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Promoting Conceptual Change in Chemical Reactions and Energy Concepts through the Conceptual Change Oriented Instruction

Kavramsal Değişim Yaklaşımına Dayalı Öğretim Yoluyla Öğrencilerin Kimyasal Reaksiyonlar ve Enerji Kavramlarının Geliştirilmesi

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Abstract

This study was designed to investigate the effectiveness of the conceptual change oriented instruction through demonstration over traditionally designed chemistry instruction on 10th grade students' understanding of chemical reactions and energy concepts and their attitudes towards chemistry as a school subject. One of the groups was defined as control group in which students were taught by traditionally designed chemistry instruction (TDCI), while the other group defined as experimental group in which students were instructed by conceptual change oriented instruction through demonstrations (CCID). The results showed that CCID caused significantly better acquisition of the scientific conceptions related to chemical reactions and energy concepts than TDCI. Also, the results showed that there was a significant difference between post-test mean scores of students taught with CCID and those taught with TDCI with respect to their attitude toward chemistry as a school subject in favor of CCID.

Keywords: conceptual change approach, chemical reactions and energy concepts, misconceptions.

Öz

Bu çalışma, kavramsal değişime dayalı öğretim yönteminin kullanımının 10. sınıf öğrencilerinin kimyasal reaksiyonlar ve enerji konularındaki kavramları anlamalarına ve öğrencilerin kimyaya karşı olan tutumlarına etkisini geleneksel kimya öğretim yöntemi ile karşılaştırarak incelemek için tasarlanmıştır. Gruplardan bir tanesi kontrol grubu olarak tanımlanmış ve bu gruba geleneksel öğretim yöntemi uygulanmış, diğer grup ise deneysel grup olarak tanımlanmış ve bu grupta kavramsal değişim yaklaşımına dayalı öğretim yöntemi uygulanmıştır. Sonuçlar kavramsal değişim yaklaşımı kullanılan öğrencilerin, kimyasal reaksiyonlar ve enerji kavramlarını, geleneksel kimya anlatımı kullanılan gruba göre daha iyi anladıklarını göstermektedir. Ayrıca, sonuçlar öğrencilerin kimyaya karşı tutumlarına göre değerlendirildiğinde, kavramsal değişim yaklaşımı kullanılan grubun son-test ortalaması ile geleneksel kimya anlatımı kullanılan grubun son-test ortalaması arasında, kavramsal değişim yaklaşımı kullanılan grubun lehine anlamlı bir farklılık olduğu görülmektedir.

Anahtar Sözcükler: Kavramsal değişim yaklaşımı, kimyasal reaksiyonlar ve enerji kavramları, kavram yanılgıları.

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Introduction

For many years, the notion that students come to classes with blank slates has been accepted. However, research on science education have consistently showed that students' existing knowledge about the phenomena and concepts to be taught were constituted in students' mind before students come into the science classes (Dykstra¸ Boyle & Monarch, 1992; Guruswamy, Somars & Hussey, 1997; Novak, 2002). Generally students existing ideas are inconsistent with the accepted scientific conceptions or even completely opposite to them (Duit, 2002). Students' conceptions or ideas that are differ from the definitions accepted by experts or scientific community are generally called alternative conceptions (Petersson, 2002) or misconceptions (Sungur, Tekkaya & Geban, 2001).

Because the misconceptions are hold in students' cognitive structure, students cannot link the new conception, which is a scientific conception, to existing knowledge. Therefore, weak understanding or misunderstanding occurs. It is quite difficult to alter these ideas with scientific ones even after large amounts of instruction (Wandersee, Mıntzes & Novak, 1994). Many misconceptions within the domain of chemistry are available in the literature such as the chemical equilibrium (Huddle & Pillay, 1996), solubility (Hawkes, 1998), oxidation and reduction (Garnett & Treagust, 1992), acid–base (Nakhleh, 1994).

Chemical reactions and energy is one of the subject areas of chemistry. A large number of research studies in chemical education have revealed students' alternative conceptions about chemical reactions and energy concepts (Cohen & Ben-Zvi, 1992; Barker & Millar, 2000; Ben-Zvi, 1999; Boo, 1998; Greenbowe & Meltzer, 2003; Harrison, Grayson & Treagust, 1999; Kesidou & Duit, 1993; Lewis & Linn, 1994; Thomas & Schwens, 1999; Yeo & Zadnik, 2001). The alternative conceptions identified by the previous researches are summarized in Table 1.

