Conceptual change achieved through a new teaching program on acids and bases

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Abstract: The purpose of this study was to investigate the effects on students' achievement and misconceptions of new teaching material developed for the unit 'acids and bases'. Also, the students' attitudes towards chemistry were explored. The new material included worksheets based on the conceptual conflict strategy. The sample consisted of eighty-eight students. The research was carried out with an experimental/control group design, and lasted for four weeks. Two instruments 'The Concept Achievement Test' and 'Chemistry Attitude Scale' were used to collect data before and after the study as pre-tests and post-tests. The results from the post-tests indicated that the students in the experimental group, taught with the new teaching material, showed significantly greater achievement in the unit than did the students in the control group. In addition, the experimental group had a significantly higher score than the control group with regard to their attitudes toward chemistry. This shows that the implementation of the new material produced better results both in terms of achievement and attitudes. The students' misconceptions in experimental group were less than the control group. [*Chem. Educ. Res. Pract.,* 2005, **6** (1), 36-51]

Keywords: *new teaching material; chemistry education; conceptual conflict; conceptual change and misconceptions.*

Introduction

Research has indicated that students often construct their own theories about how the natural world works, prior to formal science education, but their theories are frequently contrary to those of scientists (Osborne et al., 1985). Students' self-constructed conceptions have been referred to in the literature as misconceptions, alternative conceptions, preconceptions, naive conceptions etc (Driver et al., 1978; Krishnan et al., 1994; Demircioğlu et al., 2001). Throughout this article, the term 'misconceptions' has been used to refer to these ideas that are not in agreement with accepted scientific ideas. There are a variety of sources of misconceptions. These are: experiences encountered in daily life (Head, 1982), traditional instructional language (Bergquist et al., 1990), teachers, mismatches between teacher and student knowledge of science (Hodge, 1993), chemical terms that have changed their meaning (Schmidt, 1999; Schmidt et al., 2003) and textbooks (Stake et al., 1978). Misconceptions are resistant to change, persistent, and difficult to extinguish even with instruction designed to address them. Also, the misconceptions learners may hold generally hinder their subsequent learning (Ben-Zvi et al., 1986; de Vos et al., 1987; Haidar et al., 1991; de Posada, 1997). So, learners' misconceptions should be taken into consideration in the developing of science curricula. Unfortunately, many of the current science curricula and textbooks have not addressed the persistence of any misconceptions. In the conventional curriculum development, curricula have been generally taken up as a whole and prepared by

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central commissions, and teachers' ideas have often been ignored. Kelly and Monger (1973) explored that, with this approach, the expected achievement level hasn't been reached.

According to the constructivist view of learning, which is a relatively new approach in curriculum development in science, learners' existing ideas are important to make sense of new experiences and new information (Wittrock, 1974; Hand et al., 1991; Duffy et al., 1991). In this model, it is suggested that learners construct their knowledge and concepts in the direction of their abilities and experiences (Osborne et al., 1983). This shows that each individual's learning style is different. For this reason, curriculum development has begun to be conducted for individual topics or concepts during the last three decades or so (Osborne et al., 1982; Osborne et al., 1985).

Over the last three decades or so, various teaching models have been developed to change learners' misconceptions into scientific conceptions. This type of studies has been phrased as 'conceptual change models' (Posner et al., 1982). In general, conceptual change has been described as part of a learning mechanism that requires the learners to change their conceptions about a phenomenon or principle either through restructuring or integrating new information into their existing schemata (Hewson, 1996). The best-known conceptual change model has been that of Posner, Strike, Hewson, and Gertzog (1982), which describes the conditions of conceptual change. In this model, there are four steps: (1) learners must become dissatisfied with their existing conceptions; (2) the new conception must be intelligible; (3) the new conception must be plausible; and (4) the new conception must be fruitful. After these conditions have been met, students can experience conceptual change.

