WCES-2010

Evaluating the effect of teaching chemical equilibrium based on analogy and laboratory on students' achievement

Nagihan Yıldırım, Yasemin Şengün, Zeliha Ceng, Alipaşa Ayas

Fatih Education Faculty, Karadeniz Technical University, Trabzon, 61335, Türkiye

Received October 6, 2009; revised December 15, 2009; accepted January 4, 2010

Abstract

The main aim of this research is to find out the effect of analogy and laboratory based instructions on student achievement about chemical equilibrium in comparison with traditional instruction. Semi-experimental research method was used. The sample was composed of 65 students from a high school in Trabzon. The classes were randomly determined as two experimental groups and one control group. A concept Test, semi-structured interview and unstructured observation were used as data gathering instruments. At the end of the study a significant difference was found in favor of the laboratory group over analogy, and a significant difference was found in favor of the experimental groups over the control groups.

Keywords: Four-step constructivist teaching strategy; analogy; laboratory; dynamic structure of equilibrium; success.

1. Introduction

A number of studies research in the related literature about students’ conceptions of the chemistry have identified common misconceptions of the nature of the chemical equilibrium held by students (Wheeler ve Kass, 1978; Yıldırım, 2000; Sepet vd., 2004; Quilez, 2004). Because, this topic includes abstract concepts and some words used in everyday language have different meanings create problems in understandings, for example in daily life have static nature. Some students see chemical equilibrium macroscopically as a stable and static system too. On the other hand, at microscopic level the system is dynamic not only because of molecular movement but also the process of breaking and creating bonds go on with the net result of zero. So the materials and teaching technologies which help students to understand the dynamic nature of chemical equilibrium are important for better learning. The main aim of this research is to find out the effect of analogy and laboratory based instructions on student achievement about chemical equilibrium in comparison with traditional instruction.

2. Method

A semi-experimental research methodology was used in this study. The sample was composed of 65 students from 3 different classes of year 11 from an high school in city the center of Trabzon. The study was carried out in the fall
term of 2008-2009 academic year. The classes in the schools were randomly determined as two experimental groups and one control group. In one of the experimental groups the subjects were thought with teacher guide material, based on analogy (ABGM) and in the other experimental group the subjects were thought with teacher guide material, based on laboratory (LBGM). Each teacher guide materials consists of five lesson plans for teachers and five worksheets for students. And in control groups the subjects were thought in the normal way.

2.1. The Data Gathering Instruments and the Data Analyzing Methods

Concept Test on Chemical Equilibrium, semi-structured interview and unstructured observation were used as data gathering instruments. The test was developed by Yıldırım and the others, (2007). The Test consist of 16 two tier questions. Concept Test on Chemical Equilibrium was applied as pre-test and post-test. The answers of students to the Concept Test on Chemical Equilibrium were compared in and between groups with Statistical Package for the Social Sciences (SPSS 10.0). In the comparisons between the groups were analyzed with Kruskall Wallis and Man Whitney U tests. The semi-structure interviews were conducted with three students of the each experiment groups. Three questions were asked to the students and the answers of the students were recorded. The mutual interactions between student-student and student- teacher were observed with unstructured observations. The datas which gained form interviews and observations were analyzed by descriptive methods.

3. Results (Findings)

3.1. The results gained from Chemical Equilibrium Concept Test

The comparisons between groups’ pre and post tests’ results were given in this section with Tables 1, 2, 3, 4 and 5.

The results of the analysis in Table 1 shows that there was no significant difference among the pre-test scores of the three groups ($K^2(2)= 0.46, p>.05$). When the mean ranks of the groups are considered, there were no significant differences among the groups as well. The analysis results in Table 2 shows that there was a significant difference among the average post test scores of the groups ($K^2(2)= 16.56, p<.05$). The results of Mann Whitney U test, conducted to detect what is the source of this difference, are presented below in Table 3 and 4.

Concerning the analysis results in Table 3, there was no significant difference between the final test scores of the ABGM and LBGM groups ($U=167.5; p>.05$). When the analysis results in Table 4 are examined, there was not a significant difference between the post test scores of ABGM and control groups ($U=138.00; p>.05$). Considering the results in Table 5, it can be said that there is a significant difference between the post test scores of the LBGM and control group students ($U=74.00; p<.05$), favoring LBGM group.
3.2. The findings obtained by the semi-structured interviews carried out with the students in ABGM and LBGM groups.

In the interview, the students were first given the information that H₂ and I₂ molecules are let undergo reaction by providing suitable conditions in a closed system and reached equilibrium and after a while they form hydrogen iodide and reach equilibrium. Then the students were asked to draw which substances are there in the reaction container at the beginning, at the equilibrium moment and after equilibrium for this reaction.

