Hacettepe Üniversitesi Eğitim Fakültesi Dergisi (H. U. Journal of Education) 41: 112-123 [2011]

USING CONCEPTUAL CHANGE TEXTS WITH ANALOGIES FOR MISCONCEPTIONS IN ACIDS AND BASES

KAVRAMSAL DEĞİŞİM METİNLERİYLE VERİLEN ANALOJİLERİN ASİT-BAZ KONUSUNDAKİ KAVRAM YANILGILARI İÇİN KULLANIMI

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ABSTRACT: This study was conducted to explore the effectiveness of conceptual change oriented instruction over traditional instruction on students' understanding of acids and bases concept. Besides, effects of gender difference and science process skills on students' understanding of acids and bases were also investigated. Analysis of the results showed that establishing an analogical thinking during the instruction via conceptual change text caused better acquisition of scientific conceptions and elimination of misconceptions. In-depth interviews after the post-tests showed that students' lack of knowledge and misinterpretation of solutions and bonds concepts result in serious misconceptions in acids and bases concept. Especially, students have problems when they relate the concentration and strength with acidity, basicity and pH. Results also showed that science process skills of the students could be a strong predictor of their achievements in acids and bases whereas there was no significant effect of gender on students' understanding of acids and bases.
Keywords: misconceptions, conceptual change, conceptual change texts, analogy, acids and bases

ÖZET: Bu çalışma, kavramsal değişim öğretim yönteminin geleneksel öğretim yöntemine göre öğrencilerin asit ve bazlar konusundaki anlamlı öğrenmelerine etkisini araştırmak amacıyla yapılmıştır. Ayrıca cinsiyet ve bilimsel işlem becerilerinin öğrencilerin asit ve bazlar konusunu anlamaya etkisi de araştırılmıştır. Analiz sonuçları, kavramsal değişim metinleriyle birlikte verilen benzeştirme yönteminin, öğrencilerin bilimsel gerçekleri daha iyi anlamasında ve kavram yanılgılarının giderilmesinde etkili olduğunu göstermiştir. Mülakatlar sonucu, öğrencilerin çözeltiler ve bağlar konusundaki yanlış anlamalarının ve bilgi eksikliklerinin asitler ve bazlar konusunda kavram yanılgılarına yol açtığı saptanmıştır. Öğrencilerin özellikle konsantrasyon ve kuvvetlilik kavramlarını asitlik, bazlık ve pH kavramlarıyla birleştirmede problem yaşadıkları görülmüştür. Ayrıca, bilimsel işlem becerilerinin öğrencilerin asit ve bazlar konusundaki başarılarını tahmin etmede etkili olduğu fakat cinsiyetin bir etkisi olmadığı görülmüştür.
Anahtar sözcükler: kavram yanılgıları, kavramsal değişim, kavramsal değişim metinleri, benzeştirme, asitler ve bazlar

1. INTRODUCTION

Constructivist learning theory states that learning is not the result of teaching rather it is the result of what students do with the new information they are presented with. If the new information does not fit with what students already know, they often choose to reject it and leave the classroom having learnt nothing. Motivation and attention are important factors in learning but there is an even more important factor to be considered as what the students already know. If we understand which pre-instructional conceptions are forming students' current thinking, we might be able to strategize ways for students to question those beliefs and overcome them. The process of changing these beliefs, ideas or ways of thinking is called as conceptual change (Duit & Treagust, 2003).

There are some specific procedures for promoting conceptual change and removing misconceptions. Using conceptual change texts is one of them. Different from the traditional textbooks, conceptual change texts are specifically designed to point out students' misconceptions of the related topics and their weaknesses in explaining or solving a problem in order to remove them. For this purpose, topics are introduced with questions and students' possible answers that are not scientifically correct are mentioned directly to create dissatisfaction. Then, scientifically acceptable explanations, which are more plausible and intelligible, are given. There are some studies reporting the importance of conceptual change texts in facilitating conceptual change and removing misconceptions

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(Baser & Geban 2007; Calık et al. 2007; Ozmen et al. 2009; Palmer 2003; Uzuntiryaki & Geban 2005; Yuruk 2007). There are many strategies that foster conceptual change but most of them are appropriate for small classes, however conceptual change texts can be used in large classes, which are commonly observed in developing countries.

