



Effect of Case-Based Learning Laboratory Instruction and Scientific Reasoning Ability on Science Preservice Teachers' Understanding of Some Chemistry Concepts

Aylin ÇAM*, Gökhan GÜVEN**, Yusuf SÜLÜN***

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Abstract

The purpose of the study was to investigate the effect of case-based learning laboratory (CBLL) over traditional laboratory (TL) instruction on freshman science preservice teachers' (SPTs') understanding of some chemistry topics. The participants in this study consisted of 37 freshman SPTs from two intact classes of a rural educational faculty with the same instructor. Each teaching method was randomly assigned to one class. The experimental group was applied with CBLL, whereas the control group was TL. In the experimental group, life cases were presented in a small group format; in the control group, lecturing and discussion was carried out. The results showed that there was no significant difference between the experimental and control groups with respect to their understanding of some chemistry concepts. However, regarding scientific reasoning ability (SRA) level, there were significant differences among the understanding of these chemistry topics by concrete, formal, and post-formal reasoners, in favor of formal reasoners. In addition, SPTs' SRA levels were affected equally in CBLL and TL.

Keywords: Case-based learning laboratory, traditional laboratory, scientific reasoning ability, science preservice teachers.

* Muğla Sıtkı Koçman University, Faculty of Education, Muğla, Turkey; aylincam@mu.edu.tr

** Muğla Sıtkı Koçman University, Faculty of Education, Muğla, Turkey; gokhanguyen@mu.edu.tr

*** Muğla Sıtkı Koçman University, Faculty of Education, Muğla, Turkey; syusuf@mu.edu.tr

Fen Bilgisi Öğretmen Adaylarının Bazı Fen Kavramlarını Anlamaları Üzerine Bilimsel Düşünme Yeteneklerinin ve Örnek Olay Temelli Öğrenme Laboratuvar Uygulamalarının Etkisi

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Aylin ÇAM*, Gökhan GÜVEN**, Yusuf SÜLÜN***


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Öz

Çalışmanın amacı, birinci sınıf Fen Bilgisi öğretmen adaylarının bazı kimya konularını anlamalarına örnek olay temelli laboratuvar öğretiminin (CBLL) geleneksel laboratuvar öğretimi (TL) üzerine etkisini araştırmaktır. Bu çalışmanın katılımcıları, aynı öğretim elemanının ders verdiği kırsal kesimde yer alan bir eğitim fakültesinin iki özdeş sınıfında öğrenim gören 37 birinci sınıf öğretmen adayından oluşmaktadır. Her öğretim yöntemi rasgele bir sınıfa atandı. Deney grubunda CBLL uygulanırken kontrol grubunda TL uygulandı. Deney grubunda yaşamla ilgili örnek olaylar küçük grup formatında sunulurken; kontrol grubunda ders anlatımı ve tartışma gerçekleştirildi. Sonuçlar kimya kavramlarının anlaşılması bakımından deney ve kontrol grubu arasında anlamlı bir farklılık olmadığını göstermiştir. Ancak, bilimsel düşünme yeteneklerine (SRA) ilişkin somut, soyut ve soyut sonrası dönemlerindeki kimya konularını anlamaları arasında soyut düşünenler lehine anlamlı farklılıklar bulunmuştur. Ek olarak, Fen Bilgisi öğretmen adaylarının bilimsel düşünme seviyeleri örnek olay temelli öğrenme ve geleneksel laboratuvar öğretiminden aynı ölçüde etkilenmiştir.

Anahtar kelimeler: Örnek olay temelli öğrenme laboratuvarı, geleneksel laboratuvar, bilimsel düşünme yeteneği, fen bilgisi öğretmen adayları.

* Muğla Sıtkı Koçman Üniversitesi, Eğitim Fakültesi, Muğla, Türkiye; aylincam@mu.edu.tr

** Muğla Sıtkı Koçman Üniversitesi, Eğitim Fakültesi, Muğla, Türkiye; gokhanguven@mu.edu.tr

*** Muğla Sıtkı Koçman Üniversitesi, Eğitim Fakültesi, Muğla, Türkiye; syusuf@mu.edu.tr

1. Introduction

Science education students face difficulties for understanding complex concepts or processes (Moser, Zumbach & Deibl, 2017). The study investigates the effectiveness of case-based learning laboratory (CBLL) over traditional laboratory (TL) instruction on freshman science preservice teachers' (SPTs') understanding of some chemistry concepts in terms of their scientific reasoning ability (SRA) levels. In the present study, the particulate nature of matter, chemical and physical change, concentration, stoichiometry, reaction rate, and factors affecting the reaction rate and chemical equilibrium were examined. These chemistry topics are complex, abstract, and important for understanding other topics such as acid-base equilibrium and solubility equilibrium. Thus, it is important for students and SPTs to understand them. It is also important for SPTs to study them because they will eventually teach these topics in their real classrooms. Understanding of the concepts and achievement was related to SRA levels. To investigate this, SPTs understanding was evaluated in terms of their SRA levels.

