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Facilitating Conceptual Change in Rate of Reaction Concepts Using Conceptual Change Oriented Instruction

Reaksiyon Hızı Konusunda Kavramsal Değişime Dayalı Öğretim Metodu ile Kavramsal Değişimin Oluşturulması

Ebru KAYA* Ömer GEBAN**

Middle East Technical University

Abstract

The purpose of this study was to investigate the effects of conceptual change-oriented instruction through demonstrations (CCOITD) on 11th grade students' understanding of rate of reaction concepts when compared to traditionally designed chemistry instruction (TDCI). The sample consisted of 69 11th grade students from two classes in a public high school. Reaction Rate Concept Test was administered to both groups as a pretest and posttest to assess students' understanding of the concepts. The data was analyzed by using one-way ANOVA. The results show that the experimental group in which CCOITD used had a significantly better acquisition of scientific conceptions related to rate of reaction than the control group.

Keywords: Conceptual Change Oriented Instruction, Rate of Reaction, Misconception, Demonstration.

Öz

Bu çalışmanın amacı, gösteri deneyleriyle desteklenmiş kavramsal değişime dayalı öğretim yönteminin, geleneksel kimya öğretimine kıyasla 11. sınıf öğrencilerinin reaksiyon hızı kavramlarını anlamalarına etkisini incelemektir. Çalışmanın örneklemi, genel bir lisedeki iki kimya sınıfında öğrenim gören toplam 69 on birinci sınıf öğrencisinden oluşmaktadır. Öğrencilerin reaksiyon hızı ile ilgili kavramları anlamalarını değerlendirmek için Reaksiyon Hızı Kavram Testi her iki gruptaki öğrencilere öntest ve sontest olarak uygulanmıştır. Veriler tek yönlü Varyans Analizi (ANOVA) kullanılarak analiz edilmiştir. Sonuçlar, gösteri deneyleri ile desteklenmiş kavramsal değişime dayalı öğretimin geleneksel kimya öğretimi ile kıyaslandığında, reaksiyon hızı ile ilgili kavramların anlaşılmasında daha etkili olduğunu göstermiştir.

Anahtar Sözcükler: Kavramsal Değişime Dayalı Öğretim, Reaksiyon Hızı, Kavram Yanılgısı, Gösteri Deneyi (Demonstrasyon).

Introduction

Science education aims to enhance conceptual understanding of students for performing complex activities such as making scientific explanations (Smith, Blakeslee, & Anderson, 1993). Learning as active construction of students' conceptions (Nieswandt, 2000) occurs in consequence of the interaction between students' current and new conceptions (Linn, 1987). Students' existing knowledge and concepts affect their learning. However, students might have some difficulties while learning science. These difficulties in understanding scientific concepts stem from the misconceptions which students bring with them to the classroom before the instruction (Hewson & Hewson, 1983). Once misconceptions are integrated into a student's cognitive structure, they become an obstacle in his/her learning. Thus, the student has difficulty in connecting new

* Dr. Ebru KAYA, Middle East Technical University, Faculty of Education, Ankara, ebrukaya@gmail.com

** Prof. Dr. Ömer GEBAN, Middle East Technical University, Faculty of Education, Ankara, geban@metu.edu.tr

information into his/her cognitive structure including inappropriate knowledge. In this situation, since new knowledge cannot be integrated to cognitive structure, students develop misconceptions (Nakhleh, 1992). Misconceptions which are not consistent with the accepted explanations, meanings, and theories of science are resistant to change (Novak, 1988). If teachers are aware of their students' misconceptions related to core chemical concepts, they are likely to design their instruction to address and remediate the alternative conceptions of the students (Thomas & Schwenz, 1998). Therefore, during science instruction, considering students' misconceptions has a key role for promoting conceptual change in students.

Understanding many concepts in chemistry is difficult for most students because of the abstract nature of chemistry (BouJaoude, 1991). Therefore, students have many misconceptions in chemistry. Some research have focused on the following subjects: particulate nature of matter (e.g., Griffiths & Preston, 1992), chemical bonding (e.g., Taber, 2003), chemical equilibrium (e.g., Gorodetsky & Gussarsky, 1986), gases (e.g., Cho, Park, & Choi, 2000), heat and temperature (e.g., Harrison, Grayson, & Treagust, 1999).