Using analogies during the instruction is another alternative strategy in promoting conceptual change. Analogies make new information intelligible to students by comparing it to the information that is already familiar to them. Students find topics more interesting when they have some relevance with their daily lives and experiences. Many experimental studies have been carried out to probe the effect of analogies in learning complex scientific contents and promoting conceptual change (Calık et al. 2009; Clement 1993; Orgill & Bodner 2004; Savinainen et al. 2005; Treagust et al. 1996). Analogies are also used by chemistry teachers in teaching acids and bases. For example, dating analogy was used for acid-base titrations (Delorenzo 1995) and football analogy was used to explain weak/strong acids and bases (Silverstein 2000). In the present study, bulb analogy was used to explain the strength of acids and bases, bus analogy was used to explain the concentrated/dilute acids and bases and rainbow analogy was used to explain the function of indicators.

In high school chemistry curricula, acids and bases occupy an important place. Because, understanding of acids and bases have a central role in clearly understanding other concepts such as chemical reactions, especially oxidation-reduction reactions, acid-base equilibrium and organic chemistry. However, most students have difficulty in meaningful understanding of the topics related to acids and bases (Banerjee 1991; Bradley & Mosimege 1998; Cros & Maurin 1986; Kousathana et al. 2005; Ross & Munby 1991; Treagust 1988).

In this study, conceptual change oriented instruction was used to overcome the students' misconceptions related to acids and bases. Besides, effect of science process skills on students' understanding of acids and bases was investigated as cognitive factors play an important role in chemistry achievement. For example, low performance in science process skills can be considered as an indicator of serious instructional problems and poor teaching (Fraser, 2001). Effect of gender difference on students' understanding was also investigated because gender issues take the attention of science educators and researchers (Tsai & Wen, 2005). A number of probable causes for gender differences in science achievement were reported as different cognitive abilities (Griffiths & Bettle, 1985), personality characteristics (Meece & Holt, 1993), out-of-school experiences (Johnson, 1987) and attitudes toward science (Jones et. al, 2000). Baker (1983) found that girls have more negative attitudes toward science than boys, but still have higher science grades. However, this is not always the case if specific disciplines of science are studied. More research is needed related to chemistry achievements of students regarding the gender differences.

2. METHOD

2.1. Purpose

The main purpose of this study was to compare the effectiveness of conceptual change text oriented instruction based on analogies over traditionally designed chemistry instruction on 11^{th} grade students' understanding of acids and bases concept. Effect of gender differences and science process skills on the students' understanding of acids and bases was also investigated. As a result, role of treatments, gender difference and interaction between gender and treatment with respect to students' achievement in acids and bases were identified.

2.2. Sample

Subjects of the study were 50 tenth-grade students (22 boys and 28 girls) from the two intact classes of the same chemistry teacher in an urban public high school in Ankara. Each of two instructional methods was randomly assigned to one class after individuals were already in each class. Data were obtained from 26 students in the experimental group and 24 students in the control group.

2.3. Instruments

Conceptual Change Text: It was prepared by the researchers in the light of the information obtained from the literature considering the objectives of the national curriculum. The four conditions of the conceptual change proposed by Posner et al. (1982) were taken into account to design the conceptual change texts. For this aim, students are asked explicitly to predict what would happen in a situation before being presented with the information that demonstrates the inconsistency between common misconceptions and scientific conceptions. First strategy is to activate students' misconceptions by this way via the text. Then, instructor presents students' common misconceptions that have been found to be wrong by presenting evidence countering them. Scientific conceptions are also explained with analogical examples to increase the text's comprehensibility and intelligibility. Finally, the text provides reasoning that would seem plausible to students and examples are given so that students could see the fruitfulness of the explanations. During the instruction, teacher directs students to read the text silently. At the end of a paragraph in which a question is posed, students are asked to stop reading. Then, teacher discusses the statements and questions in the text with students.

The text in the study was 10 pages including the topics related to meaning, strength, concentration, reactions and properties of acids and bases, pH concept, neutralization and indicators. Analogies emphasized during the instruction were also written in the conceptual change text. By this way, students had a chance to read and remember the analogies that were discussed in the classroom whenever they want from the text given. Conceptual change texts can be easily prepared by classroom teachers as a supplementary material to the instruction. Besides, they are practical to apply in teaching environments especially in large classes and helpful in replacement of misconceptions.

Acid-Base Conceptions Test (ABCT): It was developed by the authors. There were 21 multiple-choice questions in the test including only basic concepts related to acids, bases, salts, pH, indicators and neutralization. All items in the test were conceptual and no quantitative calculations were needed to answer the questions. Each question in the test had one correct answer and three distracters. Test was developed by considering the instructional objectives of the acid-base concept, misconceptions stated in the literature and discussions with teachers. Classification of students' misconceptions used in the test is presented in Table 1 and examples of the questions are presented in Appendix A.