1.1. Scientific Reasoning Abilities and Understanding

One of the general goals of science education is to develop students' reasoning ability. Koenig, Schen, and Bao (2012) stated that "scientific reasoning...can be understood as a set of abilities necessary in carrying out scientific practices—abilities both related to the collection and analysis of evidence, as well as those used to generate a cohesive evidence based argument" (p.2). According to Lawson (2004), scientific reasoning includes the following *reasoning types*: conservation, proportional reasoning, identification and control of variables, correlational reasoning, probabilistic reasoning, and combinatorial reasoning.

It has been suggested that students with sophisticated scientific reasoning can understand science easily, construct science concepts, and eliminate misconceptions (Oliva, 2003; She & Liao, 2010). Misconceptions could prevent learning, and students could have difficulty understanding new concepts (Limón & Mason, 2002); misconceptions occur when students' preconceptions differ from scientific conceptions and their ideas about the concept do not coincide with scientific knowledge.

It is important to assess the possible relationship between students' scientific reasoning and misconceptions (Oliva, 2003; Lawson, 2003). According to Lawson (2003), students should become conscious of their misconceptions and scientific concepts via evidence and reasoning. Scientific conceptions should be supported and prior misconceptions should be contradicted by the evidence. Oliva (2003) discovered that sophisticated formal reasoners can eliminate their misconceptions easily, although they have well-organized misconceptions. Sungur and Tekkaya (2003) found that there was a statistically significant mean difference between concrete and formal reasoning students in terms of achievement. Lee and She (2010) stated that students with higher SRA alter their misconceptions more efficiently than those with lower ability using the conceptual change approach. The understanding of abstract topics requires formal reasoning abilities. Thus, in the present study, SPTs chemistry understanding and misconceptions were examined in terms of their SRA.

In this study, students' misconceptions about atoms, molecules, concentration, rate of reaction, and chemical equilibrium were investigated because these concepts are abstracts. In order to eliminate such misconceptions, laboratory applications could be helpful (Basheer, Hugerat, Kortam & Hofstein, 2017). Such applications have following advantages: Students make abstract

concepts into concrete ones, understand basic concepts, produce and test hypotheses, and make linkages between theoretical and hands-on science. Students could therefore produce scientific knowledge related to the concept by doing experiments and become aware of the nature of scientific knowledge of the concept (Geçer, 2005). However, students' misconceptions could not change via TL because students use step-by-step procedures, and so they could not relate concepts with their conceptual framework. Thus, it is better to use constructivist teaching methods in order to eliminate students' misconceptions (Çam & Geban, 2013). In this study, the effectiveness of CBLL, which is a constructivist approach, was investigated.

Case-based learning has similarities with problem-based learning in terms of the usage of stories and inductive approach. In case-based learning the case includes message whereas in problem-based learning the case includes problem in story (Çam & Geban, 2017). Gürses, Açıkyıldız, Doğar, and Sözbilir, (2007) stated that problem-based approaches are ideally utilized in physical chemistry laboratories. Monahan and Yew (2002) used case-based and cooperative learning to enrich a veterinary parasitology laboratory. Their study included parasitology facts to show students how these cases are essential in their field. Students in the laboratory were active and showed more positive attitudes toward parasitology than in their previous laboratory type. Although they did not do any statistical computations, the authors showed that students' practical exam results were similar in the two laboratory types. They explained that these students had higher achievement in this course and that they prefer hands-on activities without considering its type. To our knowledge, there has not been extensive research in science teacher education on the effectiveness of case-based learning in laboratory instruction. Thus, in the present study, the effectiveness of CBLL over TL instruction was examined.

1.2. Case-Based Learning Instruction

According to the constructivist approach, students construct new knowledge into their already existing knowledge (Lorsbach & Tobin, 1992). In this approach, students are active in the learning environment. This environment should be real, helpful for the construction of knowledge, and include context-rich and experience-based activities. Jonassen (1994) stated that real-life examples and case-based learning environments facilitate the constructivist approach. In case-based learning instruction, students participate actively, so their learning can be constructed. In the present study, Herreid (1998) approach of case-based learning with small group activities was used. According to this, the teachers play the role of facilitator; they ask interesting question at the beginning of the lesson in order to start the discussion. Then, they guide the discussion and summarize the case and topic. Students were presented with the cases involving stories related to the topic; the stories were discussed and questions were addressed. Thus, pre-service teachers make abstract chemistry concepts concrete and on the contrary to other methods; case-based learning is useful for pre-service teachers. The reason of the usefulness is that pre-service teachers could enjoy stories related to chemistry and they could use this stories while they became a teacher. In this study, small group activities were used because students interact more in this format. In their groups, the students examined, interpreted, and discussed the case and solved questions related to it. Here, cases were developed by considering SPTs misconceptions.

