger than the products. Accordingly, when the Kc grows the reactant concentration becomes smaller than the products. Table 14 shows that the PSTs' misconceptions were tried to be determined of the groups on Q5.

Table 14. Misconceptions about Q5.

	Frequency of misconceptions					
	Pre-test			Posttest		
	E1	E2	E3	E1	E2	E3
Misconceptions	15	11	15	8	10	12
1-Kc becomes smaller, the concentration of the reactant will be smaller than the products	5	4	6	3	4	5
2-Kc becomes higher, the concentration of the reactant will be higher than the products	7	5	5	4	4	4
3-When Kc becomes higher or smaller, the concentration of reactants and products do not change	3	2	4	1	2	3

According to Table 14, it is seen that misconceptions decrease in all groups after implementation. It was determined that the most decrease was in E1. Based on the context, the examples of incorrect drawing made by the PSTs on the question are given in Figure 7.

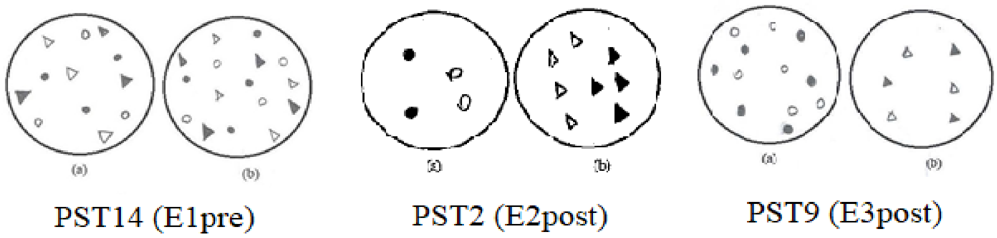


Figure 7. Examples of Misconceptions of PSTs in Q5

According to Figure 7, it is seen that PST_{14} from $E1_{pre}$ draws the concentrations of the reactants and products in both containers equally. PST_2 from $E2_{post}$ and PST_9 from $E3_{post}$ drew only the reactants in the first container and only the products in the second container.

Findings related to Q6

Q6 is related to temperature change, which is one of the factors affecting the equilibrium constant. This question, therefore, is addressed in the context of *changing equilibrium conditions* theme. In Q6, the PSTs are expected to draw products and reactants in particle size when the temperature is increased and the system comes back to equilibrium in an exothermic reaction. The PSTs were expected to perform their drawings in this direction considering that the equilibrium would shift to the reactants direction if the temperature was increased in an exothermic reaction. However, the achievement of all groups in the pre-test as well as the posttest is low can be seen in Table 3 and Table 4. Similarly, the graph of Figure 1 and 2 shows that the effect of temperature in exothermic and endothermic reactions was not fully understood by research groups. Table 15 shows that the Wilcoxon Signed Rank Test results of the groups on Q6.

Table 15. Wilcoxon Signed Rank Test Results on Pre- and Posttest Scores on Q6

Groups		n	Mean Rank	Sum of Ranks	z	p
E1	Negative Ranks	0[a]	.00	.00	1.732[b]	.083
	Positive Ranks	3[b]	2.00	6.00		
	Ties	16[c]				
	Total	19				

E2	Negative Ranks	0[a]	.00	.00	-1.414[b]	.157
	Positive Ranks	2[b]	1.5	3.00		
	Ties	13[c]				
	Total	15				
E3	Negative Ranks	0[a]	.00	.00	-1.414[b]	.157
	Positive Ranks	2[b]	1.5	3.00		
	Ties	16[c]				
	Total	18				

Table 15 shows that there is no statistically significance difference between the groups' pre- and posttest mean average scores. This result shows that none of the teaching methods is effective on the temperature effect of equilibrium and the subject is difficult to understand. Table 16 shows that the PSTs' misconceptions were tried to be determined of the groups on Q6.