It is important to create a learning environment in the classroom where students can make sense of science and use science to make sense of the world. The methods and strategies used in such an environment should guide students toward science. Based on conceptual change theory, cognitive conflict is known as an important factor in conceptual change (Posner et al., 1982; Hewson et al., 1984; Hewson et al., 1989; Niaz, 1995), even though there are still questions about its positive and negative effects on science. A cognitive conflict can be produced by a situation consisting of disequilibria – that is, questions of felt lacunae that arise when the student attempts to apply existing schemas to a new situation (Mischel, 1971). Several researchers have shown that instruction based on conceptual change can be effective at changing students' chemistry conceptions (Basili et al., 1991; Ebenezer et al., 1995). Hewson and Hewson (1983) employed a conceptual change approach to promote conceptual change in students regarding density, mass and volume concepts. This study showed that the use of instructional strategies taking students' misconceptions into account results in better acquisition of scientific conceptions. Basili and Sandford (1991), however, have found that most students retain their misconceptions, and teachers may have difficulty teaching for conceptual change. Roth (1985) also prepared specific curriculum materials, engaging students in a process of knowledge restructuring. Moreover, many strategies have been suggested for facilitating conceptual change in the literature (Driver, 1989; Dykstra et al., 1992; Guzzetti et al., 1993; Smith et al., 1993).

Students' conceptions of acids and bases

It is known that chemistry is one of the most difficult subjects in secondary schools. Therefore, many of the students have difficulties in understanding fundamental concepts (Kavanaugh et al., 1981). Research on students' understanding of chemistry concepts has revealed that students have many misconceptions. The concepts examined include equilibrium (Banerjee, 1991; Demircioğlu et al., 2000), phase changes (Bar et al., 1991), chemical reaction (Barker et al., 1999), gases (Benson, et al., 1993), stoichiometry (BouJaoude et al., 2000), atoms and molecules (Griffiths et al., 1992), acids and bases (Ross et al., 1991), and covalent bonding (Peterson et al., 1986; Ünal et al, 2002). Many of the

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topics about which students hold misconceptions are basic to chemistry knowledge and are interrelated. Two of these fundamental concepts in chemistry are acids and bases. The concepts are related to many of the other chemistry concepts, such as the nature of matter, chemical equilibrium, chemical reaction, stoichiometry, and solutions. In the literature, there have been a number of studies that address various aspects of students' understanding about acids and bases (Cros et al., 1986; Cros et al., 1988; Hand et al., 1991; Nakhleh et al., 1993; Nakhleh et al., 1994; Botton, 1995; Sisovic et al, 2000; Demircioğlu et al., 2001; Demircioğlu, 2003; Demircioğlu et al, 2004). These studies involved students at different stages in their school or university training. Some of these studies are reviewed below.

Cros et al. (1986), investigating 400 first-year university students' conceptions of the constituents of matter and conceptions of acids and bases, found that the students knew more about acids than bases and had a good knowledge of formal descriptive aspects, but they had inadequate conceptions of concrete phenomena, such as heat being released during an acid-base reaction. They noted that students found it easy to give examples of acids; the most frequently mentioned being hydrochloric (93%), sulphuric (61%), and ethanoic acids (56%), but when asked to list three bases, 43% couldn't name more than two. In addition, 17% answered that pH was a measurement of the degree of acidity. Ross and Munby (1991) reported this misconception in their study too. In a follow-up study done by Cros (1988), it was found that some of the students in the second year had modified their concepts; for example, the former descriptive definition for acids (*pH less than 7*) replaced a scientific definition *(an acid releases or can release* H^+). However, other concepts had hardly changed.

Hand and Treagust (1991) identified five key misconceptions about acids and bases among sixty 16-year-old students. Then, they developed and implemented a curriculum about 'Acids and Bases' based on the conceptual change approach, which aimed to remedy the student misconceptions. These were: (1) An acid is something which eats material away; an acid can burn you, (2) Testing of an acid can only be done by trying to eat something away, (3) To neutralize is to break down an acid or to change from an acid, (4) A base is something which makes up an acid, and (5) A strong acid can eat material away faster than a weak acid. Almost all these misconceptions relate specifically to acids. The results showed that students taught by using the new curriculum about 'Acid and Bases' topic have had a higher achievement than those taught by using conventional methods. Hand (1989) followed up twenty-four of the students reported in Hand and Treagust (1991). Some students had been taught more sophisticated ideas in a pure chemistry course, while others had studied a broader based science course or biology. A test based on the five original misconceptions was administered to the group. The results of the test showed that only students studying chemistry could answer basic recall questions correctly, while those studying biology did best overall. The author concluded that the biologists did better because they were not having any interference from new definitions.