Recent research on science education showed that traditional instruction is not sufficient for students to understand concepts clearly, and to integrate students' ideas into coherent conceptual framework (Teichert & Stacy, 2002). New teaching and learning strategies which are based on constructivist view of learning were developed to overcome students' alternative conceptions in science education. In this view, the notions that knowledge is constructed by the individual through his interactions with his environment and the process of learning is the interaction between new knowledge and existing knowledge accepted as important ingredients of learning (Akkuş, Kadayifci, Atasoy & Geban, 2003).

One of the effective instruction methods that overcome students' alternative conceptions and improve students' understanding in science education is the instruction based on conceptual change approach. The ideas of conceptual change approach and constructivism are similar. The difference is that whereas constructivism deals with the general process of learning, the conceptual change approach deals with the specific conditions whereby existing structures are modified by new information (Weaver, 1998). Also, the conceptual change model is based on the constructivist notion claiming that learning is a process of personal construction of knowledge (Cobern, 1996).One of the conceptual change theory was proposed by Posner et al. (1982). According to this theory, it was suggested that four conditions are necessary for conceptual change to occur in an individual's understanding: (1) there must be dissatisfaction with existing conceptions (dissatisfaction); (2) a new conception must be intelligible (intelligibility); (3) a new conception must appear initially plausible (plausibility); (4) a new conception should suggest the possibility of a fruitful research program (fruitfulness). Some studies showed that the instruction based on conceptual change approach facilitated students' understandings of science subjects better (Alparslan, Tekkaya, & Geban, 2003; Chambers & Andre, 1997; Hynd, Alvermann, & Qian, 1997; Niaz, 2002; Sungur, Tekkaya, & Geban, 2006).

Table 1.
Students' Alternative Conceptions of Chemical Reactions and Energy

Heat and Temperature
1. Heat is a substance.
2. Heat is not energy.
3. Temperature is the 'intensity' of heat.
4. Skin or touch can determine the temperature.
5. Materials like wool have the ability to warm things up.
6. The temperature of an object depends on its size.
7. Heat and temperature are the same thing.
8. Perceptions of hot and cold are unrelated to energy transfer.
9. Heat is a type of substance that can accumulate an object, threfore, temperature is simply to measure of the amount of heat held by an object.
Exothermic and Endothermic Reactions
10 Burning of a candle is an endothermic reaction.
11. Burning (combustion reactions) involve fire or a flame.
12. A spontaneous reaction is always exothermic.
13. Endothermic reactions cannot be spontaneous.
14. All reactions that occur naturally, i.e. without overt application of heat, are exothermic.
15. Chemical reactions cannot occur if there is no external intervention such as heating.
16. Types of burning are different than each other, i.e. Burning wax was melting, burning of alcohol was evaporating and burning of wood was changing into ashes.
Chemical Reactions Energetics
17. The definitions of the terms "system" and "surroundings" cannot be distinguished in the context of energy transfer.
18. Bond dissociation releases energy, while bond formation consumes energy.
19. Bond breaking and bond making processes are view as requiring energy.
20. Chemical bonds are seen as a physical entity.
Hess' Law
21. Chemical equation is a mathematical puzzle rather than as a symbolic representation of a dynamic and interactive process.
22. Hess law is a simple arithmetical calculation, it does not related what has occurred at molecular level.

To create conceptual change in the student, teaching strategies should be realistic with respect to abilities of teachers and students (Weaver, 1998). Using demonstrations in science classrooms make the environment more realistic and give an opportunity to students to explain some conceptions in a more concrete dimension. Moreover, students may be motivated by presenting real world, attention catching applications and phenomena. Students always find learning environments that are based demonstrations to be fun and natural (Candela, 1997).

In the light of related literature, it can be concluded that alternative conceptions affect students' subsequent learning. Despite of the use of different teaching strategies, students may continue to hold their incorrect conceptions. This study mainly focuses on comparing the effectiveness of conceptual change oriented instruction through demonstration versus traditionally designed chemistry instruction on not only understanding of chemical reaction and energy concepts but also their attitudes towards chemistry as a school subject.