Table 1: Taxonomy of Misconceptions in Acid-Base Conceptions Test

1. The strength of an acid depends on the number of hydrogen atom and a base depends on the number of hydroxide group.
2. Any substance that contains H is an acid, OH is a base.
3. Strong acids always have a higher pH than weak acids.
4. At pH=0 substances are neither an acid nor a base.
5. Acids and bases show opposite properties of each other.
6. Strong acids only react with strong bases and weak acids only react with weak bases or vice versa.
7. Reactions of acids and bases always result in a neutral solution.
8. Strong acids contain more hydrogen bond than weak acids.
9. Acids are more dangerous than bases.
10. Indicators are used to provide the neutralization in acid-base reactions.
11. Acids conduct electricity, bases do not
12. Soil cannot be acidic because things grow in it.
13. H_2O cannot act as an acid or a base, it only serves as a solvent
14. Fruits are basic.
15. Concentrated acids always have a high pH value; dilute acids have a low pH value.
16. Acids are irritating and burning.
17. Acids are burning because they contain sharp particles; bases are slippery because they contain round particles.
18. Strong acids are more concentrated than dilute acids.
19. Any concentrated acid solution is always more acidic than a dilute acid solution and any concentrated base solution is always more basic than a dilute base solution.
20. Indicators are used as a measure of acidic strength.

All questions were piloted and necessary modifications were made prior to application of the test. The content validity of the test items was carried out by a group consisting of one professor of chemistry and two chemistry teachers. Internal consistency of the test was found to be 0.81. It was given to all groups as a pre-test to control students' knowledge of acids and bases prior to the instructions and as a post-test to determine the effect of treatments on students' understanding of acids and bases concept.

Science Process Skill Test (SPST): Developed by Burns, Okey and Wise (1985). It contains 36 four-alternative multiple-choice questions and measures the intellectual abilities of students. It was administered before the instruction to determine whether there was a significant mean difference between the experimental and control groups with respect to science process skills and also to determine whether there was a significant contribution of science process skills to the variation in students' understanding of acids and bases after the treatment.

Interviews: Randomly selected 12 students (6 from experimental group and 6 from control group) at the medium achievement level in the post-test were interviewed to get an in-depth idea of the nature and reasons of students' misconceptions related to the concept. Interviews were conducted in semi-structured format by asking 10 structured questions followed by unstructured questions for clarification. Questions were based on the common misconceptions occurred in the post-ABCT such as 1) meaning of a strong acid, 2) if there is a relationship between the strength and concentration, 3) if there is a relationship between the strength and pH, 4) factors effecting the strength e.g. is there an effect of number of H/OH in the substance?, 5) meaning of being dilute or concentrated, 6) meaning of concentrated HCl and dilute HCl, 7) if there is a relation between being concentrated and pH value, 8) explanation of pH, 9) determination of pH of a solution after acid-base reactions, 10) stating the conditions for the formation of neutral solutions. Selected examples of excerpts from the interviews are provided in Appendix B.

2.4. Procedure

This study was conducted in four weeks. There was one experimental group and one control group. The classroom instruction for both groups had four 45-minutes periods per week. The same topics were covered for both groups. Treatments were randomly assigned to the two classes of the teacher.

In the control group, students received traditional instruction. The teacher followed lecture and discussion method to teach acids and bases concept. Teaching strategies relied on teacher's explanation and textbooks with no consideration of the students' misconceptions. Teacher structured the entire class as a unit, wrote notes on the board about the definition of concepts and solved quantitative problems.