In order to investigate students' understanding of acids and bases, Ross and Munby (1991) conducted two audio taped interviews with each participant. The study was started with a multiple-choice test. This test was used to gain additional information for the interviews and to select the participants. The first interviews conducted three days after the administration of the multiple-choice test included tasks written on a card that contained a stimulus in the form of a drawing, diagram, or picture. In the second interviews, each student was asked to write five words or phrase he or she associated with acids and bases. The second interviews were conducted four weeks after the first interviews. The interviews were grounded on a model concept constructed from the curriculum. The results were depicted in concept maps and compared to the model concept map. Ross and Munby (1991) found that students understand more about acids than bases and had particular problems with the ionic nature of acids and bases. Driver et al. (1994) suggested that pupils' ideas about acids are

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derived from sensory experiences such as tasting sour foods, and from advertisements for antacid remedies and crime stories about acid baths and news about the effects of acid rain.

Since Nakhleh and Krajcik (1994) investigated how different levels of information, presented by various technologies, influenced secondary students' understanding of acid, base, and pH concepts, they used concept maps constructed from the propositions that the students used in interviews conducted before and after a series of acid-base titration. After the initial interviews, students were divided into three groups. Within each group, students individually performed the same set of titrations using different technologies: chemical indicators, pH meters, and microcomputer-based (MBL). The results indicated that the order of the influence of technology on understanding is: MBL>chemical indicator>pH meter. In addition to this, they also established that some of students who participated in the study had the following misconceptions.

1. The pH is inversely related to harm and bases are not harmful. 2. Bubbles or bubbling is a sign of chemical reaction or strength. 3. Acids and bases have their own particular color or color intensity (bases are colored blue, acids are colored pink, and even different pH solutions have different colors). 4. The molecules fight and combine, and phenolphthalein helps with neutralization. 5. Acids melt metals, acids are strong and bases are not strong. 6. pH is a compound called phenolphthalein, a chemical reaction and a number related to intensity.

Schmidt (1991) has stressed the example of a common misconception about neutralisation: that the *neutral*isation of acid and base always gives a *neutral* product. He refers to the *'neutralisation' label* as 'a hidden persuader': after all pupils are usually introduced to neutralisation reactions through examples where strong acids react with strong bases to give a neutral solution.

In order to investigate students' understanding of acids and bases, Demerouti, Kousathana, and Tsaparlis (2004a) constructed and utilized a questionnaire consisting of ten multiple-choice and eight open-type questions. The test was given to 119 Greek students in the twelfth grade. They found that the students had misconceptions and difficulties on the following topics: dissociation and ionization, definition of Brønsted-Lowry acids and bases, ionic equilibria, neutralization, pH, buffer solutions, and degree of ionization. Some of the misconceptions are similar to those reported elsewhere in the literature. Demerouti, Kousathana and Tsaparlis (2004b) investigated the effect of two psychometric variables: developmental level and disembedding ability or cognitive style on twelfth-grade upper-secondary students' ability to deal with conceptual understanding and chemical calculations. They found that both variables played an important role in the performance of the sample (N = 119). Disembedding ability clearly had a larger effect. Developmental level was connected to most cases of concept understanding and application, but less so with situations involving complex conceptual situations and/or chemical calculations. On the other hand, disembedding ability was involved in situations that required conceptual understanding alone, especially in demanding cases, and in combination with chemical calculations.

Only one of the studies above, conducted by Hand and Treagust (1991), was designed to change students' misconceptions about acid and bases to scientific conceptions**.** Some of the misconceptions identified in the above studies were used to develop the test in the study reported here**.**

The Science Curriculum in Turkey

The current Turkish Education System consists of these components: a) Basic Education which is eight years, compulsory, and free of charge in public schools, b) Secondary Education which is three years, not compulsory and free of charge in public schools. Science was a compulsory subject in Turkish schools until recently. When students came to the

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secondary schools (Lycees) they had to take chemistry, physics and biology as compulsory subjects. The curricula for these three subjects comprise only textbook based syllabuses. There are no accompanied teacher guides, laboratory manuals or computer programs for simulations etc. Moreover, the worldwide problems of education such as overcrowding, lack of materials, inadequate laboratories, and poor teacher preparation are commonly faced in the study context as well (Ayas et al., 1993; Ayas et al., 2001). The concepts of acid, base and salt are taught initially in the eighth grade (age 13-14) of the basic education. In the second year of secondary (tenth grade) school, the concepts are studied in more detail again. It is the last unit in the curriculum. The time devoted to the unit is 17 hours. The unit contains the theories of acids and bases, the properties of acids and bases, strength of acids and bases, neutralization (titration), hydrolysis of salts, and buffers.