Rate of reaction as a highly structured topic is a central part of chemistry curriculum (Cachapuz & Maskill, 1987). Therefore, comprehension of concepts with respect to rate of reaction and factors affecting it has a key role in learning of chemistry (Cachapuz & Maskill, 1987; Ragsdale, Vanderhooft, & Zipp, 1998). Because of the abstract nature of the title, students face with difficulties, and also they have some misconceptions about the rate of reaction concepts (deVos & Verdonk, 1986; Justi, 2002). Students are required to conceptualize descriptive, particulate, and mathematical modeling regarding chemical kinetics and the interrelations between them in order to improve their understanding of reaction rate concepts (Cakmakci, Donnelly, & Leach, 2003). In addition, rate of reaction concepts is an essential prerequisite for some chemistry concepts, especially chemical equilibrium. In educational research, although there has been substantial research on students' understanding of chemical equilibrium concepts, there is limited research related to students' understanding of rate of reaction concepts. (e.g. Gorodetsky & Gussarksy, 1986; Van Driel, 2002; Cakmakci, 2005; Calik, Kolomuc, & Karagolge, 2010). Therefore, in this study, students' misconceptions as regards rate of reaction were investigated, and in order to develop students' understanding of this topic, conceptual change oriented instruction was applied.

The conceptual change model is one of the effective methods for coping with misconceptions and for understanding concepts. The **c**onceptual change model which is based on constructivist notion claims that learning is a process of knowledge construction (Cobern, 1996). In this model, as proposed by Posner, Strike, Hewson, and Gertzog (1982), there are four conditions for the accommodation phase to occur: intelligibility, plausibility, fruitfulness, and dissatisfaction with the existing concepts. Intelligibility indicates whether the student knows the meaning of the conception or not. If the conception is intelligible for the student, s/he can find a way of representing that conception. If the student believes that the conception is true, s/he finds that conception as plausible. Thus, that conception gets consistent and more easily accommodated with his/her previous conceptions. According to the fruitfulness condition, a student should believe that the conception solves other problems and suggests new possibilities and ideas (Hewson & Thorley, 1989). Dissatisfaction is related with changes in status of a conception. If a student does not find the conception as plausible or fruitful, s/he is dissatisfied with this conception.

To overcome students' misconceptions, a large amount of research has explored the effects of several instructional tools based on conceptual change approaches in science, such as concept maps (Tekkaya, 2003), conceptual change texts (Sungur, Tekkaya, & Geban, 2001), cooperative learning strategy (Basili & Sanford, 1991), computer assisted instruction (Snir, Smith, & Raz, 2003), analogies (Bozkoyun, 2004), and etc. However there is limited research on the effect of using conceptual change approach through demonstration (Azizoglu, 2004). Demonstration is an effective method used in chemistry classrooms to increase students' conceptual understanding. During a demonstration activity, generally teacher carries out a demonstration about the topic and students observe this activity. Discussions following demonstrations provide opportunity for teacher and students to share their ideas about their observations related to demonstrations, making it easy for students to engage in discourse in classroom and to understand science concepts (Milne & Otieno, 2007). Use of demonstrations as a teaching strategy is based on cognitive conflict strategy encouraging students to engage in conceptual change (Baddock & Bucat, 2008). The key feature of demonstrations based on cognitive conflict strategy is that students' observation is contrary to their expectations. Since chemical principles are emphasized during a demonstration, students can learn basic definitions in chemistry and recall examples regarding these principles (Ophardt, Applebee, & Losey, 2005).

In sum, the purpose of this study is to investigate the effect conceptual change oriented instruction through demonstrations on students' understanding of rate of reaction concepts when compared to traditional designed chemistry instruction.

Research Question

a) Is there a significant mean difference between post-test mean scores of the students taught with conceptual change oriented instruction through demonstrations and the students taught with traditionally designed chemistry instruction with respect to their understanding of rate of reaction concepts?

Methodology

Design

This study was conducted based on quasi-experimental design (Gay & Airasian, 2000). Since it is not possible to randomly assign participants to the groups, intact groups were used in the study.

Participants

The participants of this study consisted of 69 eleventh grade students (27 males and 42 females) from two chemistry classes taught by the same teacher in a public high school. Two teaching methods were randomly assigned to the groups. The experimental group instructed by conceptual change oriented instruction accompanied demonstrations consisted of 34 (15 males and 19 females) students, while the control group instructed by traditionally designed chemistry instruction consisted of 35 (12 males and 23 females) students. The ages of the students in both groups ranged from 16 to 17 years.