Table 16. Misconceptions about Q6

	Frequency of misconceptions					
	Pre-test			Posttest		
	E1	E2	E3	E1	E2	E3
Misconceptions	16	12	15	13	10	13
1-If the temperature were increased in an exothermic reaction, both products and reactants' concentrations would decreased.	10	8	8	8	7	6
2-If the temperature is increased in an exothermic reaction, reactants' concentrations is decreased while the products' concentration is increased.	6	4	7	5	3	7

According to Table 16, it was determined that PSTs' misconceptions were high in this question. In the posttest, misconceptions decreased in all groups, but this decrease was not significant. The wrong drawing examples of all the groups seen in Figure 8 support this result.

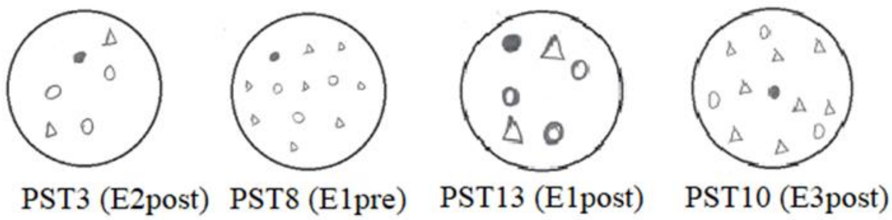


Figure 8. Examples of Misconceptions of PSTs in Q6

According to Figure 8, PST_3 from $E2_{post}$ and PST_{13} from $E1_{post}$ draw according to the initial equilibrium state of the reaction. PST_8 from $E1_{pre}$ and PST_{10} from $E3_{post}$ increased the concentration of the products in their drawings.

Findings related to Q7

Q7 was related to *rate vs. extent* theme. In Q7, PSTs should draw a particle representation of a reaction in the equilibrium given with the graph. In the pre-test, the success of the E2 group was higher than that of E1 and E3, whereas the success of E1 and E2 was higher than E3 in the posttest (see Table 4 and 5). Table 17 shows that the Wilcoxon Signed Rank Test results of the groups on Q7.

Table 17. Wilcoxon Signed Rank Test Results on Pre- and Posttest Scores on Q7

Groups		n	Mean Rank	Sum of Ranks	z	p
E1	Negative Ranks	0[a]	.00	.00	-2.646[b]	.008
	Positive Ranks	7[b]	4.00	28.00		
	Ties	12[c]				
	Total	19				
E2	Negative Ranks	0[a]	.00	.00	-1.732[b]	.083
	Positive Ranks	3[b]	2.00	6.00		
	Ties	12[c]				
	Total	15				
E3	Negative Ranks	0[a]	.00	.00	-1.732[b]	.083
	Positive Ranks	3[b]	2.00	6.00		
	Ties	15[c]				
	Total	18				

In Q7, the E1 group increased its success after the application compared to other groups (z=-2,646; p<.05). However, it is concluded that in all three groups the equilibrium concentration is understood to show in particle size within the graph. Table 18 shows that the PSTs' learning difficulties of the groups on Q7.

Table 18. The Analyses of Drawings on Q7.

Drawings	Frequency of drawings					
	Pre-test			Posttest		
	E1	E2	E3	E1	E2	E3
True	9	11	7	16	14	10
False	10	4	11	3	1	8

According to Table 18, all groups increased the correct drawing rate in the posttest. The highest increase was in E1. Figure 9 shows the incorrect drawing examples of all groups.