The curriculum should normally include general purposes, topics of domain, special aims of topics, and behavioral objectives, teaching and learning activities, teaching tools, learning results, assessment tools and methods (Ayas, 1993). However, in Turkey, it only contains general purposes, topics of subject area and subtitles of each topic, with the remainder resting on the shoulders of teachers. That is, determining special aims of topics, behavioral objectives, teaching and learning activities, teaching tools, learning results, assessment tools and methods left to teachers. However, Akdeniz, Karamustafaoğlu and Keser, (2000) found that teachers, even experienced ones, could not describe behavioral objectives at the expected level for each of the topics. In recent curriculum development studies, aims and behavioral objectives of related topic have been determined, as in the 'Chemistry Draft Program' developed and piloted by the National Ministry of Education in 1998, but it has not been pursued since then. In addition, several chemistry textbooks are prepared according to the national curricula prepared by the National Ministry of Education. All textbooks are sequenced in the same order of topics.

The purpose of the present study

Students' interests in science were another important factor in learning science (Hofstein et al., 1976). Different and new materials developed for teaching any science topics were thought to play an important role on students' attitudes toward science. Thus, our hypothesis is that the developed teaching material in this study increases students' achievement and attitudes regarding chemistry.

For this study, we developed new teaching material (NTM) designed to encourage conceptual conflict for those students holding misconceptions about acids and bases. The purpose of this study was to investigate the effects of the NTM about the unit 'acids and bases' on students' chemistry achievement, misconceptions and attitudes toward chemistry in the tenth grade. The following research questions were specifically addressed;

1. Would the new teaching material or traditional introduction be more effective in improving students' achievement and attitudes?
2. Does the new teaching material promote conceptual change concerning acids and bases?

The Development of the New Teaching Material

The new teaching material related to the unit 'acids and bases' was taught to grade 10 students. The NTM was designed to help students: a) correlate scientific knowledge with their existing conceptions and b) use their new knowledge when they describe and explain new phenomena. To develop the NTM, we examined a number of related resources such as the Turkish chemistry textbooks, lycee II chemistry curriculum, and annual plans prepared by chemistry teachers to determine the depth, size and time devoted for teaching the unit. Then,

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we developed nine worksheets, five demonstrations and three analogies aiming at remedying the misconceptions identified from the interviews and the concept achievement test implemented prior to the study. In total, we prepared material that consists of eighteen lesson plans (each lesson lasts 45 minutes) and requires the students' active participation. The NTM was developed and implemented with a conceptual conflict strategy. In this strategy, there was a need to determine the students' preconceptions and the existence of any misconceptions before any teaching plan was prepared. The NTM covered the entire content of the current curriculum about the unit 'acids and bases', the same number of lessons, but with a different teaching approach. The implementation procedure of one of the worksheets used in this study is shown in Figure 1. As can be seen from this, each worksheet consists of three sections. These were: (1) the student misconceptions identified from interviews and pre-tests, (2) the practical activity (3) questions. While preparing the NTM, we benefited from the ideas of ten experienced chemistry teachers and two chemistry educators. The NTM was first piloted in a tenth grade class consisting of forty students. During the pilot study, paper-and-pencil tests, informal students and teachers interviews and classroom observations were carried out. Based on the results, it was revised.

Method

Subjects

The subjects for this study were eighty-eight tenth grade students from a secondary school on the north coast of Black Sea Region in Turkey. The school has nearly 900 students in total. There are eight classes at grade 10, each of which consisted of 22-24 students. Students' ages ranged from 16 to 17 years old. Two of the four chemistry teachers in the school volunteered to participate in the study. Each teacher had two tenth grade classes that participated in the study. Once one of the teachers and her two classes were randomly chosen as the experimental group, the other teacher and her two classes became the control group. The experimental group teacher (teacher A), using the new material, had 13 years of experience teaching chemistry, although she only transferred to the present school five years ago. The control group teacher (teacher B), using the traditional approach, had 12 years of experience and has only ever taught in this school. From this, we could say that the teachers had similar experience in teaching chemistry.

