International Journal on New Trends in Education and Their Implications
April 2013 Volume: 4 Issue: 2 Article: 19 ISSN 1309-6249

AN INVESTIGATION OF CHEMISTRY STUDENT TEACHERS' UNDERSTANDING OF CHEMICAL EQUILIBRIUM

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ABSTRACT

The purpose of the study is to investigate chemistry student teachers' levels of understanding and alternative conceptions concerning chemical equilibrium. The study was conducted with totally 97 chemistry student teachers (16 from first grade, 15 from second grade, 22 from third grade, 22 from fourth grade and 22 from fifth grade) who are enrolled in the department of secondary science education of Fatih Faculty of Education at KTU. A test, consisting of 13 two-tier multiple choice questions, was used to collect data. The first tier is a question with three choices, while the other tier involves four possible reasons for all possible answers in the first tier. The questions in the test were taken from literature related to chemical equilibrium. The results of the present study confirmed many alternative conceptions that had been identified in previous studies and showed that fourth-year student teachers are more successful than the other classes.

Key Words: Chemistry Education, Chemical Equilibrium, Student Teacher.

INTRODUCTION

Students develop their concepts and construct their own theories based on their experiences, attitudes, background, and abilities before coming to school (Nakhleh, 1992). These concepts and theories which are brought to classroom by students are usually different from scientific conceptions. Students' self-constructed ideas have been called in literature as misconceptions, alternative conceptions, preconceptions, naive conceptions etc. (Nakhleh, 1992). There have been many studies on students' understanding of basic chemical concepts. The studies have revealed that many of students have difficulties in understanding chemistry concepts and hold a lot of alternative conceptions (Demircioğlu et al., 2004). One of the most important reasons for this is that chemistry concepts are abstract in nature and require abstract reasoning. Another reason is that chemistry concepts generally require that students must be able to use representations in three different levels: *macroscopic, microscopic, and symbolic levels* (Johnstone, 2000). Macroscopic level refers to what can observe with our senses. We can observe the macroscopic events. Microscopic level refers to what is actually taking place at the particulate level in a chemical reaction involving the movement of electrons during bond breaking and bond forming. We cannot observe chemical changes taking place in this level. For this reason, students have difficulty explaining chemistry phenomena in the microscopic level and tend to attribute the macroscopic properties of matter to its microscopic particles (Ben-Zvi, Eylon and Silberstein, 1986). Symbolic level refers to the symbolic representations of atoms, molecules, and compounds used in writing chemical formulae and equations. Students have more difficulty in learning microscopic and symbolic representations than macroscopic one because these levels are invisible and abstract.

In the literature, one of the chemistry concepts often studied is chemical equilibrium. It is considered to be one of the most difficult concepts to teach and to learn because it relates a number of chemistry concepts such as oxiditation-reduction, acid and base, reaction rate and solubility equilibrium, and requires to use representations at macro, micro and symbolic levels (Yıldırım et al., 2011). The results of studies in the literature show that most students in different age levels retain many alternative conceptions about chemical equilibrium (Hackling and Garnett, 1985; Huddle et al., 2000; Piquette and Heikkinen, 2005; Solomonidou and Stavridou, 2001; Voska and Heikkinen, 2000). Some of alternative conceptions discovered in these studies are: "the concentrations of all species at equilibrium are equal"; "the more the value of equilibrium constant increases, the more the rate of reaction increases"; "the rate of forward reaction increases until equilibrium is established".

And also, literature shows that student teachers hold alternative conceptions about a number of basic science concepts (Demircioğlu and Baykan, 2012; Yadigaroğlu and Demircioğlu, 2012). Wandersee et al. (1994) claim that teachers often have similar alternative conceptions with their students. And also, teachers can transfer their alternative conceptions to their students (Wilson and Williams, 1996). So, an investigation of chemistry student teachers' alternative conceptions on chemistry concepts would be worthwhile. The major aim of this study is to investigate chemistry student teachers' levels of understanding and alternative conceptions concerning chemical equilibrium.

METHOD

The Sample

The sample consisted of 97 chemistry student teachers in the department of secondary science education of Fatih Faculty of Education at KTU. All student teachers voluntarily participated in the present study. The numbers of the participants ranged from grade 1 to grade 5: 16 from grade 1, 15 from grade 2, 22 from each of grade 3, 4, and 5.

Data Collection

In this study, Chemical Equilibrium Concept Achievement Test (CECAT) has been used to collect data. The test consisting of 13 two-tier multiple choice questions has been taken from literature related to chemical equilibrium (Özmen, 2008; Tyson et al, 1999). In the test, the first tier is a question with three choices, while the other tier involves four possible reasons for all possible answers in the first tier. This type of tests has often been used to determine students' alternative conceptions in science education. Third question randomly selected from the test is presented below as an example. This question is about reversible reactions.