Method

The main purpose of this study was to investigate the effectiveness of conceptual change oriented instruction through demonstration (CCID) over traditionally designed chemistry instruction (TDCI) on 10^{th} grade students' understanding of chemical reactions and energy concepts, and attitudes towards chemistry as a school subject. In addition, effects of gender on students' understanding of chemical reactions and energy concepts and attitudes towards chemistry as a school subject were investigated.

Sample

The subjects of this study were selected from tenth grade students in an urban high school. 61 tenth grade students (33 male and 28 female) taught by the same teacher were used in this study. Each of two instructional methods was randomly assigned to one class. The experimental group who received conceptual change oriented instruction through demonstration consisted of 31 students while the control group who received traditionally designed chemistry instruction consisted of 30 students.

Instruments

Chemical Reactions and Energy Concepts Test (CRECT): This test consisted of 20 multiple choice questions, five of them were taken from the literature (Yeo & Zadnik, 2001) and the rest of the questions were developed by the researchers. CRECT covered fundamental concepts of chemical reactions and energy, endothermic and exothermic reactions, the meaning of enthalpy, energy concepts related bond dissociation and bond formation, Hess's law. The multiple choice items in the test included one correct answer and three or four distracters that reflected students' probable alternative conceptions identified in the related literature (see Table 1) and interviews with chemistry teachers. Before using of this test in its actual aim, a pilot test was conducted to evaluate its reliability and validity aspects. Cronbach alpha reliability of the pilot scores was found 0.79.

Attitude Scale toward Chemistry (ASTC): This scale was developed by one of the authors in this study. It was used to measure students' attitudes towards chemistry as a school subject. This scale consisted of 15 items in 5-point likert type scale in which each item expresses agreement or disagreement (strongly agree, agree undecided, disagree, and strongly disagree). The reliability was found to be 0.89. This test was given to students in both groups before and after the treatment.

Science Process Skills Test (SPST): The test was developed by Okey, Wise and Burns (1982). This test consisted of 36 four-alternative multiple choice questions. The reliability of the test was found to be 0, 85. This test includes five subsets designed to measure the different aspects of science process skills. These are identifying variables, identifying and stating hypothesis, defining operationally, designing investigations, graphing and interpreting data.

Treatment

This study was conducted over six-week period. 61 tenth grade students from two chemistry classes of same teacher were participated in the study. One of these classes were assigned as the experimental group in which the instruction was designed with respect to conceptual change through demonstration, the other class was assigned as the control group in which the instruction was designed with respect to traditional instruction. During the treatment, the chemical reactions and energy topics were covered as part of the regular curriculum in the chemistry course. The classroom instruction was five 40-minute sessions per week.

In the control group, the teacher used lecture/discussion method to teach concepts. The students were instructed with respect to teaching strategies that are relied on teacher explanation and textbooks without considerations of students' alternative conceptions. Before the lessons, reading the related topics in the textbooks on their own was offered to the students. The definitions of the concepts and chemical reactions were written to the chalkboard and worksheets were passed out for students to complete. The main underlying principle was that the whole knowledge about the subject was known only by teacher and it is the teacher's responsibility to transfer that knowledge as fact to students. After teacher's explanations of concepts, discussion environment was directed by teacher's questions to discuss some concepts that were not understood completely by students. The worksheets involved some practice activities, open-ended questions to reinforce the concepts presented in the classroom sessions.