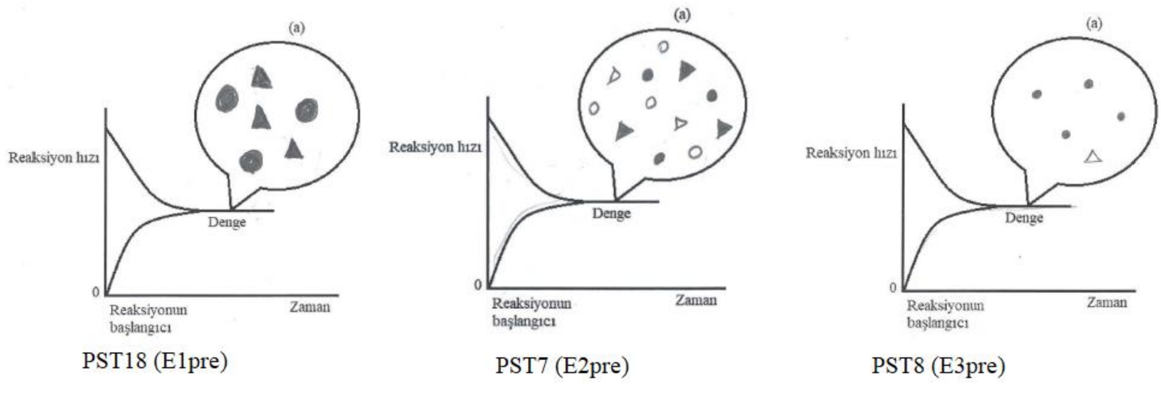


Figure 9. Examples of Misconceptions of PSTs in Q7

According to Figure 9, it is seen in all drawings that the concentrations of the substances in the reaction are not taken into account.

Discussion, Conclusion and Recommendations

This research has been developed and implemented within three interventions to determine which teaching method was more effective than others in terms of PSTs’ conceptual understanding levels of chemical equilibrium. The intervention organized based on the *Students Team Achievement Divisions (STAD)* and *Reading-Writing-Application (RWA) method of cooperative learning*, and *Individual Learning (IL)* methods. In addition, the PSTs' conceptual understandings of chemical equilibrium both qualitatively and quantitatively identified. The analysis of the PSTs’ drawings of MT and using Kruskall Wallis, Wilcoxon test and descriptive analysis were done.

The first research question was whether there was a difference among the experimental groups with respect to the understanding level gained through the different learning methods. This research question was analyzed in terms of independent samples. The analysis showed that, there was no statistically significant difference between the experimental groups at the beginning of the study. Considering the classes and pre-learning of the PSTs, it is expected that there will be no difference among the groups in the pre-test. However, mean scores of the groups on the Q7 in the two cooperative learning groups (STAD and RWA) were higher than individual learning (IL) group at the end of the study. At the same time, when the mean score is examined, it is seen that the success of E3 group is lower than the other groups except Q4. According to these results, it can be said that cooperative learning methods are more effective than individual learning in increasing PSTs' understanding in chemical equilibrium issues.

The second research question was about the effect of STAD, RWA and IL methods on the conceptual understanding levels of the PSTs after the implementation. The results point to an increase in the PSTs conceptual understanding level on the chemical equilibrium through all the three different intervention between pre- and posttest in terms of mean scores. However, this increase was statistically significant in favor of all groups in Q2 related to the catalyst effect on chemical equilibrium. All methods were effective on the understanding that the catalyst did not affect the chemical equilibrium and the magnitude of the equilibrium constant. It is thought that all groups are successful in this question since PSTs can easily understand the concept of catalyst after application. Unlike this result, Erdemir Özdemir et. al. (2000) stated that students think that a catalyst leads to higher yield of product.

After the implementation, only the STAD method was effective on the conceptual comprehension level in Q3, Q5, and Q7. These three questions are related to the particle size representations of an equilibrium reaction. Q3 refers to writing the equilibrium constant of a given reaction in particle size representation. It can be said that STAD method is more effective than to others. The correct response rate of the PSTs towards the question increased after the training given in the STAD method and the others did not change much. E1 is considered more successful as there are both teacher expression and group work stages in STAD. Similarly, Doymuş (2008) stated that most PSTs could not comprehend the effect of the equilibrium constant on the distribution of reaction systems. However, the PSTs in the E1 and E2 (cooperative learning groups) understood the topic of equilibrium constants well when compared to individual learning method (E3). Q5 was about showing the number of particles in the cups of a given reaction, considering that the Kc value of the equilibrium particles in the cups was high or low. In the posttest, all groups reduced misconceptions, but only a significant difference was observed in E1 in Q5. Parallel with this result, Doymuş (2008) stated that there is a decrease in the average of the PSTs about the magnitude of the equilibrium constant but that cooperative learning groups are more successful. Q7 related to drawing particle representation of the reactants in equilibrium of a given reaction. The reason why STAD method is more prominent in this context is that the working groups have to be successful in the questions both individually and in groups. Individuals within the group discussed and answered questions together and corrected the drawing misconceptions of their group friends. The PSTs had to justify the views of others, evaluate their peer understanding, and summarize the concepts that each PST contributed (Yeung, 2015). Raviolo (2001) stated that the numbering of particles allows us to assess the understanding of the dynamic aspect of the equilibrium.