There have been some studies related to the elimination of students' misconceptions using case-based learning instruction (Gürses et al., 2007; Tarhan, Kayalı, Urek, & Acar, 2008). However, only a few of these studies were related to chemistry topics (Tarhan et al., 2008) and conducted in a laboratory (Gürses et al., 2007); the others were related to other topics. Tarhan et al. (2008)

studied the intermolecular forces on grade-9 students and found that the CBL performed well in eliminating misconceptions. Gürses et al. (2007) investigated the adsorption, viscosity, surface tension, and conductivity on grade-4 preservice teachers in the laboratory. They demonstrated that a problem-based learning laboratory was helpful for the learning process. However, there is not much of case-based learning study in the particulate nature of matter, chemical and physical change, concentration, stoichiometry, reaction rate and factors affecting the reaction rate and chemical equilibrium. They also stated that students participated actively, thereby integrating and synthesizing a variety of knowledge. In the present study, unlike Gürses et al. (2007) using problem based learning, case-based learning was carried out in the general chemistry laboratory in order to eliminate SPT' misconceptions related to some chemistry topics.

The present study is important in order to determine SPT's SRA level on the understanding of some chemistry concepts. The investigation of SPTs' SRA is important for several reasons. First, these abilities are related to SPTs' understanding of concepts. Second, according to the SPTs' developmental stages, instructional activities could be designed to target physical and neural changes. Third, SPTs could then develop their future students more effectively. Thus, in the present study, SPTs' SRA was investigated in two different types of chemistry laboratory instruction.

The research questions were as follows: (1) Is there a statistically significant mean difference between the control and experimental group SPTs in terms of their previous understanding of some chemistry concepts? (2) Is there a statistically significant mean difference between the scientific reasoning levels on the understanding of some chemistry concepts?

2. Method

2.1. Sample

The study sample consisted of 36 freshman SPTs from two intact classes of a rural educational faculty that were taught by the same instructor. These classes were randomly assigned as a control group and an experimental group. Experimental group were instructed through CBL instruction (18 SPT), while the control group was instructed with TL instruction (18). The mean age of the SPTs was 20.

Power was set at .80 a priori because Hinkle, Wiersma and Jurs (1998) stated that type 1 error is more serious than type 2 error and proposed that there should be a 4:1 ratio of β to α . According to this ratio, the power should be .80 at a .05 significance level. Hinkle et al. (1998) proposed that when the power is 80% with a large effect size (1.00σ) at a .05 significance, 17 participants are needed for each group. Thus, the sample size of the present study is reasonable.

2.2. Instrumentation

All SPTs were administered two instruments, namely 1) the chemistry concepts test and 2) the scientific reasoning abilities test.

Chemistry Concepts Test (CCT): It was developed by Akkuş (2004) and he administered this test to 10th grade students. In the present study, before administering this test to SPTs, pilot study was conducted and the expert opinions were obtained. Then, the instrument was implemented to measure SPTs' understanding of the selected chemistry topics. It includes 28 multiple choice items, most of which require SPTs to reflect misconceptions, while the others require computations. Distracters for each item were designed in a way that they reflect misconceptions

students have related to the topics. The reliability coefficient was found to be .65, and this value is similar to that of the original instrument. This instrument was administered to both experimental and control groups as a pre- and post-test to determine their understanding of the topics.

Scientific Reasoning Abilities (SRA): In this study, the revised version of *Classroom Test of Scientific Reasoning* (Lawson, 1978) was used to determine SPTs' SRA. This test consists of a 12-item paper and pencil test and takes about 50 minutes. It covers the following *reasoning types*: conservation, proportional reasoning, identification and control of variables, correlational reasoning, probabilistic reasoning, and combinatorial reasoning. For each item, there are two-tier questions requiring SPTs to provide both the answer and the reason for it. When the answer and the reasoning were correct, SPTs received 1 point; they received 0 otherwise. In the test, SPTs could obtain a minimum of 0 and a maximum of 12 points. According to the SPTs' answers, they were *classified* as concrete (0–4), formal (5–8), or post-formal reasoners (9–12) in line Lawson (1978) classification. Concrete reasoners cannot “test hypotheses involving observable causal agents,” formal reasoners can sometimes test such hypotheses, and post-formal reasoners can “test hypotheses involving observable causal agents or unobservable entities” (Ateş & Çataloğlu, 2007, p. 1166, Lawson, 2007). This instrument was adapted for Turkish by Ateş (2002), and the Cronbach alpha reliability of the adapted instrument was found to be .79. This result is similar to the original one. The instrument was administered to the experimental and control groups before the treatment.

2.3. Treatment

All SPTs were taught by the same instructor in two classes throughout the semester. The classes were observed to control for teacher effects and for treatment verification. Thus, the researchers observed the two classes to ensure that the instructor was providing the appropriate instruction in each class. SPTs instructed about the particulate nature of matter, chemical and physical change, concentration, stoichiometry, reaction rate, and factors affecting the reaction rate and chemical equilibrium.

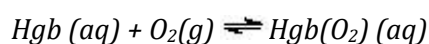
The intervention took three months. This study was conducted in the laboratory for both groups. However, the types of intervention for the groups were different. Both groups carried out the same experiments, but the experimental group discussed a case related to the experiment and then performed the experiment.