The chemistry course in the school consists of five 45-minute periods per week; it includes three lectures and two laboratory sessions. However, the chemistry teachers in the school generally conduct lectures in the classroom setting and rarely use the laboratory. Informal interviews with the teachers showed that their main goals for the chemistry course were to help students pass the University Entrance Examination. According to them, students, parents, and school principals value success on this examination. So, the teachers encouraged their students to solve many multiple-choice questions to prepare themselves for University Entrance Examination in the chemistry courses. Thus, an important part of the courses was used for this aim.

Procedure

The teacher of the experimental group was introduced to the NTM and to the teaching strategy (conceptual conflict) for two weeks and underwent training on the appropriate use of the NTM before implementation in order to be sure that the NTM was used as we planned. In addition, the researchers held meetings as often as necessary to correct any misuse of the NTM as well as the teaching strategy. Both experimental and control groups were observed during the implementation of the unit. In a typical instructional sequence, while the experimental teacher tried to help their students recognize and resolve the conflict between

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personal knowledge and scientific knowledge with the NTM, the control group teacher used a teacher-centered approach mainly involving talk and chalk sessions without practical sessions.

The two groups spent equal time studying the unit. However, the lessons in the experimental group generally focused on the prepared worksheets, analogies and demonstrations from the NTM, designed to encourage conceptual conflict for those students holding misconceptions about acids and bases. As an example, the implementation procedure of one of the worksheets is described below:

The first stage of each worksheet was focused on the misconceptions described at the top of each worksheet (Figure 1). At this stage, the students encountered the misconceptions without any indication that they were misconceptions. This was used at the start of the lesson to create a cognitive conflict. During this process, the misconceptions were checked up in our sample. The students indicated that these phrases were generally true. If the students have different misconceptions, other than the ones on the worksheet they were discussed before going forward to the actual activity. These were usually done before the second stage. Then the practical activity on the worksheet was carried out to create a clear sign of the concept under investigation in the students' mind. At the end of each practical activity, small group (four or five students per group) and whole class discussions took place under the guidance of the class teacher to encourage students to think about their misconceptions and the outcome of the activity. After these discussions, the students have changed their misconceptions, as well as the misconceptions presented at the top of each worksheet, to scientifically sound concepts. In each of the activities, we generally preferred to use substances often used in daily life, such as lemon juice, red cabbage, vinegar, baking soda, coke, etc. In addition, the teacher made use of the pre-designed analogies for some concepts, such as theories of acid and base, relative strengths of acids and bases and equilibria of weak acid and base. Also, experiments that could be harmful to the students were demonstrated by the teacher.

Figure 1: Example of a worksheet used in the study

The purpose of the following activity is to remedy the following student misconceptions; *i. whether a liquid is an acid or a base can just be determined by using litmus paper; ii. The only way to test a sample whether it is an acid or a base is to see if it eats something away, for example metal, plastic, animal, and us.*

Tools and materials needed for the activity: test tubes, dropper, HCl solution, NaOH solution, litmus, methyl orange, phenolphthalein, lemon juice, vinegar, red cabbage, soapy water.

Carrying out the activity: In this test you will be using three known indicators and red-cabbage juice. Follow the sequence in the chart below. In each test, place about 4 cm^3 of each solution in different test tubes. Then place 2-3 drops of the indicator into each of the test tubes. Carefully record the color in the test tubes. You are going to test the unknown solution after finishing the other tests.

Solution	Litmus	Phenolphthalein	Methyl orange	Red cabbage
1. HCl solution				
2. NaOH solution				
3. Lemon juice				
4. Vinegar				
5. Soapy water				
6. An unknown solution				

Questions: Which solutions used in the activity are acidic? Why?
Can you use red-cabbage juice to test a liquid whether it is an acid or a base?
What do you have to know about an indicator before you use it? Why?

