The effect of the constructivist method on pre-service chemistry teachers' achievement and conceptual understanding about aqueous solutions

El efecto del constructivismo y la comprensión conceptual sobre las soluciones acuosas de los estudiantes de licenciatura de química

DENIZ SARIBAS, FITNAT KÖSEOGLU

Graduate School of Institute of Educational Science, Department of Chemistry Education, Gazi University, Ankara, Turkey
Faculty of Education, Department of Chemistry, Gazi University, Ankara, Turkey
denizsaribas@yahoo.com, fitnat@gazi.edu.tr

Abstract

This paper will present a report discussing the effects of teaching methods on university students' conceptual change and achievement about aqueous solutions. For this purpose concept test (CT) and achievement test (AT) were developed. In this study, pre-test and post-test control group design was used. AT and CT were conducted both as pre and post-tests while TOLT (test of logical thinking) and PKT (prior knowledge test) were conducted only as pre-tests. The sample was assigned to two treatment classes, one of which was experimental group and the other was control group. The experimental group was instructed by the constructivist approach and the control group was taught by the traditional method. Results indicate that only an appropriate teaching strategy provides students' conceptual development rather than prior knowledge. Students' reasoning ability did not have a significant effect on either their achievement or conceptual change about aqueous solutions.

Key words: *constructivist, aqueous solutions, achievement, conceptual.*

Resumen

Este trabajo presenta un informe de los efectos de la enseñanza con métodos de cambios conceptuales y el logro de los estudiantes de la universidad para comprender las soluciones acuosas. Fueron desarrolladas, la prueba de concepto (CT) y la prueba de aprovechamiento (AT). En este estudio, fueron usados la prueba preliminar y el diseño de grupo de control posprueba. AT y CT fueron dirigidos como pre- y pospruebas, mientras TOLT (la prueba de la idea lógica) y PKT (la prueba de conocimientos previa) fueron dirigidos solamente como pruebas preliminares. La muestra fue usada en dos grupos *(grupo experimental y de control). En el grupo experimental se utilizó el enfoque constructivista, y en el grupo de control - el método tradicional. Los resultados indican que solamente las estrategias de enseñanza apropiadas proveen el desarrollo conceptual de los estudiantes en vez de conocimientos previos. La habilidad de razonamiento de los estudiantes no tenía un efecto importante sobre sus logros o el cambio conceptual sobre las soluciones acuosas.*

***Palabras clave**: constructivismo, soluciones acuosas, logro, conceptual.*

INTRODUCTION

The concepts that were studied under the topic of aqueous solutions are closely related to each other. Furthermore, the understanding of the ionization and solubility concepts requires the grasping of concepts concerning atoms, molecules and ions, in other words understanding at the particulate level (Nakhleh & Krajcik, 1994). Therefore, one can conclude that aqueous solution chemistry requires a deep understanding of atoms, molecules and ions. However, traditional teaching approaches seem to have some problems in helping the students comprehend the chemical events at the particulate level, in other words, to obtain a conceptual knowledge.

Constructivist learning theory focuses on the learner and is based on the view that the learner has the responsibility of his/her own learning. According to this theory, the learners should actively participate in the learning process in order to formulate the meanings in their minds and to understand them (Treagust, 1991; von Glasersfeld, 1995; Staver, 1998; Shiland, 1999; Zarotiadou & Tsaparlis, 1999; Schneider, Krajcik, Marx & Soloway, 2002; Hugerat, Zidani & Kurtam, 2003). From the constructivist point of view, the learners construct new knowledge by relating the new objects and phenomena to existing ones (Treagust, 1991; Hewson, 1992; Driver, 1995; Niaz, 1995; Osborne, 1996; Kelly, 1997; Shiland, 1999).

A significant characteristic of constructivism is constructing a hypothesis. It is extremely important for an active learner to generate and test hypotheses and to draw conclusions in a learning process, in order to acquire scientific knowledge (Osborne, 1996).

Another significant component of constructivism is social interaction. Over the last few years, there has been a growing emphasis on the process of interaction in learning (Driver, 1995). A growing number of researchers claim that new knowledge is built up by means of social interchange in its many forms (Driver, 1995; Staver, 1998; Shiland, 1999). Student-to-student and teacher-to-student interaction is very important in this respect. The teacher should guide the students to interact with him/her and each other, provide learning situations that reveal the students' alternative conceptions and create a cognitive conflict in the students' minds (Treagust, 1991).