The control group was instructed through lecturing and discussion in the laboratory; SPTs were passive listeners, and followed a handout that looked like a “cookbook” listing the experimental steps. At the beginning of the lesson, SPTs performed their experiments in line with the steps in the handout in groups of four or five. After they completed their experiments, they discussed follow-up questions, first in their groups and then as a class. The instructor emphasized topics in the handout; if SPTs had questions, the instructor answered them and the SPTs took notes. The instructor's role was to transmit the facts and concepts to the SPTs. In addition, SPTs were required to read related material before the lesson; afterward, worksheets were provided and the SPTs responded to them. Questions on the worksheets were directly related to the topic. However, SPTs' misconceptions and previous knowledge were not considered by the instructor while teaching.

The experimental group was treated with CBLL. According to Herreid (1998), there are four types of case-based learning, as follows: individual assignments, lectures, discussion, and small group activities. In each, the definition of the case is the same; however, the students' and the teacher's roles change. In this study, CBLL was employed in a small group format with the instructor as a facilitator. Thus, SPTs could learn more from each other. Furthermore, the learning of the chemistry topics chosen is difficult, because the concepts are abstract. Thus, small a group format was suitable to promote SPTs' learning.

In the experimental group, at the beginning of the laboratory, SPTs discussed the cases in groups and then performed the related experiment. Ten cases related to real life scenarios were used. Each case followed questions that integrated issues related to the case and misconceptions. Each week's case was given one week prior to the laboratory class and SPTs studied the case before the laboratory. At the beginning of the laboratory, SPTs discussed the cases in small groups and with the whole class. Then, they were required to answer questions related to the case in groups and with the whole class. Next, SPTs performed the experiment in their groups using the same handouts as the control group; these were prepared by the researchers, and developed considering experiments in the literature related to the chemistry topics chosen. While the SPTs were doing the experiment, the instructor guided them by connecting the case with the experiment. SPTs' misconceptions and previous knowledge were considered by the instructor while studying both the experiment and the case. Thus, teacher prepared the lesson plan and the cases in line with their possible misconceptions. After SPTs completed their experiments, they came to conclusions about each case and experiment. The case presented in Figure 1, involving mountain climbing, relates to the chemical equilibrium topic.

Ali likes trekking, and today he decides to climb a high mountain. As he walks, he starts feeling tired and develops a headache. Coming home, he tells his mother that he wants to go to the doctor. However, his mother is a biochemist, and tells him that in blood, the following chemical equilibrium reaction occurs:



Hgb and Hgb(O₂) are the formulas for hemoglobin and oxidized hemoglobin.

Hemoglobin is a blood protein that transports oxygen in the lung to the muscles and other tissues for energy production.

Ali's mother states that if he stays on the mountain longer, he will feel less tired.

Background Information:

Chemical equilibrium is defined as the state in which the rate of a forward reaction is equal to the rate of the reverse reaction. According to Le Chatelier's principle, there is a dynamic equilibrium, where changing one of the variables in the equilibrium system causes the position of the equilibrium to shift in order to counteract this change.

Figure 1. The Example of Case.

This case was given to SPTs one week prior to the laboratory lesson. When asked their opinion on the case, they generally stated that "body systems follow equilibrium rules," "we can see Le Chatelier's principle in our body," and "our body is in equilibrium because it uses Le Chatelier's principle." Then, the case was presented in the laboratory and small group discussion (4–5 SPTs in each group). Each group then discussed the following case question: *Why did Ali feeling tired while climbing the mountain?* The instructor observed SPTs as they solved this question, taking

note of some responses. One group stated that “when he climbed to a higher altitude, the amount of oxygen in the blood decreased, so he felt tired,” while another stated that “enough oxygen could not be transported to the tissues and muscles.” After this question was solved, the SPTs addressed the next question: *What is the direction of the chemical equilibrium reaction when atmospheric pressure and oxygen concentration are lower than the body’s normal values?* Again, the SPTs discussed this question; according to one group, “equilibrium goes to the left because the amount of oxygen is low.” Another stated that “according to Le Chatelier’s principle, the equilibrium reaction goes to left.”

After all questions were discussed in the group, the SPTs discussed the case as a class. Follow-up questions such as the following were directed toward the SPTs to enhance their understanding of the important concepts: What is Le Chatelier’s principle? Why does the given equilibrium go to the right at the highest altitude? How does our body system attain equilibrium? If you stay on the mountain longer, you will feel less tired. Why? At the end of this discussion, SPTs revealed and summarized the important concepts of the case. Thus, they solved the related questions and understood Le Chatelier’s principle.

The cases directed the SPTs toward a conclusion or provided resources and context to discuss and debate issues dynamically. With the instructor, the researchers prepared an outline of concepts and sub-concepts to be discussed through the case. The instructor was trained in case-based learning instruction by the researchers. Cases related to the topic were prepared by the researchers, then examined by the instructor and experts concerning the appropriateness of the topic and SPTs’ cognitive level. In the experimental group, the experiment related to the case (in this case, the experiment was related to Le Chatelier’s principle of K_2CrO_4 and HNO_3 ; $CuSO_4$ and HNO_3) was then implemented; finally, the SPTs summarized both the case and the experiments.