Instruments

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The Concept Achievement Test (CAT)

A twenty-item test related to the concepts of acids and bases unit was constructed for the purpose of identifying the students' understanding and misconceptions in chemistry. The items in CAT were multiple-choice and constructed based on a methodology used by Peterson, Treagust, and Garnett (1986) and Treagust (1988). Each item in the CAT included one scientifically acceptable answer; one common misconception revealed in the previous studies and found out during the interview sessions, and three reasonable and plausible distracters. During the development of the CAT, the following steps were taken into consideration. First, instructional objectives related to the acids and bases topic were determined, based on the current curriculum. Second, the literature related to students' misconceptions about the acids and bases concepts was examined. Third, interviews were conducted with ten high school students who were randomly selected from the sample to investigate in depth their misconceptions. The interviews were analyzed to obtain a list of students' misconceptions about acids and bases. And then, a review of research on students' misconceptions about these concepts was conducted to gather more information and validate the findings of interviews (Hesse, 1988). The identified misconceptions were used to develop the multiple-choice items of CAT. An example of items in CAT was:

Item 8: Which one of following is a correct statement about the effects of the acids and bases?

A.	Acids burn and melt everything
B.	Beverages with soda contain weak bases.
C.	Strong acids melt and destroy metals.
***D.**	Some weak acids can be tasted.
E.	All acids have bubbles.

The correct answer of this item was option 'D', as marked by an asterisk (*). The common misconception in this item was that "Acids burn and melt everything".

For purposes of content validation and reduction of errors, the CAT was examined by a group of experts consisting of three chemistry educators in the Chemistry Department in the Faculty of Education and five high school chemistry teachers who had taught chemistry for over ten years at the central lycees in the city of Trabzon. These experts checked the correspondence between the items in the CAT and the identified misconceptions, and they determined that there was an acceptable correct choice for each item of CAT. In addition, CAT was piloted with forty students from grade 10. For the reliability of the CAT, an item analysis was made. After conducting the item analysis, the final form of CAT has included the elected 20 items. The alpha reliability coefficient (KR20) was found 0.92. Students completed CAT in a 45 minutes period. The *t*-test was used to compare the pre-test and post-test scores of the groups.

Interviews with students

The grade 10 students were individually interviewed for 30 to 40 minutes to obtain their preconceptions about the concepts of the acids and bases. The interviews were conducted approximately three months before teaching the acids and bases topic. For the interviews, students were categorized by the grades they received on the teacher-made exams in chemistry as high achievers, middle (average) achievers, and low achievers. The teachers were asked to select ten volunteers from middle achievers in chemistry. A semi-structured approach was used in the interviews. Six students were male and four female. All the interviews were audio taped and transcribed verbatim by the researchers. Appendix A shows the questions used in the interviews. Interview results were used to construct the items of the CAT.

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Chemistry Attitude Scale **(CAS)**

We also developed the CAS, which contains 25 attitude statements (11 positive and 14 negative). Items in the CAS were designed to measure students' attitudes toward the learning of chemistry. Because a goal of the NTM was for the students to hold more positive attitudes toward the learning of chemistry after they were taught with the NTM, items in the CAS needed to measure this. Sample attitude items crafted for instrument included: "*I like chemistry*", "*I am looking forward to taking more chemistry courses*", and "*I enjoy learning how to use chemistry in daily life*". One factor was identified by factor analysis: attitude towards chemistry. This factor explained 44% of variance. The CAS contains items in a 5-point Likert-scale (strongly agree, agree, undecided, partially disagree, strongly disagree). After an item analysis based on a pilot, we selected 25 items from 42 items. The reliability coefficient was 0.84 and validated by three professors in the field of education. While the ratings ranged from Strongly Agree (5) to Strongly Disagree (1) for the 11 positive statements, the reverse ratings, Strongly Agree (1) to Strongly Disagree (5), were used for the 14 negative statements. The score from the CAS can range from the lowest (25) to the highest (100). In the analysis of the CAS, firstly, the total score of each student on the CAS and then mean score of each group were computed. The mean scores of the groups were compared by using *t* test for both the pre-tests and post-tests.

Design

The study utilized 'a nonequivalent pretest-posttest control group design' (Campbell and Stanley, 1963, p. 43). Because we were unable to assign the students randomly to the groups due to constrains of the context, this study was quasi-experimental in nature.

	Pre-test	Instruction	Post-test
EG	T_1, T_2	X_1	T_1, T_2
CG	T_1, T_2	X_2	T_1, T_2

EG represents Experimental Group, using the NTM (X_1) while CG represents the control group, using the traditional approach (X_2). T_1 represents CAT, T_2 the CAS.