Table 6. The examples of the answers the first question given by the students in ABGM and LBGM groups

<table>
<thead>
<tr>
<th>S.C</th>
<th>The students’drawings</th>
<th>The students’explanations</th>
</tr>
</thead>
<tbody>
<tr>
<td>SA1</td>
<td><img src="image1.png" alt="Image" /></td>
<td>The reactants start to decrease and the products start to form, towards equilibrium the forward reaction and reverse reaction rates approach to each other and get equal; equilibrium is reached. Following the equilibrium the forward and reverse reactions go on but they cannot be observed because the reaction rates are the same.</td>
</tr>
<tr>
<td>SA2</td>
<td><img src="image2.png" alt="Image" /></td>
<td>The reaction starts with hydrogen and iodine. There are H₂ and I₂ in the reaction container. Then they separate and bind and form HI. HI form H₂ and I₂ while H₂ and I₂ form HI. These events cannot be observed because the rate of reactant conversion to product and the rate of product conversion to reactant are the same. There are three substances in the reaction medium.</td>
</tr>
<tr>
<td>SL1</td>
<td><img src="image3.png" alt="Image" /></td>
<td>At the beginning, there are H₂ and I₂ molecules in the medium. Until the equilibrium is reached, one ion approaches and binds to the other by effective collisions and HI is formed at the equilibrium. On the other hand, at the same time formed HI goes on decomposing into H₂ and I₂. That is, both forward and reverse reactions continue and forward and reverse reaction rates get equal. And again all three substances exist in the medium. But observable events are over however forward and reverse reactions still continue.</td>
</tr>
<tr>
<td>SL2</td>
<td><img src="image4.png" alt="Image" /></td>
<td>Since they are put at the beginning, there are H₂ and I₂, then they undergo reaction. As collision theory say, HI is formed as a result of the effective collisions, the reaction from the reactant goes on. Then the reaction from products to reactants starts, when reverse reaction rate becomes equal to the forward one the equilibrium happens. HI again decompose into H₂ and I₂ and there are hydrogen and iodine in the reaction medium.</td>
</tr>
</tbody>
</table>

S.C : students codes, SA1,SA2, SA3, SL1,SL2,SL3

In the second question of the interview, the reaction; \( \text{HEAT} + \text{N}_2\text{O}_4(g) \rightleftharpoons 2\text{NO}_2(g) \) is given to the students and they were asked to draw concentration versus time graphs during the process until the equilibrium is reached for the cases of; adding some more N₂O₄ gas into the medium under the constant temperature and volume, increasing the temperature with constant volume, decreasing the volume with constant temperature. The drawings, the students made about this question are presented in Table 7.

Table 7. The examples of the students’ answers of the ABGM and LBGM groups to the second question.

<table>
<thead>
<tr>
<th>S.C</th>
<th>Equilibrium Changes of the concentration</th>
<th>Changes of the temperature</th>
<th>Changes of the volume</th>
<th>Equilibrium Changes of the concentration</th>
<th>Changes of the temperature</th>
<th>Changes of the volume</th>
</tr>
</thead>
<tbody>
<tr>
<td>SA1</td>
<td><img src="image5.png" alt="Image" /></td>
<td><img src="image6.png" alt="Image" /></td>
<td><img src="image7.png" alt="Image" /></td>
<td>S</td>
<td>L</td>
<td>1</td>
</tr>
<tr>
<td>SA3</td>
<td>No drawings</td>
<td>No drawings</td>
<td>No drawings</td>
<td>S</td>
<td>L</td>
<td>3</td>
</tr>
</tbody>
</table>

S.C : students codes, SA1,SA2, SA3, SL1,SL2,SL3

Examining Table 7, it can be observed that generally students drew concentration vs. time graph right for the process until \( \text{HEAT} + \text{N}_2\text{O}_4(g) \rightleftharpoons 2\text{NO}_2(g) \) Reaction reaches the equilibrium. However SA3, in his/her drawing, described as the reactants are used up completely and amount of products increases continuously. SA1, SA2, SL1 and SL3 made right drawings for the case some more N₂O₄ gas was added to the medium under the constant temperature and volume. In their graphs, N₂O₄ concentration increased then decreased by time and finally got
constant but the final concentration is higher than the initial one; and NO2 concentration increased for a while and then became constant. On the other hand SA3 and SL2 made no drawings. Only SA3 could not draw anything for the case temperature was increased under constant volume and the case volume was reduced with constant temperature. The rest of the students made right drawings for the cases.

In the third question of the interviews; the students were given \( \text{CuCl}_4^{2-} + 4\text{H}_2\text{O(s)} \rightleftharpoons \text{Cu(H}_2\text{O)}_4^{+2} + 4\text{Cl}^- + \text{HEAT} \) reaction and the changes happened as results of some effects. Then the students were asked to interpret what might be these effects. \( \text{CuCl}_4^{2-} \) is green and \( \text{Cu(H}_2\text{O)}_4^{+2} \) is a blue solution. Table 8 shows the student answers about when the solution turned into green and when it was blue.