3. Findings

3.1. Effectiveness of the Treatments on SPTs’ Understanding

In this study, independent samples t-test was conducted, with instructional methods as the independent variable, SPTs’ previous learning in the chemistry topics as a dependent variable. Then, another independent samples t-test was conducted in order to determine the effect of the instruction. In this case, instructional method is independent variable; SPTs’ understanding of the chemistry topics as dependent variable. Their understanding of the topics was measured by post-CCT. Table 1 shows both independent samples t-tests results.

Table 1. Independent t-test results

		X	sd	t	p
Pre-test	Experimental group	12.83	2.52	.389	.700
	Control group	12.50	2.61		
Post-test	Experimental group	14.83	2.85	1.382	.176
	Control group	13.17	4.25		

*Significant at $p < 0.05$

The independent samples t-test results indicated that there was no statistically significant difference between the experimental and control groups’ mean CCT pre-test scores ($t = .389$; $p = .700$). It can be stated that both groups did not differ at the beginning of the intervention study. For the post-test scores of SPTs’ chemistry understanding, there was no statistically significant difference between the experimental and control groups’ mean CCT post-test scores ($t = 1.382$, $p = .176$). However, the experimental group demonstrated better performance than the

control group. The experimental group's mean score was $M=14.83$, whereas the control group's was $M=13.17$.

3.2. SPTs' Reasoning Levels

SPTs' SRA levels are given in Table 2. Most SPTs in the experimental group (61.10%) were in the concrete stage, while in the control group (72.22%), they were mostly in the formal stage. In the present study, we did not want to match the two groups in terms of their reasoning abilities; rather, we wanted to demonstrate the effect of reasoning abilities of SPTs on their chemistry understanding with two different teaching methods.

Table 2. Descriptive Statistics of SRA

	Concrete		Formal	
	N	%	N	%
<i>CBLL</i>	11	61.10	7	38.90
<i>TL</i>	5	27.78	13	72.22

3.2.1. Effectiveness of Scientific Reasoning Ability Levels on SPTs' Understanding

The independent samples t-test was conducted to determine the effect of SRA on their previous understanding of chemistry topics with SPTs' SRA levels as the independent variables, previous understanding of the chemistry topics as dependent variable. SPTs' previous understanding of the chemistry topics was measured by pre-CCT. Another independent samples t-test was conducted to determine the effect of SRA on their understanding of chemistry topics with SPTs' SRA levels as the independent variables, understanding of the chemistry topics as dependent variable. SPTs' understanding of the chemistry topics was measured by post-CCT. Table 3 shows the results.

Table 3. Independent samples t-test results

		<i>X</i>	<i>sd</i>	<i>t</i>	<i>p</i>
Pre-test	Concrete reasoners	12.94	2.64	.566	.575
	Formal reasoners	12.45	2.50		
Post-test	Concrete reasoners	15.38	2.68	2.11	.042*
	Formal reasoners	12.90	4.02		

*Significant at $p<0.05$

The independent sample t-test results indicated that there was no statistically significant mean difference between SPTs' previous understanding of the chemistry concepts among concrete, and formal, reasoners ($t=.566$, $p=.575$). Thus, it could be stated that at the beginning of the intervention both reasoners' chemistry understanding of the concepts did not differ. Another independent t-test results showed that there was a statistically significant mean difference between concrete and formal reasoners in terms of SPTs' understanding of the chemistry concepts ($t=2.11$, $p=.042$). This difference favors concrete reasoners ($M=15.38$).

In order to examine each group's chemistry understanding in terms of SPTs' reasoning levels; independent samples t-test was conducted. For experimental group, there was no statistically significant mean difference between concrete and formal reasoners in terms SPTs previous understanding ($t=-1.881$, $p=.078$). At the end of the intervention, also, there was no significant difference between concrete and formal reasoners in terms of their chemistry understanding in experimental group ($t=1.767$, $p=.096$). For control group; there was a statistically significant mean difference between concrete and formal reasoners in terms of their previous understanding ($t=3.075$, $p=.007$), this difference favors concrete reasoners. After intervention, there was no statistically significant difference mean between concrete and formal reasoners in terms of SPTs' understanding of chemistry concepts ($t=.882$, $p=.391$)

When we examined SPTs' conceptual chemistry understanding in terms of their SRA level, it was found that concrete reasoners contributed to the CBLL more than the other SPTs. Furthermore,

according to Table 4, the CBLL was more helpful for concrete reasoners. On the other hand, the TL was more helpful for formal reasoners.

Table 4. Concrete and formal reasoners chemistry understanding

	Concrete Reasoners		Formal Reasoners	
	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>
CBLL: pre-test	12.00	1.95	14.14	2.91
CBLL: post-test	15.72	2.53	13.43	2.94
TL: pre-test	15.00	3.00	11.54	1.76
TL: post-test	14.60	3.13	12.62	4.59

Some CCT Items

The misconceptions reflected by the CCT distracter items were common misconceptions about these chemistry topics. The post-test average percent of correct responses in the experimental group was 15.16, and that in the control group was 13.94. When the proportion of correct responses and misconceptions determined by the item analysis for the experimental and control groups was examined, there was a significant difference between these groups in favor of the experimental group.