Because of these characteristics, the constructivist method seems to be a hopeful approach to science education for giving the students opportunity of having a conceptual understanding.

The purpose of the present study is to compare the effectiveness of the constructivist approach to that of the traditional method on students' achievement and conceptual understanding of aqueous solution chemistry. It is suggested that the teaching strategy based on the constructivist approach would foster concept acquisition, and that appropriate activities designed for the constructive framework would facilitate the learning of the nature of the chemical processes.

METHODOLOGY

Sample

Thirty-four students entering the Analytical Chemistry-I course at Gazi University Gazi Faculty of Education, Department of Chemistry Education in the 1st semester of 2002-2003 participated in this study

The population was randomly assigned into two instructional treatment classes, one of which was control group and the other was experimental group; each consisted of 17 students. The control group was taught by the traditional method, while the experimental group was instructed by the constructivist method.

PROCEDURE

The classroom instruction was carried over a three week period with two hours per week for each group. To minimize the teacher effect, the same instructor taught the two groups. The researcher was present during all the instructional times and always available for consultation.

The instruction was given to each group about the subjects of electrical conductivity of solutions, chemical equilibrium, precipitation reactions and acids and bases under the topic of aqueous solution chemistry. During the instruction, it was intended that all the students acquire the subjects and the concepts in the 7th chapter of the Foundations of Analytical Chemistry textbook (Skoog, West & Holler; 1996).

The students in the control group were taught the topics and the concepts in the 7th chapter of the Foundations of Analytical Chemistry textbook (Skoog, West & Holler; 1996) in the same sequence as this textbook with a traditional approach during the period of the study.

The text and the sequence of application suggested by the researcher were taken into consideration, and this set precedent was used during the instruction of the experimental group. The teaching strategy suggested in this study was applied to the text that the students in experimental group were given. The researcher, following the sequence of the instruction, distributed each sheet of the text to the students page by page. Using this method proved that the students answered the questions by applying their prior knowledge and creating discussion with each other; it also prevented the students reading the sheets and instead focused their attention to the lesson. The sequence of the topics taught to the experimental group was as follows:

1. Electrical conductivity of solutions.
2. Chemical equilibrium.
3. Precipitation reactions.
4. Acids and bases.

In order to provide the integrity of the subjects and avoid the chaos of the concepts in the learners' minds, the students in the experimental group were taught chemical equilibrium and precipitation reactions before acids and bases as a counterproposal to this textbook. Another reason of changing the sequence of the subtopics during the instruction of the experimental group was to apply the stages of the teaching strategy based on the constructivist view.

The lessons in control group were mostly teacher-centered and student-to-student and teacher-to-student interactions were at minimum level. Although the concepts were sometimes discussed in the classroom, no additional attempt was made to construct the concepts.

The method conducted in experimental group was characterized by the construction of hypotheses, obtaining data to test the hypotheses, social interaction of students and constructing new ideas by the students themselves. The lessons given in the experimental group began with the presentation of the phenomenon. The phenomena presented in this study were of some materials, reactions and pictures on the chalkboard and in the texts given to the students. Soon after the presentation students were asked some questions about this phenomenon. It was intended to make the students apply to their prior knowledge, and discuss the answers with each other in order to answer these questions and construct their own hypotheses. The materials of symbolic and molecular pictures, an analogy and an experimental demonstration were used in the lessons for the experimental group in order to make the students portray the chemical events in their minds and construct their hypotheses. The instructor guided the students instead of directing, but when she noticed them inclining towards a misconception she presented new pictures or phenomena to the students and asked them some other questions.

In the present study, pre-test and post-test control group design was used. Students' reasoning ability and prior knowledge of chemistry were assessed prior to the instruction as pre-tests. Their performance on the achievement and conceptual knowledge about aqueous solutions was assessed as pre-tests and post-tests.

INSTRUMENTATION

Reasoning Ability: Students' reasoning ability was determined by using the Test of Logical Thinking (TOLT) (Tobin & Capie, 1981). The TOLT test consisted of 10 items that tested 5 logical operations, each of which had two items, including proportional reasoning, probabilistic reasoning, controlling variables, correlational reasoning and combinatorial reasoning. TOLT test was applied to both the control and the experimental group before instructions only as a pre-test. The alpha reliability coefficient of the TOLT test is 0.80. In the present study, TOLT test was used as a covariate in ANCOVA analysis to determine whether the TOLT test had a significant effect on the scores of post-test of AT (achievement test) and CT (concept test), rather than categorizing students with respect to their reasoning ability.

