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EFFECTIVENESS OF ANALOGIES ON STUDENTS' UNDERSTANDING OF CHEMICAL EQUILIBRIUM

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Abstract

This study investigates the effect of analogy-based instruction (ABI) versus traditional instruction on students' understanding of chemical equilibrium in a first-year general chemistry course. A quasi-experimental design was used in the study. The study utilized a pre-test/post-test design and one comparison group (CG) and one experimental group (EG) were used in the study. In the study, a delayed-test was also implemented to both groups' students in addition to pre- and post-tests. Each treatment (analogy and traditional) was randomly assigned. The study was carried out in two different classes in the department of science and engineering during the 2009–2010 academic years at Marand Azad University in Iran. In Iran, chemical equilibrium has been studied in fourth year in chemistry course of secondary school. Participants in the study were 65 university students who enrolled in the general chemistry course, from the two classes of the same teacher. One class was randomly assigned to the experimental group (n=30) while the other was the control group (n=35). Twelve analogies were used in experimental group. Four of them were adapted from the literature and the others were prepared by the researchers. During a five-week period; each group received an equal amount of instruction. The Chemical Equilibrium Achievement Test (CEAT) was administered as pre-test, post-test and delayed-test to collect data. The CEAT consisted of 20 multiple-choice questions prepared by the researchers. Collected data were analyzed by using t-test and ANCOVA. The results of the study indicated that the students in the experimental group showed significantly greater achievement than the students in the control group. Based on the results, we can say that analogies can help students visualize abstract concepts, organize their thinking about a given topic, and learn a topic meaningfully.

Keywords: Chemistry education, chemical equilibrium, analogy

INTODUCTION

There are several methods using in teaching of chemistry such as concept mapping, concrete models, simulations, laboratory activities, multimedia representations, conceptual change texts, animations (Harrison &Treagust, 2000; Özmen, Demircioğlu & Coll, 2009). Analogies are one of these methods. Analogies can help students build conceptual bridges between what is familiar and what is new. Studies about analogies have shown that analogies cause a significantly better acquisition of scientific concepts than the traditional instruction and help students integrate knowledge more effectively (Bilgin & Geban, 2001; Glynn, 2007; Piquette & Heikkinnen, 2005). In addition, many reports indicate that analogies may be useful for teaching target concepts that are conceptually difficult or abstract (Duit, 1991). Using analogies is not new in education; they have been used through the ages by researchers to help students understand theoretical concepts (Huddle, White & Rogers, 2000).

Simply, an analogy is a comparison between two domains of knowledge-one that is familiar and one that is less familiar. The familiar domain is often referred to as the "vehicle," "base," "source," or "**analog**" domain; the less familiar domain, or the domain to be learned, is usually referred to as the "**target**" domain. According to Gentner (1989), an analogy is a mapping of knowledge between two domains such that the system of relationships that holds among the objects in the analog domain also holds among the objects in the target domain. Thus, the purpose of an analogy is to transfer a system of relationships from a familiar domain to one that is less familiar (Mason & Sorzio, 1996). Analogies are most often used in an educational setting to help students for understanding new information in terms of already familiar information and to help them relate that new information to their already existing knowledge structure (Beall, 1999).

In chemistry, chemical equilibrium occupies a central place. Although there are several concepts about which students have difficulty, chemical equilibrium is considered to be one of the most difficult topics in general chemistry curriculum (Solomonidou & Stavridou, 2001; Piquette & Heikkinen, 2005; Özmen, 2008), owing to its abstract character, its demand of a mastery of a large number of subordinate concepts (Quilez-Pardo & Solaz-Portoles, 1995) and the essential role in developing an understanding in other areas of chemistry such as acid-base behavior, solubility, and oxidation-reduction reactions (Voska & Heikkinen, 2000). Although there have been many studies investigating the students' understanding and alternative conceptions related to chemical equilibrium, there is a lack of studies that focus on determining the effect of different instructional approaches in understanding chemical equilibrium. Recently, for example, Solomonidou and Stavridou (2001) and Saricayir, Sahin and Uce (2006) investigated the effect of computer animations on students' understanding of chemical equilibrium. In addition, Canpolat et al. (2006) and Özmen (2007) investigated the effect of conceptual change tests on students' understanding of chemical equilibrium. Pekmez Sahin (2010) used analogies to prevent students' misconceptions about chemical equilibrium. On the other hand, there were many analogies which explained the dynamic aspect of chemical equilibrium such as dancing couples, two groups throwing the balls/apples back and forth, fish between two aquariums and bees in a beehive (Russel, 1988; Sarantopoulos & Tsaparlis, 2004). In this paper, we tried to use several analogies including dynamic equilibrium, reversibility, equality of rates, calculation of equilibrium constant and the application of Le Chatelier's principle, based on assumption that analogies may help students learn abstract concepts by visualization (Treagust & Chittleborough, 2001). With this regard, a major aim of this study was to determine the effects of analogies on students' understanding of chemical equilibrium. Depending on this aim, these research questions were addressed: Is there any significant difference in test scores;

- ✓ between pre-tests of experimental and control groups?
- ✓ between post-tests of experimental and control groups?
- ✓ between delayed-tests of experimental and control groups?