When SPTs were asked the volume-mole relationship under the same conditions (Question 11), 42.1% in the experimental group answered correctly, stating that mole does not change by volume change. However, as shown in Table 5, 12.5% of the SPTs in the TL answered the same question correctly after the instruction. The common misconceptions among the control group were that when volume increased two times, mole decreased by half of the original volume (50%); when the volume increased two times, mole increased twice (25%), or we cannot say anything without knowing the values of temperature and pressure (12.5%).

Table 5. Item 11

<i>Alternatives</i>	<i>Control group</i>
	<i>Percent correct</i>
<i>A</i>	50.0
<i>B</i>	25.0
<i>C*</i>	12.5
<i>D</i>	0
<i>E</i>	12.5
<i>Total</i>	100

(*) Correct

SPTs were asked how mole and concentration change when solutions are diluted (Question 12). The desired response was that mole does not change, while concentration decreases twice. Although 57.9% of the SPTs in the experimental group gave the correct answer, as shown in Table 6, the percent of correct responses for control group SPTs was 37.5%. Some SPTs (37.5%) in the control group held the misconception that “both mole and the concentration of solution decrease twice.” Only 5% of the experimental group SPTs held the same misconception. In addition, 12.5% of SPTs in the control group thought that “both mole and the concentration of solutions increase twice” and “mole decreases twice and concentration does not change.”

Table 6. Item 12

<i>Alternatives</i>	<i>Control group</i>
	<i>Percent correct</i>
A	37.5
B	12.5
C	0
D	12.5
E*	37.5
<i>Total</i>	<i>100</i>

(*) Correct

When SPTs were asked why the rate of reaction decreased with time at constant temperature (Question 24), 47% of the SPTs in the experimental group gave the correct answer that “concentration of reactants decreased.” As shown in Table 7, only 12.5 % of the SPTs in the control group answered it correctly. The common misconceptions related to this concept among control group SPTs were that “activation energy decreased” (31.3%) and “all catalyst was consumed” (25.0%). However, no SPTs in the experimental group held the latter misconception.

Table 7. Item 24

<i>Alternatives</i>	<i>Control group</i>
	<i>Percent correct</i>
A	25.0
B	31.3
C	12.5
D	18.8
E*	12.5
<i>Total</i>	<i>100</i>

(*) Correct

When SPTs were asked which quantities are constant in chemical reaction (Question 6), 62.5% SPTs in the control group correctly answered “mass, types, and number of atoms.” However, 57% of the experimental group SPTs responded to the same question correctly. As shown in Table 8, 18.8% of the control group SPTs answered “only mass,” 12.5% stated “volume, mass, mole, type and number of atom, number of molecules,” and 6.3% stated “volume, mass, mole, type and number of atom.”

Table 8. Item 6

<i>Alternatives</i>	<i>Control group</i>
	<i>Percent correct</i>
A	18.8
B	0
C*	62.5
D	6.3
E	12.5
<i>Total</i>	<i>100</i>

(*) Correct

4. Discussion and Conclusions

The results indicate that SPTs’ prior understanding of these chemistry topics was similar between groups. However, it differed in terms of their reasoning type. Most SPTs in the experimental group were concrete reasoners, while most of those in the control group were formal reasoners. Thus, the presence of concrete reasoners in the present study supports Fetsco and McClure (2005)

views that most adolescents do not develop formal operational reasoning, and that this reasoning stage is uncommon. However, at the end of the intervention, SPTs' SRA were not measured again through a post-test.

There was a significant difference between the understanding of the chemistry concepts among concrete and formal reasoners, favoring concrete reasoners. Thus, the chemistry understanding of concrete reasoners was higher than that of other SPTs.

There was a significant mean difference between concrete and formal reasoners in terms their chemistry understanding in favor of concrete reasoners. The mean chemistry post-test score of concrete reasoners was higher than that of formal reasoners in CBLL. Moreover, the mean chemistry post-test score of formal reasoners was higher than that of concrete reasoners in the TL group. Nevertheless, CBLL was more helpful for concrete reasoners because they had the opportunity to understand abstract concepts. Meanwhile, formal reasoners did not perform as highly in the CBLL because they are accustomed to TL. In terms of TL, formal reasoners performed well because they like listening and lecturing, but concrete reasoners did not, because they could not understand abstract concepts from lecturing and TL. Differences related to the SPTs' understanding could come from differences in their SRA. The present study results suggest that CBLL and TL should be designed to promote both concrete and formal reasoners' understanding.

In this study, we found no significant difference between experimental and control group SPTs in terms of their understanding of the chemistry topics. Thus, when SPTs' reasoning abilities were not considered, no significant difference was found between the experimental and control groups' chemistry understanding. According to the results, it is suggested that while designing intervention for promoting SPTs' chemistry understanding, researchers should be aware of SPTs' reasoning abilities.