Prior Knowledge: Prior knowledge test (PKT) was prepared by the researcher to determine the students' general chemistry knowledge that constituted the basis of the aqueous solution chemistry. The items of the PKT were adapted from the tests of University of Wisconsin-Madison Chemistry Department, U.S. National Chemistry Olympiad National Test and U.S. National Chemistry Olympiad Local Test by the researcher. This test consisted of 21 multiple-choice items and assessed student achievement with regard to electron configurations of atoms, chemical bonding, electrochemistry, chemical reactions, reaction rate, solubility and precipitation. PKT included both algorithmic and conceptual questions. PKT was applied to both the control and the experimental groups only as a pre-test. This test has a maximum score of 21. The PKT test has an alpha reliability coefficient of 0.61 and it was used as a covariate in ANCOVA analysis.

Achievement: Achievement test (AT) was designed by the researcher to evaluate the students' achievement with respect to the topics and the principles of aqueous solution chemistry. The AT test was designed to include the topics and the principles of the 7th Chapter, the topic of Aqueous Solutions in the Foundations of Analytical Chemistry textbook (West, Skoog & Holler, 1996). The items of the AT test were adapted from the tests of U.S. National Chemistry Olympiad National Test, U.S. National Chemistry Olympiad Local Test and various Analytical Chemistry and General Chemistry textbooks by the researcher. This test consisted of 25 multiple-choice questions and has a maximum score of 25. AT assessed the students' retention of definitions of some concepts, their factual knowledge and their problem solving applications of the concepts about aqueous solutions. This test required students to define some concepts and to recall algorithmic formulas to solve the problems. AT was applied to both the control and the experimental group as a pre-test and post-test. The alpha reliability coefficient of AT test is 0.68.

Conceptual Knowledge: Students' conceptual knowledge about aqueous solutions was assessed by concept test (CT) that was prepared by the researcher. The content of this test was determined on the basis of the concepts of the 7th Chapter, the topic of Aqueous Solutions in the Foundations of Analytical Chemistry textbook (West, Skoog & Holler, 1996). The items of the CT were adapted from the tests of U.S. National Chemistry Olympiad National Test, U.S. National Chemistry Olympiad Local Test, various Analytical Chemistry and General Chemistry textbooks and some literatures (Niaz, 1995; Orna, 1994). This test consisted of 22 multiple-choice questions and has a maximum score of 22. CT required students to comprehend the chemical events at the particulate level, to apply the concepts about aqueous solutions presented in the instruction to new situations and to apply reasoning strategies in order to generate solutions to the new problems. This test was applied to both the control and the experimental group as a pre-test and post-test. The CT test has an alpha reliability of 0.69.

RESULTS AND DISCUSSION

The data obtained from the study were assessed by using SPSS (Statistical Package for the Social Sciences) program. ANCOVA and t-test were utilized to assess the hypotheses. In the present study, ANCOVA was used in order to find the factors affected the post-test scores and minimize the error. The hypotheses were tested in the 0,95 confidence interval. Table-1 shows means and the standard deviations of the scores of the pre-tests. The results of t-tests showed that there were no significant differences between the control and the experimental groups in terms of their achievement and conceptual knowledge about aqueous solutions, reasoning ability and prior knowledge.

Table 1
Mean Scores and Standard Deviations of the Pre-Tests

	Group	N	Mean	Std. Deviation
Concept Test	Experimental	17	8,4706	3,5552
	Control	17	8,1176	3,2955
Achievement Test	*Experimental*	17	10,7059	3,197
	Control	17	12,4118	3,7593
Prior Knowledge Test	*Experimental*	17	14,6471	2,9779
	Control	17	14,1765	3,3022
Test of Logical Thinking	*Experimental*	17	5,8824	2,9975
	Control	17	5,00	2,7386

The results of ANCOVA analysis of the AT post-test showed that the scores of the pre-tests, AT and PKT, had a significant effect while the teaching method and the scores of TOLT did not have a significant effect on the scores of the AT post-test. The results of ANCOVA analysis of the post-test of AT are reported in table-3. Table-4 shows the ANCOVA analysis of conceptual change of the two groups. As shown in table-4, the factors that affected the CT post-test results were the teaching method and the CT pre-test results.