METHODOLOGY

Method

A quasi-experimental design was used in this study. The study utilized "a pre-test/post-test non-equivalent comparison group design" and one comparison group (CG) and one experimental group (EG) were used in the study. In quasi-experimental research design, each group is given both a pre-test and a post-test, measuring the dependent variable both before and after exposure to the independent variable. In this study, a delayed test was also implemented to both groups in addition to pre- and post-tests.

Sample

The study was carried out in two different classes in the department of science and engineering during the 2009–2010 academic years at Marand Azad University in Iran. Participants were 65 university students who enrolled in the general chemistry course, from the two classes of the same teacher. One class was randomly assigned to the experimental group (n=30) while the other formed the control group (n=35).

Instruments

Chemical Equilibrium Achievement Test (CEAT): CEAT consisted of 20 multiple-choice items was used in the study to collect data. While some of the questions in CEAT were taken from the literature (Özmen, 2008), the others were prepared by the researchers. Six conceptual areas, namely physical and chemical equilibrium, reversible reaction, Le Chatelier's principle, equilibrium constant, heterogeneous equilibrium and disturbing a chemical equilibrium were evaluated in the study. Two chemistry educators and three experienced chemistry teachers examined the instrument for content validity. The reliability of the CEAT based on Cronbach's alpha was 0.80. One example of the test questions are presented below.

Procedure

While the experimental group was taught with the analogical instruction, the control group was taught with traditional instruction. During a five-week period; each group received an equal amount of instruction. Duration of the lesson was four 45-minute periods in a week. Twelve analogies were used in experimental group. Four of them were adapted from the literature and the others were prepared by the researchers.

In the study, the same topics were covered for both experimental and control groups. In general, students were given equal opportunities to perform the activities in each group. The control group received traditional instruction which involves lessons using lecture methods to teach the concepts. Teaching strategies based on teacher explanation and textbooks, with no direct consideration of the students' alternative conceptions. The students studied the textbooks individually before the lesson. Students in the experimental group worked with analogical instruction. Harrison and Coll's (2008) Focus-Action- Reflection (FAR) model was used to teach each topic and topics were developed from an analysis of chemistry textbooks to provide the most adaptable to classroom teaching. At the instruction time, FAR model was used step-by-step and twelve analogies were analyzed. During the instruction, some analogies were showed directly to students and it was assisted to them both join the lesson and make relation between basic chemical equilibrium concepts and analogies by the help of some questions.

At the end of presented analog and target concepts again. So the students who found incorrect relation between analog and target concepts re-organized their opinions.

Data Analysis

In the analysis, each of the questions was given 2 points, so a student can collect 40 points totally if (s)he responds the all of the questions correctly. Dependent and independent t-test and ANCOVA were used for the statistically analysis.

RESULTS and DISCUSSION

As seen in Table 1, in the pre-test, there is no statistical difference between the control and experimental group in terms of success ($t = 0.093$, $p = 0.654$). It means there were no differences between groups at the beginning. There are statistically significant difference between groups in post-test, which indicating the successful nature of the experimental group compared to the control group ($t = 26.42$, $p = 0.000$). This result is similar to that reported in the literature, which suggest that analogy-based teaching improves student understanding toward chemistry (Pekmez Sahin, 2010). The results of the delayed-test reflected that mean score of experimental group was higher than the control group one and there was significant differences between groups ($t = 13.53$, $p = 0.001$). This result showed that teaching with analogies caused a significantly better acquisition of the concept than the traditional instruction. The main difference between the two methods was that the analogies oriented instruction explicitly dealt with students' pre- and alternative conceptions relating chemical equilibrium while the traditional method did not.

Table 1. Independent group t-test result for pre, post and delayed test scores of CEAT

	Pre-test		Post-test		Delayed-test	
	EG	***CG***	***EG***	***CG***	***EG***	***CG***
N	***30***	***35***	***30***	***35***	***30***	
Mean (20 item)	***24.7***	***23.9***	***38.1***	***33.2***	***36.0***	***27.4***
Standard Deviation	***12.9***	***11.3***	***8.1***	***8.4***	***8.9***	***10.5***
t	***.093***		***26.42***		***13.53***	
p	***P= 0.654 >0.05***		***P= 0.000 <0.05***		***P= 0.001 <0.05***	

After the delayed test was conducted to the both group students, the analysis of covariance (ANCOVA) was used to compare the retention of the knowledge acquired during the intervention. In this analysis, post-test scores were used as covariate to control the group differences. The results of ANCOVA showed significant main affects for treatments on students' retain their knowledge ($F(1,62)=68.14, p< 0.05$). Although the students' CEAT scores in both groups decreased from posttest to delayed test, the decrease in the EG students' scores is lower than in the CG ones. Specifically, while the mean score of students in the EG decreased from 38.1 to 36, a drop of 2.1, the mean score of the students in the CG decreased from 33.2 to 27.4, a drop of 5.80. The adjusted mean score of the EG was 30.42 on delayed test and that of the CG was 25.64 (Table 2).