Rate of Reaction Concept Test

The test was developed to measure students' understanding of rate of reaction concepts. The Rate of Reaction Concept Test (RRCT) was prepared by considering the instructional objectives of the rate of reaction unit, eleventh grade chemistry textbooks, the questions asked in University Entrance Exam in Turkey and the literature in relation to the misconceptions in rate of reaction subject (e.g. Bozkoyun, 2004; Cakmakci et al., 2003; Calik et al., 2010; Van Driel, 2002). The test contained 25 four-distracter multiple choice items. For every item in the test, the distracters were prepared based on the students' misconceptions about rate of reaction. Some misconceptions considered in RRCT are given below:

- Reaction rate is the time between the beginning and finishing of a reaction.
- Reaction rate is the number of atoms colliding in a unit time.
- For a chemical reaction to occur, the colliding particles should be in gas phase.
- All collisions in gas phases produce a chemical reaction.

• When concentration of a substance increases, its kinetic energy increases; thus, rate of reaction increases.

• When concentration increases, surface area increases; thus, reaction rate increases.

• Reaction rate is independent of reactants' concentration.

• While a reaction occurs, concentration of products increases in time; thus, reaction rate increases.

• Decrease in concentration of one of the reactants increases the concentration of the other reactant; thus, reaction rate is constant.

• Change in temperature does not affect reaction rate.

• When temperature increases, rate of reaction decreases.

• When particle size of reactant is decreased, its volume is decreased and therefore rate of reaction increases.

• Because substances with big particle size move slower than those with small particle size, their reaction rate decreases.

• Catalyst is an intermediate substance which participates in a reaction as a reactant but gets out without affecting the reaction.

• Catalyst is a substance which is formed and then consumed during a reaction.

• The substance which participates in a reaction and gets out as the same substance is an intermediate substance.

• When activation energy of a reaction decreases, reaction rate decreases as well.

• Rate equation of a reaction with mechanism is the form of multiplication of the concentrations of products in the slow step.

• In a reaction with mechanism, activation energy of the slow step is smaller than that of fast step.

• The fast step in the reaction mechanism determines the reaction rate.

For content validity of the test, a group of science education experts and some chemistry teachers examined the test. Some distracters and items were improved by considering the experts' suggestions and interpretations. Before the treatment, RRCT was administered to 195 eleventh grade students from three high schools as a pilot test. The reliability of the test was found as 0.74. After completing the validity and reliability studies, it was administered to the students before the treatment as a pretest and after the treatment as a posttest.

Treatment

This study was conducted over a four-week period. Two classes of the same chemistry teacher participated in this study. One of the classes was assigned as experimental group and the other one as control group randomly. While conceptual change oriented instruction through demonstrations was applied in the experimental group, traditionally designed chemistry instruction was applied in the control group. Before the study, the teacher was trained about conceptual change based instruction. The researcher prepared a lesson plan on conceptual change based instruction for each topic. The researcher explained the lesson plans and the demonstrations to the teacher. During the treatment, rate of reaction topics were covered as part of the regular classroom curriculum in the chemistry course in both groups. The topics covered were rate of reaction and its measurement, collision theory, activation energy, factors affecting rate of reaction (concentration, temperature, catalyst, surface area), and reaction mechanism. The students in both groups used the same chemistry textbook. The teacher also gave the same homework to the students in both groups and solved the same quantitative questions in both groups. At the beginning of the treatment, the students in both groups were administered RRCT as pretests, in order to assess students' understanding of rate of reaction concepts.

In the experimental group, conceptual change oriented instruction through demonstrations (CCOITD) was used. This type of instruction was designed to address students' misconceptions about rate of reaction concepts and to eliminate them by considering four conditions for conceptual change (Posner et. al, 1982), which were dissatisfaction, intelligibility, plausibility, and fruitfulness. The teacher started the lesson by asking some questions related to the topic to the students in order to activate their prior knowledge and misconceptions related to the subject. Students had difficulties in justifying their answers to teacher's questions because of their existing knowledge on this subject. When they realized that their existing conceptions were insufficient in explaining the phenomena, they became dissatisfied with these conceptions (dissatisfaction). For instance, while the effect of temperature on rate of reaction was instructed, at the beginning of the lesson, the teacher asked the students "what will happen, if we increase the temperature of the environment in which a chemical reaction is occurring?" Students gave different answers to this question. Some of their answers were "the activation energy of the reaction will increase, thus, rate of that reaction will decrease" and "because particles will move faster, the possibility of collision among particles and the occurrence of a reaction will decrease".