Experimental group students were received conceptual change oriented instruction. In addition to the classroom instruction, they were given the conceptual change text based on analogies which contained a collection of the students' misconceptions in acids and bases, questions to activate these misconceptions, evidences of incorrectness of these misconceptions with correct explanations, related analogies with daily life examples and some pictures, figures and equations in order to help the students better understand the topic by visualizing the events. During the class, teacher directed the students to read the text silently. After reading each paragraph where a question was posed and evidence was presented that the related misconception was incorrect, students were asked to stop reading. Then, the teacher asked what they taught about the explanation they had just read. This type of discussion in terms of questioning and answering in the guidance of the teacher was handled throughout the text at each paragraph for the related topics of that class hour. Similarly, all lectures were carried out by answering of the questions in the text, discussing the answers and establishing an analogical thinking between the real life examples and the unknown while learning the new information. For example, teacher asked the question in the text 'Is there a relationship between the number of hydrogen atoms that the acids contain and acidic strength?' Because, students may think that as the number of H atoms increase in an acid, it becomes stronger. After guiding the discussions, then asked the next question in the text 'Is H_3PO_4 stronger than HCl?' and allowed students to discuss again, realize their misinterpretations and reach the correct answer. In order to establish an analogical thinking, bulb analogy was used. This time, teacher asked another text question 'How do we measure the strength of the bulbs that we use at our homes?' and guided the discussions to help the students in understanding the stated analogy in the text 'If a bulb gives off a lot of light then it is strong, a little then light it is weak. Similarly, if an acid ionizes a lot, it is strong, ionizes a little, it is weak' and 'the light of only one bulb sometimes may be more strong than the light of two or more bulbs (one bulb can give more light) like in the case of the acidic strength and the number of hydrogen atoms that an acid contains' i.e. HCl is a stronger acid than H_3PO_4 because it gives more hydrogen ions than H_3PO_4 when they dissociate in water although HCl contains smaller number of hydrogen atom. Students might also think that "concentrated acids and bases are strong, dilute acids and bases are weak". In order to explain that strength of acids/bases is not affected by concentration, bus analogy was used. According to this analogy, number of people in a bus does not affect the horse power of the bus; similarly number of moles of acids and bases in a solution does not affect their strength. As another example, function of the indicators was explained by the rainbow analogy, because, some students might think that indicators provide neutralization in acid-base reactions or show the acidic strength. This analogy states that rainbow colors occur according to different refraction indexes of the light in rain drops and indicator colors occur according to different pH values of the solutions.

In order to facilitate the proper application of conceptual change instruction, teacher was given training prior to the study and conducted several times in a week. At least one random visit by the authors was carried to each group during the instruction to confirm that lessons were delivered competently.

3. RESULTS

Prior to the treatment, independent t-test was used to determine if there is a statistically significant mean difference between the control and experimental groups with respect to science process skills and prior knowledge in acids and bases. Pre-test results of the SPST and ABCT showed that there was no significant mean difference between the experimental and control groups in terms of their understanding of acids and bases ($t=1.62$, $p> 0.05$) and science process skills ($t=1.54$, $p> 0.05$) before the treatment.

3.1. Effects of Gender Difference and Instructions on Achievement

After treatments, effects of instructions on students' achievement related to acids and bases were determined with analysis of covariance (ANCOVA) by controlling the effect of students' science process skills as a covariate. The analysis showed that there was significant mean difference between post-test results of the experiment and control group with respect to understanding of acids and bases ($F=40.86$, $p< 0.05$). Experimental group scored significantly higher than the control group taking the traditional instruction (XE=12.92, XC=8.54). Table 2 presents the results by comparing the differences in both groups with respect to pre-test and pos-test scores.

Table 2: Comparison of the Experimental and Control Groups in the ABCT before and after Treatment

Measures	Experimental Group			Control Group				
	N	Mean	SD	N	Mean	SD	t	p
Pre-ABCT	**26**	**7.42**	**2.5**	**24**	**6.29**	**2.42**	**1.54**	**>0.05**
Post-ABCT	**26**	**12.92**	**2.52**	**24**	**8.54**	**2.53**	**1.62**	**>0.05**

Considering the gender, analysis of the results indicated no significant difference between the performance of males and females ($F=1.81$, $p> 0.05$) with respect to understanding of acids and bases and no significant interaction between treatment and gender ($F=3.50$, $p> 0.05$). However, contribution of students' science process skills to the variation in their achievement related acids and bases were significant ($F=16.50$, $p< 0.05$).

When the proportion of correct responses and distracter misconceptions were analyzed item by item, striking differences among the groups were realized on several items in favor of the experimental group. Figure 1 shows the proportions of correct responses in the post-ABCT. Remarkable differences were observed in the questions 1, 4, 5, 12 and 21.