Table 2. Summary of ANCOVA on students' delayed test scores

	Experimental group			*Control group*			*F*
	Mean	***SD***	***Adj. Mean***	***Mean***	***SD***	***Adj. Mean***	
Post-test	***38.1***	***8.1***		***33.2***	***8.4***		***68.14****
Delayed- test	***36.0***	***8.9***	***30.47***	***27.4***	***10.5***	***25.64***	

Significant at p<0.05

DISCUSSION

The use of analogies to teach chemical equilibrium has been discussed for many years. In the literature, there were different analogies for the explanation of chemical equilibrium, but these analogies represented specific aspects of chemical equilibrium, such as dynamic aspect and the application of Le Chatelier's principle (Raviolo & Garritz, 2009). In other words, a few analogies demonstrate both other aspects of chemical equilibrium like the macroscopic, the submicroscopic and the symbolic level, equality of rates, reversibility, catalyze effect, constant equilibrium and its dynamic aspect and the application of Le Chatelier's principle. The findings of this study proved that although there were no significant differences between experimental and control groups before the instruction ($p>0.05$), significant differences were found between groups after the instruction ($p<0.05$). According to the results of the post-test and delayed-test, mean scores of experimental groups were higher than the control groups. These results showed that teaching with analogies has a positive effect on students' understanding and that teaching with analogies is an effective method for higher learning achievement. Previous studies in that an analogical instruction can facilitate learning of scientific concepts supports these results (Chiu & Lin, 2005; Çalık & Ayas, 2005; Iding, 1997; Tsai, 1999). Teaching with analogies allows students to actively participate in the learning process. Analogies can help students relate new information to prior knowledge, to integrate information for one subject area into another, and to relate classroom information to everyday experiences. In this process, students observe, record data and conclude that these skills are important in terms of converting abstract knowledge into concrete knowledge, learning and overcoming alternative conceptions. Previous researchers have also emphasized that analogies support meaningful learning and help students to construct topics easily; these are referred to as hard issues and include abstract concepts like chemical equilibrium (Harrison & Jong, 2005; Kargiban & Siraj, 2009; Newton, 2003). The literature also suggests that analogies not only help students to become conscious of their own alternative conceptions, but also enable them to refute their alternative conceptions and accept scientific ideas (Orgill & Bodner, 2004). On the other hand, some researchers suggest that any method has insufficiencies when they use single and using the same methods frequently may fail to produce effective results (Huddle, White & Rogers, 2000; Orgill & Bodner, 2004; Türk & Çalık, 2008). Based on this knowledge, we suggest that a combination of different methods may enhance students' understanding of chemical equilibrium and help to alter their alternative conceptions.

REFERENCES

Beall, H. (1999). The ubiquitous metaphors of chemistry teaching. *Journal of Chemical Education*, 76, 366-368.

Bilgin, I. & Geban. Ö. (2001). The effects of analogies to overcome misconceptions about chemical equilibrium. *Hacettepe University Journal of Education*, 20, 26-32.

Canpolat, N., Pinarbasi, T., Bayrakceken, S. & Geban, O. (2006). The conceptual change approach to teaching chemical equilibrium. *Research in Science &Technological Education*, *24*(2), 217 – 235.

Chiu, M. H. & Lin, W. (2005). Promoting fourth graders' conceptual change of their understanding of electric current via multiple analogies. *Journal of Research in Science Teaching*, 42(4), 429-464.

Çalık, M. & Ayas, A. (2005). An analogy activity for incorporating students' conceptions of types of solutions. *Asia Pacific Forum on Science Learning and Teaching*, 6(2), Article 6, www.ied.edu.hk/apfslt/.

Duit, R. (1991). On the role of analogies and metaphors in learning science. *Science Education*, 75, 649-672.

Gentner, D. (1989). The mechanisms of analogical learning. In S. Vosniadou and A. Ortony (Eds.). Similarity and analogical reasoning. pp. 199-241. Cambridge, MA: Cambridge University Press.

Glynn, S. M. (2007). The teaching with analogies model. *Science and Children*, 44(8), 52-55.