Table 2
Mean Scores and Standard Deviations of the AT and CT Post-Test Scores

	Group	N	Mean	Std. Deviation
AT	*Experimental*	17	16,2353	2,7507
	Control	17	16,0588	4,2201
CT	*Experimental*	17	12,9412	2,8825
	Control	17	10,7647	3,2888

Table 3
The Results of ANCOVA Analysis of the AT Post-Test
Dependent Variable: Post Test of AT

Source	Sum of Squares	Df	Mean Square	F	Sig.
Corrected Model	174,346	4	43,587	5,450	0,002
Intercept	43,979	1	43,979	5,499	0,026
TOLT	2,108	1	2,108	0,264	0,612
PKT	33,753	1	33,753	4,221	0,049
Pre Test of AT	70,225	1	70,225	8,781	0,006
Teaching Method	5,663	1	5,663	0,708	0,407
Error	231,918	29	7,997		
Total	9271,000	34			
Corrected Total	406,265	33			

R Squared = 0,429 (Adjusted R Squared = 0,350)

Table 4
The Results of ANCOVA Analysis of the CT Post-Test
Dependent Variable: Post Test of CT

Source	Sum of Squares	Df	Mean Square	F	Sig.
Corrected Model	194,962	4	48,741	9,342	0,000
Intercept	22,642	1	22,642	4,340	0,046
TOLT	4,183E-02	1	4,183E-02	0,008	0,929
PKT	12,455	1	12,455	2,387	0,133
Pre Test of CT	86,486	1	86,486	16,577	0,000
Teaching Method	29,467	1	29,467	5,648	0,024
Error	151,303	29	5,217		
Total	5123,000	34			
Corrected Total	346,265	33			

R Squared = 0,563 (Adjusted R Squared = 0,503)

The results of the present study indicate that students' prior knowledge significantly affected their achievement, but in saying this, it did not affect their conceptual change about aqueous solutions. This result indicates that only an appropriate teaching strategy provides students' conceptual development rather than prior knowledge. The results also showed that students' reasoning ability did not have a significant effect on either their achievement or conceptual change about aqueous solutions.

The results of this study show that the students instructed by the constructivist approach had a significantly better conceptual understanding of aqueous solutions than did the students taught by the traditional method. However there were no significant differences between two groups in terms of their achievement about aqueous solutions. One can interpret this result by the explanation that the students in the control group had an opportunity to have more time practicing and solving problems than did the experimental group, because the student discussions in the classroom and the analogy activities, picture presentations and chemical demonstrations took too much time from the lessons for the experimental group. Another disadvantage of the teaching strategy that is based on the constructivist approach is it requires too much time for the teacher to prepare the materials for the activities before the lesson.

As mentioned before, the sequence of the subtopics was changed during the instruction of the experimental group. The effect of the difference in the sequence of the texts between the two groups to the post-test scores was ignored.

CONCLUSIONS

From the findings of this study, one can conclude that a learning environment should enable the students to communicate with others and construct their own ideas relating to their existing knowledge. The research reported here also points out that a teaching method, which enables the learners to portray the chemical events in their minds, provides a better understanding of the scientific concepts. Analogies, demonstrations and presentations have a crucial role in this respect. In order to make the students understand the particulate level of the chemical processes, the learning environment should provide them to draw a picture in their minds of the atoms, molecules and ions within a chemical process. In this respect, the teachers working within a constructive framework should design appropriate student activities, such as picture presentations. The use of chemical demonstrations in class adds to the student learning experience. There are questions to ask and answer before performing a demonstration (WALTON, 2002). In this way, students will apply their prior knowledge. The demonstrations may also serve to initiate and maintain student interest in science (CASTKA, 1975). Some topics in chemistry are highly theoretical and give learners great difficulty. Thus, the teaching of chemistry lends itself to the use of analogies to explain abstract concepts where the analogies are generally recognized to generate meaning through a constructivist pathway (HUDDLE, WHITE & ROGERS; 2000). The results of some researches suggest that perhaps restructuring the text itself would improve learning (MUSHENO & LAWSON, 1999; YURUK & GEBAN, 2001; ERDMANN, 2001; RUDZITIS, 2003). Considering this point of view, educators should design appropriate texts useful for the instruction. A constructivist learning environment supported with presentations of pictures at the particulate level, chemical demonstrations, analogies and an appropriate text design will improve the conceptual development of other topics of chemistry, which require conceptual understanding rather than algorithmic understanding. More studies about the constructivist approach supported with other activities and materials may bring new insights into students' learning about chemistry.

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