We examined the proportion of correct responses on the CCT of the experimental and control group SPTs. On most items, SPTs in both groups had some misconceptions. On some items, the experimental group SPTs had misconceptions after CBLL. The reason for this could be the duration of the study. Moreover, the proportion of correct responses on chemistry topics in experimental group SPTs was higher than that of control group SPTs. For example, SPTs had the following misconceptions: "when volume increases two times, mole decreases by half of the original volume" and "the rate of reaction decreases with time at constant temperature because activation energy decreases." Thus, it could be stated that CBLL was more effective in the remediation of misconceptions than TL.

According to the results of this study, CBLL was not significantly effective in promoting SPTs' understanding (post-test scores) or eliminating misconceptions about the chemistry topics. However, SPTs' post-CCT scores in the CBLL were higher than those of the TL. This result is similar to that of Monahan and Yew (2002), who assessed case-based learning in a veterinary parasitology laboratory and found that students' practical exam results were similar to those obtained in their previous laboratory type. More research is needed to determine the reason for this. It might have to do with the duration of the instruction, where SPTs did not have sufficient time to develop an understanding of these chemistry concepts. This study was conducted for three months, so SPTs could not integrate their prior knowledge with scientific understanding or link cases with the concepts; thus, they were unable to construct scientific knowledge. SPTs were instructed with CBLL for the first time, and so may have had difficulty connecting daily life cases with abstract concepts. Furthermore, the number of cases might not have been sufficient for

construction of these chemistry concepts. Kelly and Finlayson (2007) found that first-year undergraduate chemistry students developed their scientific understanding and content knowledge in problem-based learning with laboratories through one year of study in comparison with TL. Thus, it could be suggested that the duration of CBLL should be increased. A third reason might be that TL is as effective as CBLL. TL could elicit SPTs' active participation by constructing their knowledge. In the TL, SPTs worked in groups so they could share their ideas with each other.

TL could also enhance SPTs' understanding of the chemistry topics and might be effective for eliminating misconceptions. Some studies have shown the effectiveness of TL, like that of Özmen, Demircioğlu, and Coll (2009). They found that laboratory activities with concept mapping were effective for understanding and eliminating misconceptions about acid-base chemistry in comparison with traditional instruction involving a lecture-type format and using a textbook for examples and illustrations. Our results suggest that when case-based learning is implemented in the laboratory, it could be as effective as TL. SPTs could integrate scientific concepts with daily life and construct scientific concepts through CBLL as in TL; SPTs could construct scientific knowledge by doing hands-on experiments, thereby integrating scientific concepts.

CBLL, properly implemented, can remediate misconceptions. The number of cases presented to SPTs should be increased in order to provide sufficient time for constructing their knowledge and covering all concepts in the topics. Thus, it could be suggested that CBLL should be implemented over a longer period. During CBLL, SPTs should read cases and prepare before the laboratory. They should also have experience working in small groups. Each group member should have equal responsibility for analyzing the cases. In discussion, SPTs consider other group members' ideas and views. The instructor should be experienced in implementing case-based learning instruction, and should guide SPTs effectively to focus on the case topic. Otherwise, the implementation will not proceed well. During discussion, the teacher should give equal opportunities to each group to contribute. In this study, concrete reasoners constructed their knowledge well on some chemistry topics through CBLL. It is suggested that the development of SRA should be investigated and case-based learning instruction should be applied to other abstract chemistry topics. Furthermore, the effectiveness of case-based learning instruction over case-based learning laboratory should be examined in order to develop SPTs' chemistry understanding.

References

- Akkuş, H. (2004). *The effect of conceptual change texts on chemical equilibrium achievement*. Unpublished doctoral dissertation, Gazi University, Ankara.
- Akkuş, H., Kadayıfçı, H., Atasoy, B., & Geban, Ö. (2003). Effectiveness of instruction based on the constructivist approach on understanding chemical equilibrium concepts. *Research in Science & Technological Education*, 21(2), 209–227.
- Araz, G., & Sungur, S. (2007). Effectiveness of problem-based learning on academic performance in genetics. *Biochemistry and Molecular Biology Education*, 35, 448–451.
- Ateş, S. (2002). *Sınıf öğretmenliği ve fen bilgisi 3. sınıf öğrencilerinin bilimsel düşünme yeteneklerinin karşılaştırılması*. Paper presented at the 5th Congress of National Science and Mathematics, Ankara, Turkey.