Then, the concepts were explained through the use of a demonstration related to the concept. For instance, in order to explain the relationship between temperature and rate of a reaction, the teacher performed the designed demonstration named as the effect of temperature on reaction rate. In this demonstration, the reaction between baking soda ($NaHCO_3$, sodium hydrogen carbonate) and vinegar (CH_3COOH, acetic acid), was shown to the students. The rate of this reaction was observed by checking the amount of carbon dioxide gas produced in a determined time interval. This demonstration was performed at three different temperatures: 0 ^{0}C, 25 ^{0}C, and 75 ^{0}C. The rate of the reaction between $NaHCO_3$, and CH_3COOH increased when temperature was increased. At the end of every demonstration, a discussion session was carried out with. The aim of these discussions was to encourage students to establish a link between new concepts and their observations on demonstrations. Thus, since the students observe sample events related to the concepts during their scientific explanation supplied by the teacher, the purpose was to make these concepts more intelligible for the students (intelligibility). After that, new examples, especially examples from daily life, related to this topic were given to the students to enhance their understanding of the rate of reaction concepts thoroughly. For instance, after explaining the effect of increase in temperature on rate of a reaction, the teacher mentioned that we keep some of our foods in the fridge and asked its reason to the students. Thus, since the students were encouraged to use new concepts in solving problems, it was aimed that these concepts were more plausible to the students (plausibility). Finally, the students were asked to use the new concept in explaining a new situation. For this aim, the teacher asked some questions related to the application of new concepts in the classroom or gave homework to the students. Thus, since new concepts helped students to explain unfamiliar phenomena and leads to new insights, these concepts were aimed to be more fruitful to the students (fruitfulness). Totally six demonstrations related to the rate of reaction concepts were prepared by using some chemistry books such as the one written by Herr and Cunningham (1999) and all demonstrations were applied in the same phase (intelligibility) of conceptual change during the instruction in the experimental group. The names of the demonstrations used in the study are: the effect of concentration on reaction rate; the effect of temperature on reaction rate; iodine clock reaction; catalysts, reaction rates, and activation energy; the effect of surface area on reaction rate; and the effect of reactant type on reaction rate.

While using all these activities in the experimental group, traditionally designed chemistry instruction was applied in the control group. During the instruction, the teacher used lecturing and discussion methods in the classroom. The sessions in this group were mainly based on teacher's presentation of the topics. The lessons began with the teacher introducing the topic to the class. When the students did not understand the subject, they asked questions and the teacher made extra explanations by giving daily life examples. However, the teacher taught the subjects without considering students' misconceptions and previous knowledge. After teacher's solving an exercise related to that topic, the students were asked to solve some exercises from either their textbook or other supplementary books. The teacher asked mostly quantitative questions to the students. At the end of the lesson, the teacher made a summary of the topic to clear it up for the students. Finally, some homework was assigned to them. In addition, the teacher distributed worksheets to the students in both groups. Some questions in the worksheet were solved in the classroom and the others were assigned as homework to the students. After treatment, all students were administered Rate of Reaction Concept Test as posttest in order to measure the effect of treatment on students' understanding of rate of reaction concepts.

Results

Independent samples t-test analyses were performed in order to check whether there was a significant mean difference between the experimental group and control group in terms of students' understanding of rate of reaction concepts measured by pre-RRCT. The results show that there was no statistically significant mean difference between the scores of the students in the experimental group and those in the control group regarding students' understanding of rate of reaction concepts ($t\ (69) = 0.634$; $p > 0.05$).

In order to find out the effect of treatment on students' understanding of rate of reaction concepts, one-way Analysis of Variance (ANOVA) was performed at the 0.05 significance level. As summarized in Table 1, the results show that there was a significant mean difference between post-test mean scores of the students in CCOITD group and the students in TDCI group with respect to their understanding of rate of reaction concepts ($F\ (1,67) = 29.192$; $p< 0.05$). CCOITD group scored significantly higher than TDCI group (X (CCOITD) = 18.85; X (TDCI) = 13.97).

Table 1.
ANOVA Summary of Post-RRCT

Source	df	SS	MS	F	p
Treatment	1	410.967	410.967	29.192	0.000
Error	67	943.236	14.078		