However, there was no statistically significant difference in Q1, Q4 and Q6 in any experimental group. Q1 and Q6 was about concentration and temperature effects of LCP respectively. The lack of a change in the conceptual understanding of these groups is thought to be because the LCP is a hard-to-understand issue. Therefore, neither group nor individual studies have been effective in understanding the subject as LCP is one of the most difficult-to-understand topics on chemical equilibrium. The reason for this is that, as Maria and Justi (2009) point out, the thermodynamic approach is complicated for those who do not understand the concept of entropy as well as the relevant mathematical tools. Erdemir Özdemir et al. (2000) stated that students have uncertainty how a temperature, volume or pressure change will alter the equilibrium concentrations. Q4 relates to mass vs. concentration and the drawing of particles of a reaction given an equilibrium constant. Although the STAD method was more successful in similar questions, it was interesting that there was no difference in this question. That is to say, these results denote that STAD method is effective in achieving conceptual learning on the catalyst effect, equilibrium constant and particle representation of a reaction in equilibrium whilst RWA and IL is also efficient in achieving on the catalyst effect. However, none of the methods has been effective on the LCP of concentration and temperature effect and drawing a reaction in a particle size with respect to equilibrium constant. In addition, Kruskall Wallis test results revealed that only STAD and RWA methods were more effective than CLBT at Q7, but when looking at the averages, it was found that cooperative learning methods (STAD and RWA) were more successful than IL group. In summary, dependent and independent samples testing for each question showed that cooperative learning methods are more effective in certain subjects of chemical equilibrium. STAD method has become more prominent especially among these techniques. Many researchers have also stated that STAD method is effective in understanding the conceptual issues of various chemistry subjects (Adesoji & Ibrahemm, 2009; Balfakih, 2003; Carpenter & McMillan, 2003; Karaçöp, 2016; Wang, 2012). At the same time, the findings of no significant difference in some of the questions are consistent with Khan and Inamullah (2011) conducted research on students studying chemistry at higher secondary level and Lantajo (2017) who chemistry students in teaching selected topics in General and Inorganic Chemistry found no statistically significant difference in the achievement between the STAD and IL method.

The second research question investigated the conceptual understandings of PSTs' of chemical equilibrium topic in terms of different teaching methods. In relation to this question, each question was also handled separately with content analyzes based on the three intervention method. Based on the analysis, the factors that the PSTs have difficulty understanding about chemical equilibrium are determined in this study as follows: *(a) the difficulty in understanding the concentration effect on the LCP, (b) believing that the catalyst increases or decreases the product and / or the reactant concentration (c) the difficulty in writing equilibrium constant a reversible reaction, (d) difficulty in drawing a reaction in a particle size using equilibrium constant (e) difficulty in determining reactant and product concentrations according to size of equilibrium constant, and (f) difficulty in understanding the effect of temperature on the LCP.*