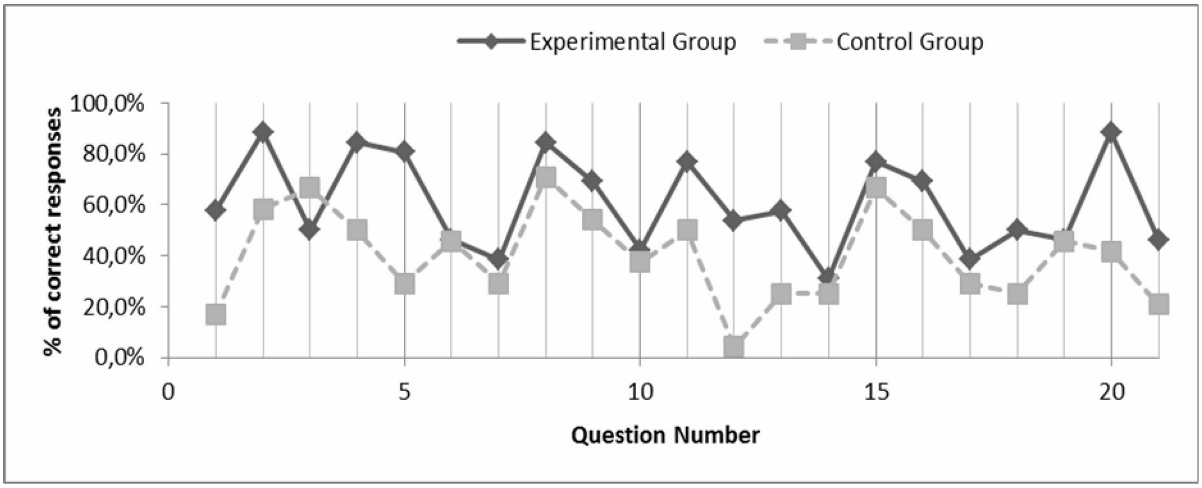

Figure 1: Comparison between Post-ABCT Scores of the Experimental and Control Groups

For example in question 1, when students were asked to select the true statement related to the nature and properties of acids, only 57% of the students in the experimental group and 16% of the students in the control group selected 'soil could be acidic' as the correct response. The most prevalent misconception among control group students was 'acids are irritating and burning' (66%). This indicates that most of the students especially those in the control group believed that all acids were burning and irritating. As a result, soil shouldn't be acidic otherwise nothing can grow in it.

In question 4, students were asked to select the most acidic substance according to given pH values. While 85% of the students in the experimental group correctly selected 'pH=0', only 50% of the students in the control group selected it. The most prevalent misconception among them was 'pH=1' (25%). This result indicates that half of the students in the control group failed to realize that pH can be 0 for acids. In fact, it is very common misconception that if pH=0, substance is neither an acid nor a base.

Another item reflecting the striking difference between experimental and control groups was related to the statements about nature of acids and bases. In this item students were asked to select the false statement about nature of acids and bases (question 5). While 80% of the students in experimental group selected 'acids contain sharp particles due to their burning property, bases contain round particles due to their slippery property', only 29% of the students in the control group selected this as the correct response. The most prevalent misconception among control group students was 'a substance must contain H atom to be acid and OH group to be base' (45%). Most of the students in control group failed to understand that any substance without H atom can be an acid and without OH group can be a base. This was again one of the most resistant to change misconception related to acids and bases.

Another drastic difference between the experimental and control groups were observed in 12th question which was related to concentrated and dilute acid solutions. While 54% of the students in experimental group selected 'for the same substance, amount of particles in concentrated acid solutions is greater than the amount of particles in dilute acid solutions, only 4% of the students in the control group selected this question correctly. The most prevalent misconceptions among the control group students were 'a concentrated acid is always stronger than a dilute acid' (45%) and 'pH of a concentrated acid solution is always greater than the dilute acid solution' (29%). It was known that strength and concentration may mean the same thing to students. In a similar question, it was asked to select the true statement(s) related to strength, concentration and pH concepts (question 21). While 46% of the students in experimental group selected 'same substance can be both concentrated and strong acid/base', only 20% of the students in control group selected this as the correct answer. The most prevalent misconceptions among control group students were 'any concentrated acid solution is always more acidic than a dilute acid solution and any concentrated base solution is always more basic than a dilute base solution' (33%).

Although students taking the conceptual change instruction performed statistically better than students taking traditional instruction, students in both groups held some serious conceptions at variance with the scientifically acceptable conceptions even after the treatments. For example, in question 14 it was asked to select the substance that is not a base?'. Percentage of correct responses (ones selecting HCOOH) was almost same (30%) for the experimental group before and after the treatment. Majority of the students in experimental and control groups (around 70%) selected 'PH3'. Because, misconception of 'any substance that contains H is an acid and OH is a base' is very resistant to change and special emphasis should be given during the instruction to overcome this misconception.

Some responses of the interviewees were given in Appendix B, according to being in experimental group (EG) and in control group (CG). Considering the students' overall responses, their answers showed that students had more difficulty in relating the concentration concept (being dilute/concentrated) with acid and base related concepts.

4. DISCUSSION AND IMPLICATIONS

Analysis of the results provide evidence that the traditional instruction was not as effective as the conceptual change instruction in eliminating misconceptions about the instructional topics, as it provides uni-directional data flowing from teachers to students. But, in spite of all advantages of the conceptual change instruction compared to the traditional instruction, there was observed some misconceptions in experimental group students even after the treatment. The most prevalent and resistant one was 'any substance that contains H atom is an acid and OH group is a base'. Besides, it was observed that students were having problems when relating concentration in the concept of acidity, basicity and pH. For example, 'concentrated acids and bases are strong, dilute acids and bases are weak' and 'pH of concentrated acid solutions is always greater than dilute acid solutions' were identified as the conceptions difficult to change. According to the students' responses during in-depth interviews, origins of the learning difficulties related to these misconceptions could be attributed mainly to inadequate acquisition of the conceptual knowledge on solutions and bonding concepts and to the insufficient explanation of the relevant concepts in textbooks. Because, students often confuse concentration with dissolving by stating 'being concentrated and being strong are the same thing'.