<table>
<thead>
<tr>
<th>Turned into green</th>
<th>To addition from the product</th>
<th>To increase the temperature</th>
<th>To remove from the reactant</th>
<th>Turned into blue</th>
<th>To addition from the reactant</th>
<th>To decrease the temperature</th>
<th>To remove from the reactant</th>
</tr>
</thead>
<tbody>
<tr>
<td>SA1,SA2,SA3,SL1,SL2,SL3</td>
<td>SA1,SA2,SA3,SL1,SL2,SL3</td>
<td>SA2,SL2,SL3</td>
<td>SA1,SA2,SA3,SL1,SL2,SL3</td>
<td>SA2,SL2,SL3</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

S.C : students codes : SA1,SA2,SA3,SL1,SL2,SL3

When Table 8 is examined, the students generally expressed that the effect, which affected the equilibrium and caused the solution turned into green, might be adding product substances or increasing the temperature. However SA2, SL2 and SL3 added that removing some of the reactant substances might also cause the solution got green. For the rest of the question, the students discoursed that the reason which made the solution blue might be adding substance to reactants and decreasing the temperature. SA2, SL2 and SL3, in addition, reported that as a result of removing some products, the solution might also turn into blue. Besides, when the students were asked whether a change related to pressure is possible, all of them noted that the substances in the reaction medium are solutions and since there is no gases it is out of question.

4. Discussion

With the framework of the present study, the Chemical Equilibrium Concept Scale was applied on experimental and control group students on pre and post test basis. Kruskal Wallis Test made to evaluate the pre-test scores of the groups showed that there were no significant differences among the pre-test scores of the three groups \((2)= 0.46, p>.05\). This shows that; prior to the application the students in experimental and control groups were equivalent in terms of achievement on chemical equilibrium concepts. Again Kruskal Wallis test showed that there were significant differences among the post-test scores of the groups \((K^2(2)= 16.56, p<.05)\). Mann Whitney U Test results, which were applied on pairs to detect what was the origin of the differences, showed that there were no significant differences between LBGM-ABGM and ABGM-Control groups \((U=167.5, U=138.0; p<0.05)\). However between LBGM-Control groups there was a significant difference favoring the students in LBGM group \((U=74; p<.05)\). This situation shows that the students in LBGM group had a higher achievement level towards chemical equilibrium concepts than the students in control group. Backed with this piece of finding, it can be said that instruction based on laboratories and animations is more effective than traditional and analogy based instruction in students’ learning the concepts about the chemical equilibrium (Sançayır, 2007). Teacher is generally lecturer and students are passive listeners in traditional instructional process. However in learning environments based on analogy and laboratory, students actively participate to instructional process. During this process, students use tools as much as possible, they observe, record data and conclude. These deeds of students are important in terms of converting abstract knowledge into concrete knowledge and learning. Previous studies have also underlined that such activities support meaningful learning and facilitate the instruction of issues, which are referred as hard issues and including abstract concepts like chemical equilibrium (Ayas et al., 1994; Çepni et al., 1995; Böyük and Erol, 2008).

When the student answers to the first question of the interview were examined, it was determined that the students generally were able to explain the events taking place during the reaction but SL1 and SL2 could not reflect these explanations into their drawings. This situation might stem from instruction and question solving methods, which the students were previously accustomed to. As a matter of fact it is a well-known fact that only the right answer is expected from the students in traditional learning environments. They are scarcely asked to explain or give
reasons for their answers with different presentations (drawings or graphs). While SA3 was answering this question, it was determined that he/she gave explanations and made drawings as if there were two different reactions going on as in one; HI is formed out of H₂ and I₂ until the equilibrium point and after that point H₂ and I₂ are formed from HI in the second. The same student, in the third question, drew a concentration vs. time graph in which the reactants are used up and the amount of products increase and he could not answer the rest of the question. This situation tells that the student could not manage the transition from one way reactions to reversible reactions. There have been studies in the literature proving that the phenomena happening on the equilibrium point are abstract for students and students have difficulties even after the instruction (Banerjee and Power, 1991; Banerjee, 1995; Ayas and Demirbaş, 1997; Voska and Heikkinen, 2000; Bilgin and Geban, 2001; Chiu et al., 2002; Akkuş vd., 2003; Canpolat et al., 2006).

Based on the observations during the implementation, it was concluded that students thought that they were going to have an examination and got nervous when the worksheets were first distributed, which we take as a good indicator of the fear of examination induced on the students in our country. It was also observed that the students in LBGM group assisted each other better; they began to work more systematically in the group lesson by lesson, and they managed better work-share in their groups than the students in ABGM group. The previous studies also determined that laboratory environment supports interest to lesson and chemistry achievement by group-work, assisting, taking responsibilities, observation and trail-and-error activities (Ayas et al., 1994; Üce and Şahin, 2001; Özmen and Yıldırım, 2005).

5. Conclusion and recommendation

As a result of the conducted study, it was determined that Laboratory based Teacher Guidance Materials (LBGM) increased student achievement about this concept better than the students in the group instructed with analogy based traditional education. This result refreshes the importance of laboratory based activities for chemistry course. Therefore, laboratory based activities for the other concepts in chemistry curriculum should be given importance. However, considering that it is not possible to find laboratory based activities for all chemistry concepts, the activities based on analogies could also be used. Actually, the observations and interviews showed that analogy based activities have some positive effects over students’ learning related concepts, even though they are not as effective as laboratory based instruction.

References