Similar difficulties have been identified in many previous studies. In LCP, the addition of more reactants or products to equilibrium is one of the most difficult factors to understand. Misconceptions in this study are; when a product is added to a system in equilibrium *(1) the concentration on both reactants and products is reduced, (2) the product concentration increases, the reactant concentration decreases, and (3) the product concentration decreases, the reactant concentration increases.* Similarly, Atasoy et.al. (2009) emphasized that PSTs interpreted LCP as an action-reaction situation and they explicated the results as if more reactants were added to the system in equilibrium the direction will shift to the side of products in order to reduce the effect and vice versa. Cheung et.al. (2009) stated that even teachers generally do not understand that if the amount of gaseous substances formed by a reversible chemical reaction is not equal to the amount of gas reactants. They found that only one out of the 109 chemistry teachers correctly stated that the number of product and reactant molecules when the equilibrium re-established after adding some amount of reactant, that is depending upon the amount of reactant in the initial equilibrium system. Most of the teachers expected the number of product molecules to increase while some of them thought there would be a decrease in the number of molecules. Our results also confirm the findings of the study and those of Karpudewan et. al. (2015) that using LCP, displayed the misunderstanding that the solution turned yellow (due to the formation of more reactant ions) to counter the increased amount of product ions. Bilgin and Geban (2006) stated that PSTs hold a misconception that when equilibrium is re-established following an increase in the concentration of NO(g) (a reactance compound), the concentrations of reactants and products will be equal to their initial equilibrium values after the implementation. Lucanus (2011) noted that without giving an idea about the kinetics that underlie the changes in equilibrium; students are left with the misconception that LCP application is going to explain them. Therefore, the factors affecting the chemical equilibrium and the LCP during a proper flow can be effective in understanding the subject. Similarly, the effect of temperature in this study was determined as one of the most difficult factors to understand (Q6). Both pre-and posttest averages of the PSTs in all groups are quite low and no teaching method has been effective in developing the conceptual understanding of the temperature effect on LCP. The PSTs' misconceptions about this question are as follows: *(1) if the temperature is increased in an exothermic reaction both products and reactants' concentrations would decreased. (2) If the temperature is increased in an exothermic reaction reactants' concentrations is decreased while the products' concentration is increased.* These findings are consistent with the of Karpudewan et. al. (2015)'s finding that in exothermic N_2 (g) + $3H_2$ (g) $\longleftrightarrow$ $2NH_3$ (g) equilibrium shifts to the right when the temperature is increased, providing the formation of more ammonia and Bilgin and Geban's (2006) finding that when the temperature is increased and disturbs the system at equilibrium, the forward reaction rate will be instantaneously greater than the rate of reverse reaction. More specifically, similar to our study, Şimşek, Doymuş, Doğan and Karaçöp (2009) stated that the when chemical equilibrium reaction had an effect and then the system was rebalanced, PSTs made significant misconceptions regarding the particle size of the reaction of this system. Explaining the effect of temperature and concentration on the LCP by visualizing chemical equilibrium displacements can help the PSTs conceptualize the relationships between concentrations in a system (Ollino, Aldoney, Dominguez, & Merino, 2018).

Additionally, some of the PSTs also had difficulty writing the equilibrium constant of a reaction in equilibrium (Q3). Kousathana and Tsaparlis (2002) highlighted that chemical equilibrium problems are the most important and at the same time, the most complex and difficult general chemistry problems. Gussarsky and Gorodetsky (1990) stated that equilibrium problems are mostly abstract. Therefore, students do not automatically understand what the algebraic symbols or other symbols actually mean in relation to the actual chemical system being studied. Furthermore, the misconceptions about dynamism seem to be resistant to instruction. Kousathana and Tsaparlis (2002) similarly to this study found that students failed to set up the expression for the chemical-equilibrium constant (5.0%) and use of number of moles instead of concentrations (21.6%).

This study aimed to determine the Effects of RWA and STAD of cooperative learning and Individual Learning (IL) methods on the conceptual understandings at sub-micro level of the PSTs in equilibrium chemistry. In the comparison of these methods, we can say that RWA and STAD methods are more effective than IL in terms of drawing the particle representation of the reactants in equilibrium. The most successful group was STAD. In this study, the factors that the PSTs had difficulties about the chemical equilibrium were also determined. When the PSTs' misconceptions related to chemical equilibrium are identified, the instructors can help students understand the scientifically accepted concept using appropriate teaching methods and techniques (Piquette & Heikkinen, 2015). In line with the results obtained from the research, in chemistry, the effect of individual and cooperative learning on different topics on conceptual understanding can be investigated.