In our study, conceptual change text oriented instruction based on analogies caused significantly better acquisition of the concepts than the traditional instruction. The greater success of experimental group students is mainly because of the instructional method and materials used. Because, activities based on conceptual change approach helped the students revise their prior knowledge, struggle with their misconceptions and eliminate them. Conceptual change text as an instructional material facilitated that process by improving the instruction. In the conceptual change text, special emphasis was given to students' misconceptions that helped the students to realize their existing conceptions, become dissatisfied with them and accept better explanations by the help of questions, examples and analogical explanations. Enhancement of analogical thinking via the conceptual change text provided better understanding of confusing concepts by serving as a bridge between the real life examples and misunderstood concepts.

Analysis of the results also showed that there was no significant mean difference between the achievements of male and female students. In addition, interaction between the gender and treatment had no significant effect on students' understanding of acids and bases. This may be because of their similar attitudes toward chemistry or their similar chemistry backgrounds. Cakır et al. (2002) also reported that gender difference had no effect on students' understanding of acids and bases concept.

Science process skill test was the other test administered to groups. Since it represents the rational and logical thinking skills that have great influence on students understanding of science, it is better if groups are similar with respect to these skills. Results showed that there was no significant mean difference between the experimental and control group with respect to science process skills. However, students' with higher science process skills had greater achievement related to acids and bases concept. It means that this ability is an underlying factor associated with chemistry achievement. It requires formal operations and formal operational thinkers can reason in terms of abstract entities, hypothetical situations and events. Many of the concepts in high school chemistry are abstract and theoretical such as acids and bases. That's why, students' science process skills can be a significant predictor of chemistry achievement in acids and bases.

Many of the misconceptions observed in this study would likely to be found among chemistry students elsewhere. Thus, these findings may provide some clues about the nature and quality of student learning in typical chemistry classes. Results also imply that more effective teaching methods other than the traditional methods are needed to be developed for meaningful learning of students. Conceptual change texts, for example, could be valuable for students especially in remembering and reading the misconceptions from the text whenever they want. We know that correction of misconceptions is difficult and challenging task and supporting the instruction by using such a written document may be an alternative in the process of overcoming misconceptions.

In future studies, this type of conceptual change text oriented instruction may be enriched by demonstrations, computer assistance, concept mapping etc. to minimize the experimental group's alternative conceptions even after the conceptual change instruction.

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Genişletilmiş Özet

Bu çalışma, kavramsal değişim metinleriyle verilen benzeştirmelerin lise öğrencilerinin asit ve bazlar konusundaki başarılarına etkisini geleneksel kimya öğretim yöntemiyle karşılaştırarak incelemek amacıyla yürütülmüştür. Ayrıca, cinsiyet farkı ve bilimsel işlem becerisinin öğrencilerin asit ve bazlar konusunu anlamalarına olan etkisi de incelenmiştir.

Çalışmanın örneklemini, Ankara merkezindeki bir devlet okulunda aynı öğretmenin ders verdiği iki ayrı sınıftaki 50 lise öğrencisi oluşturmaktadır. Araştırmada bir deney ve bir kontrol grubu vardır. Kullanılan iki ayrı öğretim metodu öğretmenin mevcut sınıflarına göre rastgele belirlenmiştir. Deney grubuna kavramsal değişim metinleriyle birlikte verilen benzeştirme yöntemi, kontrol grubuna ise sadece geleneksel kimya öğretim yöntemi 4 hafta süreyle uygulanmıştır. Asitler ve Bazlar Kavram

Yanılgısı Testi her iki gruba ön test ve son test olarak verilmiştir. Bilimsel İşlem Beceri Testi ise sadece çalışmanın başında öğrencilerin bilimsel işlem becerilerini belirlemek ve gruplar arasında anlamlı bir fark olup-olmadığını belirlemek amacıyla her iki gruba da uygulanmıştır. Araştırmanın sonunda, ortalama başarı sergileyen deney grubu ve kontrol grubu öğrencilerinden rastgele seçilen bir örneklemle mülakatlar yapılmıştır. Araştırmaya başlamadan önce, dersin öğretmeni, kavramsal değişim öğretim yönteminin uygulanması ve kavramsal değişim metinlerinin hazırlanıp sınıf içinde kullanılmasıyla ilgili olarak araştırmadan önce bilgilendirilmiştir. Ayrıca, hem deney grubu hem de kontrol grubuna rastgele ziyaretler yapılarak uygulamaların doğru yürütüldüğünden emin olunmuştur.