Students in experimental group were instructed by using the conceptual change oriented instruction through demonstration that took alternative conceptions into account and provided plausibility of scientific conceptions. In addition, instruction was designed to maximize student active involvement in the learning process. The teacher was trained about how to implement conceptual change based instruction in experimental group before treatment. The list of the alternative conceptions about chemical reactions and energy concepts that were derived from related literature and the interview sessions with teachers was given to teacher. The teacher started the lecture with inquiry questions with respect to the list of alternative conceptions to activate students' prior knowledge and misconceptions and promote the interaction in class. Teacher attempted to create a discussion environment and tried to explore students' inappropriate conceptions about the related concepts with these questions. The teacher took some notes about the responses and used these answers (both the correct and incorrect) in the class discussions. Teacher acted as a guide in this discussion and directed students to understand their conceptions were not sufficient to explain some phenomena (dissatisfaction). The students who answered incorrectly were faced with the "conflict" between their existing incorrect knowledge (alternative conception) and the scientific knowledge. This conflict is a positive element in the learning process. Then, teacher gave some information about what to be taught. Since observation and interpretation are identical and observation and interpretation depends on what one already knows, the teacher explained some phenomena and concepts related to chemical reactions and energy in an interactive way in order to made students to aware some fundamental concepts about chemical reactions and energy before demonstrations (intelligibility). After that, teacher started to conduct demonstrations that related to the taught concepts. During the demonstrations, students participated actively by teachers questions and real world integrations to be given. The teacher provided opportunities for students to be involved in discussion, questions and answers while performing the demonstrations. Demonstrations had conducted by teacher before demonstration conducted in class to confirm whether it works and some questions prepared to attract students' attention. Demonstrations were about enthalpy, endothermic reactions, exothermic reactions, calorimeter, and heat of neutralization. These demonstrations were performed to prove the plausibility of the concepts that were taught. In addition, with these demonstrations students learned the concepts deeply and made connections with real world situations and their prior knowledge (plausibility). After the demonstration, students continued to discuss the events that related with chemical reactions and energy concepts. In these discussions, the main purpose was to prove the usefulness of the learned conceptions. To provide this, students tried to give some examples about the natural events and daily life experiences that are related to their new conceptions (fruitfulness of acquired concepts).

Results

In order to examine the effect of treatment and to understand whether there was a significant difference between experimental group and control group with respect to students' previous knowledge about chemical reactions and energy concepts and their attitudes toward chemistry as a school subject, CRECT and ASTC were administered to the students in both groups before the treatment. The results showed that there was no significant difference at the beginning of the treatment between the CCID group and the TDCI group in terms of students' understanding of chemical reactions and energy concept ($t=0,406$, $p>0.05$); and attitude toward chemistry as a school subject ($t=1.167$, $p>0.05$).

ANCOVA was used to determine the effectiveness conceptual change oriented instruction, gender difference, and the interaction between conceptual change based instruction and gender difference on understanding of chemical reactions and energy concepts.The analysis results showed that there was a significant difference between the post-test mean scores of the students taught by CCID and those taught by TDCI with respect to the understanding of chemical reactions and energy concepts when science process skill is controlled as a covariate ($F=242.68$; $p<0.05$). The CCID group scored significantly higher than TDCI group ($\bar{X}$ (CCID) = 16.24, $\bar{X}$ (TDCI) = 8.4). Also, the result showed that there was no significant mean difference between male and female in terms of understanding chemical reactions and energy concepts ($F = 0.001$; $p>0.05$). The mean post-test scores were 12.30 for males and 12.57 for females. The findings revealed that there was no significant interaction effect between gender difference and treatment on students' understanding of chemical reactions and energy concepts ($F = 0.019$; $p>0.05$). On the other hand, science process skills was a statistically significant predictor for understanding of chemical reactions and energy concepts ($F=5.158$; $p<0.05$).

The proportions of correct responses and alternative conceptions were examined by using item analysis for experimental and control group. For example, one of the items related to distinguish heat and temperature concepts. In this item, students were asked to compare with the warm carton and the cold carton to reveal whether students understood perception of hot and cold are related to energy transfer. Before the treatment, 48.3% of the students in control group and 46.6% of the students in experimental group selected 'compared with the warm carton sitting on some time in countertop, the cold carton taken from refrigerator conducts heat more rapidly from one's hand' which was the desired answer**.** After the treatment, the majority of the experimental group (90%) and 58% of the students in control group selected this answer. While the alternative conceptions of 'heat and temperature are the same thing' and 'perception of hot and cold are unrelated to energy transfer' were held by 35.4% of the students in control group, 10% of the students in experimental group held these alternative conceptions after treatment (alternative conceptions 7 and 8 in Table 1). Another item reflected the striking difference among students in the experimental and control group was related to combustion reactions. In this item, some properties of combustion reactions were given to the students as sentences, and students were asked to identify which of this/these sentence/sentences is/are true. Before the treatment, 32.2% of the students in control group and 30% of the students in experimental group selected the correct choice which covered the sentences 'combustion reactions are exothermic' and 'types of burning are not different than each other'. After the treatment, while 38.7% of the students in control group selected the desired answer, 70% of the students in experimental group answer this item correctly. Moreover, 45.1% of the students in control group held the alternative conception of 'burning (combustion reactions) involve fire or a flame', whereas 13.3% of the students in experimental group held this misconception after the treatment (alternative conceptions 9, 11, and 16 in Table 1).