- Ateş, S., & Çataloğlu, E. (2007). The effects of students' reasoning abilities on conceptual understandings and problem-solving skills in introductory mechanics. *European Journal of Physics*, 28, 1161–1171.
- Basheer, A., Hugerat, M., Kortam, N., & Hofstein, A. (2017). The Effectiveness of Teachers' Use of Demonstrations for Enhancing Students' Understanding of and Attitudes to Learning the Oxidation-Reduction Concept. *Eurasia Journal of Mathematics, Science & Technology Education*, 13(3), 550-570.
- Cavallo, A. M. L., Potter, W. H., & Rozman, M. (2004). Gender differences in learning constructs, shifts in learning constructs, and their relationship to course achievement in a structured inquiry, yearlong college physics course for life science majors. *School Science and Mathematics*, 104, 288–300.
- Çam, A., & Geban, Ö. (2013). Effectiveness of case-based learning instruction on students' understanding of solubility equilibrium concepts. *Hacettepe Üniversitesi Eğitim Fakültesi Dergisi*, 44, 97-108.
- Çam, A. & Geban, Ö. (2017). Effectiveness of case-based learning instruction on pre-service teachers' chemistry motivation and attitudes toward chemistry. *Research in Science & Technological Education*, 35(1), 74-87.
- Fetsco, T., & McClure, J. (2005). *Educational psychology: An integrated approach to classroom decisions*. New York: Pearson Education Inc.
- Geçer, K. (2005). *Some difficulties faced in the laboratory practices of natural science lessons*. Unpublished master thesis, Yüzüncü Yıl University, Van, Turkey.
- Gürses, A., Açıkyıldız, M., Doğar, Ç., & Sözbilir, M. (2007). An investigation into the effectiveness of problem-based learning in a physical chemistry laboratory course. *Research in Science & Technological Education*, 25(1), 99–113.
- Herreid, C. F. (1998). Sorting potatoes for Miss Bonner: Bringing order to case-study methodology through a classification scheme. *Journal of College Science Teaching*, 27(4), 236–239.
- Hinkle, D. E., Wiersma, W., & Jurs, S. G. (1998). *Applied statistics for the behavioral sciences*. Boston: Houghton Mifflin.
- Jonassen, D. H. (1994). Thinking technology. *Educational Technology*, 34(4), 34–37.
- Kelly, O., & Finlayson, O. E. (2007). Providing solutions through problem-based learning for the undergraduate 1st year chemistry laboratory. *Chemistry Education Research and Practice*, 8, 347–361.
- Koenig, K., Schen, M., & Bao, L. (2012). Explicitly targeting pre-service teacher scientific reasoning abilities and understanding of nature of science through an introductory science course. *Science Educator*, 21(2), 1–9.
- Lawson, A. E. (1978). The development and validation of a classroom test of formal reasoning. *Journal of Research in Science Teaching*, 15, 11–24.
- Lawson, A. E. (2003). *The neurological basis of learning, development and discovery*. London: Kluwer Academic.

- Lawson, A. E. (2004). The nature and development of scientific reasoning: A synthetic view. *International Journal of Science and Mathematics Education*, 2(3), 307–338.
- Lee, C. Q., & She, H. C. (2010). Facilitating students' conceptual change and scientific reasoning involving the unit of combustion. *Research in Science Education*, 40(4), 479–504.
- Limón, M., & Mason, L. (2002). *Reconsidering conceptual change. Issues in theory and practice*. Dordrecht, Germany: Kluwer.
- Lorsbach, A. W., & Tobin, K. (1992). Constructivism as a referent for science teaching. In F. Lorenz, K. Cochran, J. Krajcik, & P. Simpson (Eds.), *Research matters...to the science teacher*. NARST monograph no. 5. Manhattan, KS: National Association for Research in Science Teaching.
- Monahan, C. M., & Yew, A. C. (2002). Adapting a case-based, cooperative learning strategy to a veterinary parasitology laboratory. *Journal of Veterinary Medical Education*, 29(3), 186–192.
- Moser, S., Zumbach, J. & Deibl, I. (2017). The effect of metacognitive training and prompting on learning success in simulation-based physics learning. *Science Education*, 101, 944-967.
- Oliva, J. M. (2003). The structural coherence of students' conceptions in mechanics and conceptual change. *International Journal of Science Education*, 25(5), 539–561.
- Özmen, H., Demircioğlu, G., & Coll, R. (2009). A comparative study of the effects of a concept mapping enhanced laboratory experience on Turkish high school students' understanding of acid-base chemistry. *International Journal of Science and Mathematics Education*, 7(1), 1–24.
- Piraksa, C., Srisawasdi, N., & Koul, R. (2014). Effect of gender on student's scientific reasoning ability: A case study in Thailand. *Procedia-Social and Behavioral Sciences*, 116, 486–491.
- She, H. C., & Liao, Y. W. (2010). Bridging scientific reasoning and conceptual change through adaptive web-based learning. *Journal of Research in Science Teaching*, 47(1), 91–119.
- Soylu, H. (2006). *The effect of gender and reasoning ability on the students' understanding of ecological concepts and attitude towards science*. Unpublished master thesis, Middle East Technical University, Ankara, Turkey..
- Sungur, S., & Tekkaya, C., (2003). Students' achievement in human circulatory system unit: The effect of reasoning ability and gender. *Journal of Science Education and Technology*, 12, 59–64.
- Tarhan, L., Kayali, H. A., Urek, R. O., & Acar, B. (2008). Problem-based learning in 9th grade chemistry class: "intermolecular forces." *Research in Science Education*, 38(3), 285–300.
- Yenilmez, A., Sungur, S., & Tekkaya C. (2006). Students' achievement in relation to reasoning ability, prior knowledge and gender. *Research in Science & Technological Education*, 24 (1), 129–138.

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