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Question 3:

Carbon monoxide and hydrogen react according to the following equation.

$CO_{(g)} + 3H_{2(g)} \rightleftharpoons CH_{4(g)} + H_2O_{(g)}$ When 0,02M CO and 0,03 M H_2 are introduced into a vessel at 800 K and allowed to come to equilibrium, what can we say about the rate of reverse and forwad reactions at equilibrium?

(a)* the rates are equal

(b) forwad reaction rate is greater than the reverse one

(c) reverse reaction rate is greater than the forwad one

Reason

(1) forwad reaction goes to completion before the reverse reaction starts

(2)* the rates of the forwad and reverse reaction are equal when the system reaches equilibrium

(3) as time passes, concentrations of products increase
(4) at the begining, the concentrations of reactants are greater than concentrations of products

*Correct option and reason

The conceptual areas covered by the test are presented in Table 2. The pilot study of the test was conducted with 52 undergraduate chemistry students. Cronbach's alpha reliability coefficient was found as 0,71 for this study.

Table 2: The Conceptual Areas Each Test Item in CECAT Attempts to Measure

Subject areas	item no
Le Chatelier's Principle	4, 12, 13
Reach to equilibrium	3, 7, 8
The equilibrium constant	1, 5, 11
Heterogeneous equilibrium	2, 9
Effect of catalyst	6, 10

Data Analysis

In this study student teachers' responses to the items are categorized as; *correct option-correct reason, correct option-wrong reason, wrong option-correct reason* and *wrong option-wrong reason*. Students' responses are scored by giving 3 points for *correct option-correct reason; 2 points for correct option-wrong reason;* 1 point for *wrong option-correct reason;* 0 point for *wrong option-wrong reason*. Thus, total score of the test is found 39. This type of scoring was used in other research as well in the literature (Demircioğlu et al., 2004). In statistically analysis of data, ANOVA and Tukey's HSD were used because there were five different groups (grade 1, 2, 3, 4, and 5).

RESULTS AND DISCUSSIONS

The descriptive statistics obtained from the test used in the present study are presented in Table 3. As can be seen in Table 2, while the highest mean belongs to grade 4 chemistry student teachers (M=19.56; S.D: 5.73), the lowest mean belongs to grade 2 chemistry student teachers (M=12.53; S.D: 5.76). The overall mean (15.93) of groups is lower than anticipated (Table 2).

Table 2: The mean and standard deviation values of given answers for items in the test

Grade	N	Mean	S.D.	Min.	Max.
Grade 1	16	13.12	6.32	7	26
Grade 2	15	12.53	5.76	6	23
Grade 3	22	16.54	6.06	6	27
Grade 4	22	19.56	5.73	10	30
Grade 5	22	16.03	6.10	9	25
Total	**97**	**15.93**	**6.14**	**6**	**30**

The ANOVA is used to determine whether there are any significant differences among the group means. Tukey's HSD post hoc test is used in order to determine which groups differ from each other. The ANOVA and Tukey's HSD results are presented in Table 3.

Table 3: The results of ANOVA and Tukey's HSD.

	Sum of Squares	df	Mean Square	F	p	Tukey's HSD
Between Groups	613.545	4	153.386	4.75	0.02	Grade 4 - Grade 1 Grade 4 - Grade 2
Within Groups	3003.363	93	32.294			
Total	3616.908	97				

As seen in Table 3, the results of ANOVA show that there are statistically significant differences between the means of sample groups ($F(4;93)= 4.75$; $p=0.02$). Tukey's HSD results shows that the differences between the means of grade 4 chemistry student teachers and grade 1 and 2 chemistry student teachers in favor of the grade 4 are statistically significant at 0.05 level.

Analysis of the results obtained from CECAT shows that students do not have a satisfactory understanding of the chemical equilibrium. For the first tier of the items, the range of correct choice is 24.7 % to 57.7% (Table 4). When the both tiers are combined, students' correct responses are decreased to a range of 6.1 % to 52.5 %. As seen in Table 4, the percentages of student teachers' correct responses for both content choice and combination are generally under 50 %.

Table 4: Percentages of Content Choice and Correct Combination

Items	Correct choice for first tier	Correct choice for both tiers
1	49.4	32.9
2	37.1	34
3	40.2	26.8
4	54.6	24.7
5	44.3	35
6	57.7	52.5
7	45.3	42.2
8	39.1	6.1
9	25.7	22.6
10	50.5	47.4
11	38.1	27.8
12	24.7	8.2
13	35	9.2

Ten alternative conceptions held by at least 20% of the sample were identified through analysis of items on the TISAC and presented in the Table 5. The percentages of alternative conceptions ranged from 23.7% to 46.3%.