Harrison, A. G. & Treagust, D. F. (2000). Learning about atoms, molecules, and chemical bonds: A case study of multiple-model use in grade 11 chemistry. *Science Education*, 84, 352–381.

Harrison, A. & Jong, O. (2005). Exploring the use of multiple analogical models when teaching and learning chemical equilibrium. *Journal of Research in Science Teaching,* 42(10), 1135–1159.

Harrison, A. & Coll, R. (eds.), (2008). Using analogies in middle and secondary science classrooms, California: Corwin Press.

Huddle, A. P., White, W. M. & Rogers, F. (2000). Simulations for teaching chemical equilibrium. *Journal of Chemical Equilibrium*, 77(7), 920-926.

Iding, M. K. (1997). How analogies foster learning from science texts. *Instructional Science*, 25, 233–253.

Kargiban, A. Z. & Siraj, S. (2009). A pedagogical development model on chemistry teaching through computer-assisted and guided inquiry. *Word Applied Sciences Journal*, 6(4), 570-578.

Mason, L. & Sorzio, P. (1996). Analogical reasoning in restructuring scientific knowledge. *European Journal of Psychology of Education*, 11, 3-23.

Newton, L. (2003). The occurrence of analogies in elementary school science books. *Instructional Science,* 31, 353–375.

Orgill, M. & Bodner, G. (2004). What research tells us about using analogies to teach chemistry. *Chemistry Education: Research and Practice*, 5(1), 15–32.

Pekmez Sahin, E. (2010). Using analogies to prevent misconceptions about chemical equilibrium. *Asia-Pacific Forum on Science Learning and Teaching*, 11(2), 1-35.

Piquette, J. S. & Heikkinnen H. W. (2005). Strategies reported used by instructors to address student alternate conceptions in chemical equilibrium. *Journal of Research in Science Teaching*, 42(10), 1112–1134.

Quilez-Pardo, J. & Solaz-Portoles, J. (1995). Students' and teachers' misapplication of Le Chatelier's principle: Implications for the teaching of chemical equilibrium. *Journal of Research in Science Teaching, 32*, 939-957.

Özmen, H. (2007). The effectiveness of conceptual change texts in remediating high school students' alternative conceptions concerning chemical equilibrium. *Asia Pacific Education Review*, 8(3), 413-425.

Özmen, H. (2008). Determination of students' alternative conceptions about chemical equilibrium: A review of research and the case of Turkey. *Chemistry Education: Research and Practice*, 9, 225-233.

Özmen, H., Demircioğlu, G. & Coll, R. K. (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, 1–24.

Özmen, H., Demircioğlu, H. & Demircioğlu, G. (2009). The effects of conceptual change texts accompanied with animations on overcoming11th grade students' alternative conceptions of chemical bonding. *Computers and Education*, 52, 681–695.

Özmen, H. (2011). Effect of animation enhanced conceptual change texts on 6th grade students' understanding of the particulate nature of matter and transformation during phase changes. *Computers and Education*, 51, 423–438.

Raviolo, A. & Garritz, A. (2009). Analogies in the teaching of chemical equilibrium: a synthesis/analysis of the literature. *Chemistry Education: Research and Practice*, 10, 5-13.

Russell J. (1988). Simple models for teaching equilibrium and Le Chatelier's principle. *Journal of Chemical Education, 65*, 871-872.

Sarantopoulos, P. & Tsaparlis, G. (2004). Analogies in chemistry teaching as a means of attainment of cognitive and affective objectives: a longitudinal study in a naturalistic setting, using analogies with a strong social content. *Chemistry Education: Research and Practice*, 5, 33-50.

Saricayir, H., Sahin, M. & Uce, M. (2006). Dynamic equilibrium explained using the computer. *Eurasia Journal of Mathematics, Science and Technology Education, 2*(2), 130-137.

Solomonidou, C. & Stavridou, H. (2001). Design and development of a computer learning environment on the basis of students' initial conceptions and learning difficulties about chemical equilibrium. *Education and Information Technologies, 6*(1), 5-27.

Treagust D. F. & Chittleborough G. (2001). Chemistry: A matter of understanding representations, In Brophy, J. (ed.) *Subject-specific instructional methods and activities,* Elsevier Science Ltd., Amsterdam, The Netherlands.

Tsai, C. C. (1999). Overcoming junior high school students' misconceptions about microscopic views of phase change: a study of an analogy activity. *Journal of Science Education and Technology*, 8(1), 83–91.

Türk, F. & Çalık, M. (2008). Using different conceptual change methods embedded within 5E model: A sample teaching of endothermic-exothermic reactions. *Asia-Pacific Forum on Science Learning and Teaching*, 9(1), 1-10.

Voska, K. & Heikkinen, H. (2000). Identification and analysis of students' conceptions used to solve chemical equilibrium problems. *Journal of Research in Science Teaching*, *37*(2), 160-176.