When the proportions of correct responses to the questions in the post-RRCT for both groups are examined, it is seen that there was a statistically significant difference in the proportion of correct responses to some questions in the post-RRCT between the experimental and control group. For example, in one of the questions, the students were asked to select the property which was not dependent on temperature during a reaction. Before the treatment, most of students in both experimental group (61.8%) and control group (60%) selected the distracter stating number of molecules that have activation energy. After treatment, while 91.2% of the students in the experimental group correctly answered this question by selecting activation energy as independent of temperature during a reaction, 48.6 % of the students in the control group correctly answered this question. In another question, the students were asked to select the alternative stating the factor and its effect on reaction rate during a reaction. Before treatment, the most selected alternative for this question was that catalyst increased activation energy of the reaction. For example, 50% of the students in the experimental group and 34.3% of the students in the control group selected the alternative stating this misconception before the treatment. However, the percentage of the students in the experimental group who had this misconception was 2.9 and the percentage of those in the control group who had the same misconception was 25.7 after the treatment. In another question, a reaction and its rate law were given and the students were asked to select the wrong statement among the alternatives related to this reaction. Before treatment, the most selected alternative was that the reaction occurs in more than one step. For instance, in the experimental group 32.4 % of the students and in the control group 22.9% of the students selected this alternative before treatment. In addition, the percentage of the students in the experimental group who selected the correct alternative was 23.5 and the percentage of the students in the control group who selected the correct one was 31.4. After treatment, 94.1% of the students in the experimental group answered this question correctly although 71.4% of the students in the control group answered this question correctly. The percentage of the most selected distracter for this question after treatment was 5.9 in the experimental group and 20.0 in the control group. As a result, the understanding levels of the students taught with conceptual change oriented instruction through demonstrations was higher than that of the students taught with traditionally designed chemistry instruction.

Discussion

Research in science education generally aims to investigate the effects of teaching strategies on students' learning of science. Some research focused on teaching strategies challenging students' misconceptions (e.g., Niaz, Aguilera, & Maza, 2002; Calik et al., 2010). After being aware of students' misconceptions, they should be eliminated for students' better understanding rate of reaction concepts. Zoller (1993) argues that traditional chemistry instruction may improve students' low-order cognitive skills but it is not effective for improving their high-order cognitive skills. Therefore, an instruction was designed based on conceptual change method through demonstrations and the effect of this instruction on eleventh grade students' understanding of rate of reaction concepts was investigated in this study.

The results show that conceptual change oriented instruction through demonstrations caused significantly better acquisition of the scientific conceptions related to rate of reaction than traditionally designed chemistry instruction. The reason of the significant difference between students' understanding of concepts in the experimental and control group may be interpreted as usage of different instruction type in each group. For instance, in the experimental group the students actively participated in classroom discourse during the instruction. The instruction was performed by considering their misconceptions and promoting conceptual change in rate of reaction subject. However, traditionally designed chemistry instruction was used in the control group. The teacher mostly used lecturing method during instruction. She enhanced discussion environment for the students. She also solved numerical problems to make practice about the concepts. However, the teacher taught the subjects without considering students' misconceptions and previous knowledge. The students were mainly passive during the instruction. As seen, the main differences between experimental group and control group were explicitly considering students' misconceptions and promoting conceptual change in their conceptions by using demonstrations (Gedik, 2001). These points might be the reasons of effectiveness of conceptual change based instruction on students' better understanding the scientific concepts. Substantial research from the literature (e.g. Abraham & Williamson, 1994; Alkhawaldeh, 2007; Cetin et al., 2009; Smith et al., 1993; Tastan, Yalcinkaya, & Boz, 2008) also support the finding related effectiveness of conceptual change based instruction. Although conceptual change based instruction caused better understanding of rate of reaction concepts and overcoming misconceptions regarding this subject, the students in the experimental group still were found out from statistical analyses and interviews conducted with them to have some misconceptions even after instruction. There is evidence supporting this finding that misconceptions are robust and resistant to change (Novak, 1988).

Conclusion

Students' misconceptions affect their understanding of chemistry concepts since they are obstacle in integrating new concepts into existing concepts. Therefore, teachers should identify students' misconceptions about the subject by applying misconceptions tests or interviewing with students before the instruction; design the instruction by considering these misconceptions in order to remediate them. Teachers should design and use conceptual change oriented instruction, which is an effective way to promote students to understand chemical concepts meaningfully, in their chemistry classes. Conceptual change oriented instruction not only enhance meaningful concept understanding but also encourage students to participate in classroom discourse through the tools used based on conceptual change method. Curriculum designers should also be aware of effectiveness of conceptual based instruction and they should take into consideration while designing or revising the chemistry curriculum. For teachers to able to use conceptual change based instruction, necessary importance should be given to conceptual change oriented instruction during teacher education and they should be trained through the use of in-service seminars related to this issue. Using demonstrations in chemistry classroom make a contribution to students' conceptual understanding since students have a chance to observe the chemical events. They are also effective in taking students' attention to lesson and motivate them in order to participate in the lesson. Therefore, teachers should use appropriate demonstrations during their chemistry instruction. In addition curriculum designers and textbooks writers should consider the importance of demonstrations in students' learning of chemistry and they should include some activities based on demonstrations in chemistry curriculum and textbooks.

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