Table 5: The Percentages of Students' Alternative Conceptions Determined in the Test

Alternative conceptions	f	%
When a catalyzer is added to a system in equilibrium, K_{eq} increases.	30	33.3
When the temperature is changed, whether the reaction is endothermic or exothermic does not affect the equilibrium.	31	31.9
When a catalyzer is added to a system in equilibrium, concentration of reactants and products increases.	26	26.8
At equilibrium system, forward reaction rate is not equal to reverse reaction rate	36	37.1
Forwad reaction goes to completion before the reverse reaction starts	32	32.9
At equilibrium, no reaction occurs	45	46.3
When a substance is added to equilibrium system, equilibrium will shift to the side of addition	23	23.7
At equilibrium, the concentration of reactant is equal to the concentration of products	40	41.2
Concentration of solids are included in the equilibrium constant	28	28.8
Le Chatelier's principle can be applied to all systems, including heterogeneous equilibrium systems	25	25.7

The main aim of this study is to investigate chemistry student teachers' levels of understanding and alternative conceptions concerning chemical equilibrium. Chemical equilibrium is a difficult concept in which students in all grade levels have misconceptions. In this study the results show that chemistry student teachers hold significant misconceptions about chemical equilibrium. These misconceptions are related to changing equilibrium conditions (temperature, concentration), effect of catalysts, Le Chatelier's principle and characteristics of equilibrium. For example, some chemistry student teachers think that *temperature changes do not affect the equilibrium* (Table 5). When the literature checked, same result is reported in a number of studies (Akkuş et al., 2003; Özmen, 2007, 2008; Şendur et al., 2011; Voska and Heikkinen, 2000). Another misconception is about effect of catalyzer on a system at equilibrium (Table 5). They think that *when a catalyzer is added to equilibrium system K_{eq} increases* and *when a catalyzer is added to equilibrium system, concentration of reactants and products change* (Table 5). This results are consistent with the findings in the literature (Bilgin and Geban 2001; Voska and Heikkinen, 2000). 37.1% of student teachers think that at equilibrium system, *forward reaction rate and reverse reaction rate are not equal* (Table 5). After a careful examination of available science education literature, this result is reported in the studies of Coştu and Ünal (2005) and Bilgin et al. (2003). 25.7% of the sample think that *Le Chatelier's principle can be applied in all systems, including heterogeneous equilibrium systems* (Table 5), similar misconceptions reported in the related literature (Özmen, 2007, 2008). While 46.3% of students' teachers think that *at equilibrium, no reaction occurs*, 23.7% of them think that *when a substance is added to equilibrium system, equilibrium will shift to the side of addition* (Table 5). Similar misconceptions are reported in the related literature (Özmen, 2007, 2008). Another misconception determined in this study is *at equilibrium, the concentration of reactant is equal to the concentration of products* (Table 5). In the literature, Canpolat et al. (2009) reported similar misconception.

CONCLUSION AND RECOMMENDATION

The results of this study show that chemistry student teachers have many alternative conceptions about basic principles and concepts of the chemical equilibrium. These alternative conceptions are parallel to literature. Two-tier multiple choice tests are useful instruments that can be used by teachers to identify their students' preconceptions and evaluate their instruction.

There are several methods using teaching of chemistry such as concept mapping, simulations, laboratory activities, analogies, conceptual change texts, worksheets (Harrison and Treagust, 2000; Özmen, Demircioğlu and Coll, 2009). Many reports indicate that these methods are useful for teaching some chemistry concepts such as chemical equilibrium (Chiu et al., 2002; Özmen, 2007; Sandberg and Bellamy, 2004; Yıldırım et al., 2011). Some of these methods are good for high ability students and some of them for low ability students. Lecturers can adapt these methods in to their lessons. A combination of different methods may develop students' understanding of chemical equilibrium and help to change their misconceptions. Students' misconceptions should be taken into account during the curriculum development and curriculum developers should develop new teaching materials about the chemical equilibrium. Lecturers and curriculum developers should give more examples related to daily life, in this way many chemistry topics like chemical equilibrium can be learn easily.

IJONTE's Note: This article was presented at 4th International Conference on New Trends in Education and Their Implications - ICONTE, 25-27 April, 2013, Antalya-Turkey and was selected for publication for Volume 4 Number 2 of IJONTE 2013 by IJONTE Scientific Committee.

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International Journal on New Trends in Education and Their Implications
April 2013 Volume: 4 Issue: 2 Article: 19 ISSN 1309-6249

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