Araştırmanın hipotezlerini test etmek amacıyla t-testi ve Ortak Değişkenli Varyans analizleri kullanılmıştır. Analiz sonuçları, kavramsal değişim metinleriyle uygulanan benzeştirme yönteminin, asitler ve bazlar konusuyla ilgili kavramların daha iyi anlaşılmasında ve kavram yanılgılarının giderilmesinde, geleneksel yöntemden daha etkili olduğunu göstermiştir. Son testte, kavramsal değişim yöntemi uygulanan deney grubu öğrencileri, geleneksel öğretim yöntemi uygulanan kontrol grubu öğrencilerine göre çok daha iyi sonuçlar elde etmiştir. Ayrıca, bilimsel işlem becerisinin öğrencilerin asit ve bazlarla ilgili başarılarının tahmininde güçlü bir belirleyici olduğu görülmüştür. Çünkü, bilimsel işlem beceri testinden yüksek puan alan öğrenciler kavram yanılgısı testinden de yüksek puan almışlardır. Sonuçlar, kız ve erkek öğrencilere göre ayrı ayrı değerlendirildiğinde ise cinsiyet farkının öğrencilerin asit ve bazlar konusundaki başarılarına istatiksel bir etkisinin olmadığı saptanmıştır. Bu duruma, öğrencilerin kimya dersine olan benzer tutumlarının veya benzer eğitim geçmişine sahip olmalarının neden olduğu düşünülmektedir.

Araştırmada kullanılan Asitler ve Bazlar Kavram Yanılgısı Testi konunun hedefleri ve kazanımları göz önüne alınarak hazırlanan, 21 soruluk, çoktan seçmeli, caydırıcı seçeneklerin öğrencilerin asitler ve bazlar konusundaki kavram yanılgıları üzerine yoğunlaştığı bir testtir. Testte kullanılan kavram yanılgıları makale taraması, öğrenci ve öğretmen görüşmeleri sonucu belirlenmiştir. Ayrıca, öğrencilere dağıtılmak ve derste kullanılmak üzere 9 sayfadan oluşan Asitler ve Bazlar Kavramsal Değişim Metni de hazırlanmıştır. Kavramsal değişim metninde konuyla ilgili kavram yanılgıları vurgulanarak doğru bilgiler günlük yaşamdan analojiler kullanılarak açıklanmıştır. Örneğin, bir asidin kuvvetliliğinin göstergesinin içeriğindeki H atomu sayısı olmadığı evlerimizde kullandığımız ampüllerin kuvvetliliğinin ampül sayısından bağımsız olduğu analojisiyle açıklanmıştır. Kavramsal değişim metinlerinin kavram yanılgılarının giderilmesinde, derste işlenen bilgilerin ve analojilerin hatırlanmasında ve özellikle de ülkemizdeki gibi kalabalık sınıf mevcudunun olduğu ortamlarda kullanılmasında konuların anlamlı bir şekilde öğrenilmesi için etkili bir araç olduğu düşünülmektedir. Analiz sonuçları da, kavramsal değişim metinleriyle birlikte verilen benzeştirme yönteminin, öğrencilerin bilimsel gerçekleri daha iyi anlamasında ve kavram yanılgılarının giderilmesinde etkili olduğunu göstermiştir. Fakat, araştırma sonunda, deney grubu öğrencilerinde bazı kavram yanılgılarının giderilmesinde sorunlar olduğu saptanmıştır. Örneğin, H atomu içeren tüm maddeler asit, OH grubu içeren tüm maddeler bazdır gibi. Asit ve bazların tanımıtla ilgili bu kavram yanılgısı lise öğrencileri çok sık görülen ve giderilmesi zor bir kavram yanılgısıdır.