These results showed that the students in experimental group who were thought with conceptual change oriented instruction had better acquisition of scientific conceptions than those in the control group who were thought by traditional instruction with respect to chemical reactions and energy concepts.

Two-way ANOVA results showed that there was a significant difference between post-test mean scores of students taught with CCID and those taught with TDCI with respect to their attitude toward chemistry as a school subject. Students taught with conceptual change oriented instruction through demonstration had more positive attitudes ($\bar{X}$= 59.96) than those taught traditionally designed chemistry instruction ($\bar{X}$=52.46). There was no significant mean difference between male and female students with respect to their attitudes toward chemistry a as school subject ($F= 0. 70$; $p>0.05$). Male students' mean score was 56.47 and female students' mean score was 55.90 with respect to their attitudes toward chemistry as a school subject. And also the results showed that there was no significant interaction effect between gender difference and treatment on students' attitudes toward chemistry as a school subject ($F= 0.156$; $p>0.05$).

Discussion and Conclusion

It was found that the conceptual change oriented instruction through demonstration (CCID) caused a significantly better acquisition of scientific conceptions related to chemical reactions and energy concepts than the traditionally designed chemistry instruction. There is a consistency between the findings in our study and the previous studies in that conceptual change based instruction can facilitate learning of scientific concepts (Chambers & Andre, 1997; Çakır, Geban, & Yürük, 2002; Hynd et al., 1997; Sungur et al., 2006; Niaz, 2002). In these studies, conceptual change strategies were used to remedy students' alternative conceptions and better acquisition of scientific conceptions. In this study, conceptual change oriented instruction through demonstration highlighted the intelligibility and the usefulness of the target scientific explanations and promoted conceptual change by challenging students' alternative conceptions producing dissatisfaction, followed by a correct explanation and demonstrations which is both understandable and plausible to the students. Moreover, the instruction in experimental group gave opportunities to students to revise their prior knowledge and struggle with their alternative conceptions. In order to remedy these alternative conceptions, cognitive conflict was created between students' alternative conceptions and scientific ones. This dissatisfaction allowed students to accept better explanations of the concepts. In experimental group, teacher-students interaction that occurred in the discussion part of the lessons helped students to share their ideas with each other and ponder these ideas in depth. In addition, demonstrations made students more enthusiastic to attend discussions during demonstrations. And also, these discussions facilitate and encourage students' understandings and restructuring of concepts. As a result, students believed that the scientifically acceptable new conception was more meaningful. This instruction ensure students involvement to the lesson, thereby this instruction have a capacity to improve students' intrinsic interest, and self efficacy.

On the other hand, the traditional instruction in this study comprised lectures given by teacher, use of textbooks, and clear explanation of important concepts. The major responsibility of the teacher in this group was to transferring the knowledge to the students. The difference between the two strategies was that while the traditional approach did not take account students' alternative conceptions, the conceptual change approach explicitly dealt with students alternative conceptions. The results found in this study support the view that traditional instruction methods have not enough quality to eliminate students' alternative conceptions.

Also, the degree of science process skills accounted for a significant portion of variation in students' understanding of chemical reactions and energy concepts in this study. It is useful to bring out analysis ability of students in solving complex problems that requires students' conceptual understanding, because it measures the intellectual abilities of students including the items related to identifying variables, identifying and stating the hypotheses, operationally defining, designing investigations and graphing and interpreting data. To understand complex concepts and problems in science, students should be able to apply fundamental facts and principles, use appropriate conceptual and theoretical frameworks, and perform calculations.

On the other hand, students were taught with conceptual change oriented instruction through demonstration had more positive attitudes than those are taught traditionally designed chemistry instruction. Conceptual change oriented instruction through demonstration gives students opportunity to actively involve to lesson. Students always find the learning environments that are based demonstrations funny and natural and this motivates students. Moreover, demonstrations are always found useful activities to attract students' interest. These factors might cause students in experimental group to have more positive attitudes. In addition, more interaction between the teacher and the students was provided, and conceptual change conditions made students dissatisfied with their existing conceptions and find new concepts intelligible, fruitful and plausible. These may have produced more positive attitudes toward science as a school subject.

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