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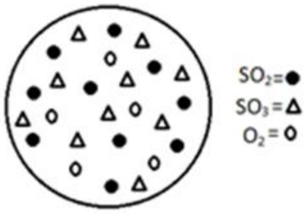
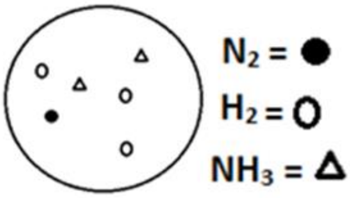
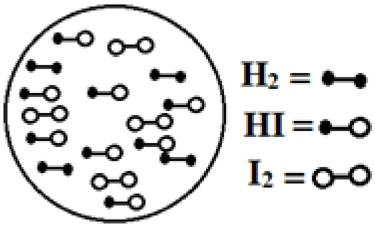
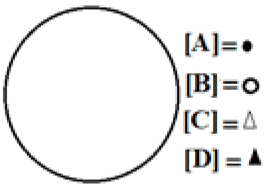
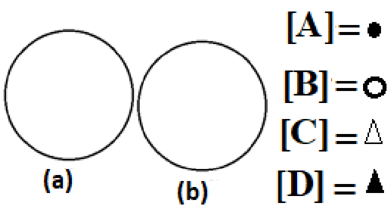
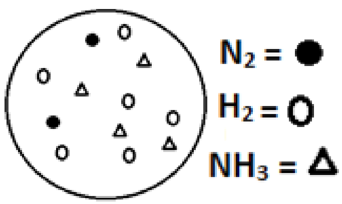
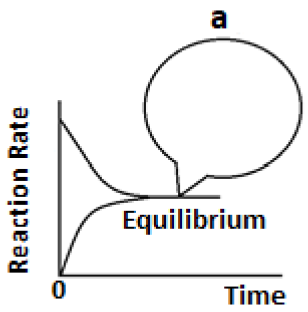
APPENDIX

MODULE TEST

	**Question 1** $2SO_{2\,(g)} + O_{2(g)} \leftrightarrow 2SO_{3(g)}$ The reaction given above is in equilibrium at 100K (Kc = $2.8x10^2$). The equilibrium representation in particle size of this reaction is as shown in Fig. A small amount of SO_3(g) is added to the equilibrium reaction. After a while, at the same temperature the system re-equilibrates. In the latter case, determine the number of particles in the equilibrium reaction in particle size.
	**Question 2** $N_{2\,(g)} + 3H_{2(g)} \leftrightarrow 2NH_{3(g)}$ The reaction given above is in equilibrium at 100K (K_c= $2,8x10^2$). The equilibrium representation in particle size of this reaction is as shown in Fig. The equilibrium reaction is catalyzed at the same temperature. Once the reaction has resumed chemical equilibrium, re-determine the number of particles in the particle size.
	**Question 3** $H_{2\,(g)} + I_{2\,(g)} \leftrightarrow 2HI_{(g)}$ The reaction is equilibrium at 100K. Write an expression for the equilibrium constant for this reaction.
	**Question 4** $Kc= \frac{[A]^2 . [B]^3}{[C]^4\ [D]}$ Taking into account to the reaction given the equilibrium constant, show the particles in the cup provided on the left.
	**Question 5** For $A_{(g)} + B_{(g)} \leftrightarrow C_{(g)} + D_{(g)}$ reaction; show the number of particles in the cup A and B (a)considering the Kc value of the particles in the container is low; (b) considering that the K_c value of the equilibrium particles in the cup is high. The symbols you will use for each item are given left.
	**Question 6** $2N_{2\,(g)} + 6H_{2(g)} \leftrightarrow 4NH_{3(g)} + Q$ The reaction given above is in equilibrium at 100K (K_c= $2,8x10^2$). The equilibrium representation of this reaction is as shown in Figure left. The temperature of the reaction in equilibrium is being increased. The reaction is coming back to re-equilibrium. Show the particle representation of the new equilibrium reaction in the following door.

	**Question 7** $2A_{(g)} + 3B_{(g)} \leftrightarrow 4C_{(g)} + D_{(g)}$ The equilibrium state of the above reaction is shown graphically. In the graph, draw the particle representation of the reactants in equilibrium into (a). [A]= ● [B]= ○ [C]= △ [D] = ▲