Son-testler verildikten sonra ortalama puan alan deney ve kontrol grubundaki toplam 12 öğrenciyle mülakatlar yapılmıştır, Mülakatlarda, her iki gruptaki öğrencilerin çoğunluğunun kavram yanılgısı testinde yanlış işaretlediği sorulara benzer sorular sorulmuştur. Mülakat sonuçları, öğrencilerin çözeltiler ve bağlar konusundaki yanlış anlamaları, öğrenme güçlükleri ve bilgi eksikliklerinin asitler ve bazlar konusunda kavram yanılgılarına yol açtığını göstermiştir. Özellikle, konsantrasyon ve kuvvetlilik kavramlarını asitlik, bazlık ve pH kavramlarıyla bağdaştırmada öğrencilerin problem yaşadıkları görülmüştür; öğrencilerin konsantre asit ve bazları güçlü seyreltik asit ve bazları ise zayıf olarak düşünmesi gibi. Konuyla ilgili bu tür yanlış kavramların giderilmesinde özellikle bağlar ve çözeltiler konusundaki bilgi eksikliklerinin tamamlanmasının ve kavram yanılgılarından giderilmesinin etkili olacağı düşünülmektedir.

Öğrencilerin, kimya dersinin yanı sıra müfredat kapsamındaki pek çok dersin içeriğiyle ilgili kavram yanılgılarına sahip oldukları ve bunların giderilmesindeki zorluklar bilinmektedir. Ders kitapları da konuları açıklamada çoğu zaman yetersiz kalmakta, kavramsal bilgiler yerine genellikle matematiksel hesaplamalar üzerine yoğunlaşarak öğrencileri ezbere yöneltmektedir. Yapılan araştırmalar ve analiz sonuçları, öğrencilerin bilimsel gerçekleri doğru ve anlamlı öğrenmesinde geleneksel yöntemden daha etkili öğretim metodlarının ve ders araç-gereçlerinin kullanılması gerektiğini göstermektedir. Ülkemizde sınıflar, öğretmenlerin her öğrenciye ulaşıp konuları anlamlı ve doğru bir şekilde anlamalarını engelleyecek derecede kalabalıktır. Bu bağlamda, kavramsal değişim metinleri, öğretmenler tarafından diğer pek çok öğretim methoduna göre kolayca hazırlanan ve uygulanan, özellikle kalabalık sınıflar için her öğrenciye ulaşabilme açısından etkili bir alternatif araç olarak düşünülmektedir.

Appendix A

Sample Questions from Acid-Base Conceptions Test

1. To understand the strength of an acid, which one of the following(s) should be definitely known?
   I-concentration
   II-number of H atom in its' structure
   III-percent ionization in water
   IV-pH value
   a-)I and II b-)only III c-)II and III d-)II and IV

2. Which one of the following statement(s) is TRUE related to acids and bases?
   I-they show opposite properties of each other
   II-at pH=0, a substance can be neither an acid nor a base
   III-pH of acids are lower than pH of bases
   VI-strong acids only react with strong bases and weak acids only react with weak bases
   a-)only II b-)only III c-)I and II d-)II and IV

3. What is the difference between strong and weak acids?
a-) strong acids have higher pH than weak acids
b-) strong acids contain more hydrogen bond than weak acids
c-) strong acids are more concentrated than weak acids
d-) strong acids ionizes more than weak acids

Appendix B

Student Interviews

Interviewer: What do you understand from the notation of being dilute and concentrated acid/base?

EG Student A: If the number of H or OH atoms in the formula is large, it means concentrated and being strong.

EG Student B: Being concentrated is related with dissolving. If substance dissolves less it means it is concentrated, if it dissolves more then it is dilute. If we add salt to water it does not dissolve completely so the solution is concentrated.

EG Student C: Being concentrated is related with being strong.

EG Student D: Being a concentrated acid means pH is closer to 7, being dilute means pH is closer to 1.

CG Student A: Being concentrated means saturated. For example, concentrated HCl means saturated: if you add more HCl it precipitates. Dilute HCl means unsaturated you can add more HCl to get a concentrated solution.

CG Student B: Being concentrated means dissolving completely, being dilute means dissolving partially.

CG Student C: If H^+ concentration or OH^- concentration is large, it can be said that it is concentrated as a result it is strong too.

CG Student D: Concentrated acids and bases dissolve other substances and form saturated solutions.

Interviewer: Is there any relation between being concentrated and pH value?

EG Student A: There is relation because if the number of H or OH atom in the formula is large it means concentrated and large amount of these ions means being strong. As a result, if something is concentrated acid it has a small pH value, if it is a concentrated base it has a large pH value.

EG Student B: There is no relation because it is related with being strong. pH is related with being more acidic or basic.

EG Student C: If something is concentrated acid it means it is more acidic in other words pH value is bigger than the dilute acid.

CG Student A: There is a relationship between being strong and pH value but there is no relationship between being strong and being concentrated. As a result there is no relation between being concentrated and pH value.

CG Student B: Concentrated solutions contain more H^+ ions than dilute ones as a result pH will be smaller.

CG Student C: Concentrated substances have higher molarity as a result have higher pH values.