Results and Discussion

The CAT and CAS were administered to both the experimental and control group students before the instruction. No statistically significant mean difference was found between the two groups with respect to chemistry achievement (t = 0.439, df = 86, p > 0.05) and chemistry attitude scale (t = 0.406, df = 86, p > 0.05), indicating that students in the experimental and control groups were similar in respect of these two variables. As there were no significant differences between the pre-test scores of the experimental and the control groups, the post-tests scores of the groups could be compared using an independent *t*-test.

The first research question asked whether the new teaching material or traditional introduction would be more effective in improving the students' achievement and attitudes. The data showed that there was a significant difference in chemistry achievement between the experimental group (M= 73.9, SD= 12.7) and the control group (M= 60.0, SD= 15.9) t= 4.496, p < 0,001 (Table 1). This finding showed that students in the experimental group exhibited significantly higher science achievement scores than did students in the control group. Although the mean difference of 13.9 raw score seemed to be quite high, the mean of the experimental group was lower than it was expected. A reason for this was that the topic

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’Acids and Bases‘ was related to many other chemistry topics, such as the particulate nature of matter, oxidation and reduction, and chemical equilibrium.

Table 1. Comparison of the Experimental and Control Groups for Overall Differences in CAT, and CAS

Groups / Measures	Experimental group			Control group			t	p
	N	Mean	SD	N	Mean	SD		
CAT	44	73.9	12.7	44	60.0	15.9	4.496	0.000
CAS	44	79.7	10.9	44	74.4	13	2.528	0.013

The results of the *t*-test (Table 1) also denoted that significant differences found between groups in favor of experimental group (t = 2.528, p = 0.013), with regard to their attitudes toward chemistry. The students were more active in the laboratory approach in the NTM than in the traditional laboratory. The experimental group students spent longer time than the control group in the laboratory. Thus, they had a lot of experience in measuring, interpreting, drawing conclusions, and making generalizations. This may generate more positive attitudes towards chemistry.

The percentages of the students’ misconceptions in both groups on the pre-test and the post-test are given in Table 2. The misconceptions reflected by the distracters in multiple-choice items in the test are the common misconceptions in a certain conceptual area. As can be seen from Table 2, the students in both groups held almost the same misconceptions on the pre-tests. The misconceptions obtained from the subject of this study support previous findings in the literature (Ross et al., 1991; Hand et al., 1991; Nakhleh et al., 1994; Ayas et al., 2002; Demircioğlu, 2003.). Prior to the instruction, the percentages of the misconceptions held by the students in the experimental group ranged from 18 % to 84 %, and those of the students in the control group ranged from 20 % to 95 %, as shown in Table 2. This shows that the subjects have a great number of misconceptions related to the concepts under investigation. Before the treatment, the most common misconception among students in both groups was that "*All salts are neutral*" (Table 2). This misconception is also widespread among the student teachers (Demircioğlu et al., 2001; Ayas et al., 2002).

The second research question asked whether the use of the teaching material based on the cognitive conflict strategy promoted conceptual change concerning acids and bases. The data indicate that it contributed significantly to a better understanding of the topic ’acids and bases‘ as the experimental group reached a higher level on post-tests. After the instruction, the percentages of the misconceptions held ranged from 0 % to 10 % in the experimental group, from 2 % to 41 % in the control group (Table 2). In both groups the percentages of student misconceptions decreased on the post-tests, but the experimental group did better than the control group. The students in the experimental group had completely corrected the following misconceptions: “as *pH increases, acids becomes harmless and bases are not harmful”, “pH solutions have different colors”*, “*The only way to test a sample whether it is an acid or a base is to see if it eats something away, for example metal, plastic, animal, and us”, “Bubbles or bubbling is a sign of chemical reaction or strength of an acid or a base”*, “*As the number of hydrogens increases in the formula of an acid, its acidity becomes stronger”*. These findings support previous research studies on the effectiveness of the teaching for conceptual change (Guzzetti et al, 1993; Tsai, 1999)

However, a few students maintained their misconceptions, which are depicted in the Table 2. Although these results are encouraging, they are still below the expected level. The

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reason for this could be the lack of active participation in acquiring of knowledge. In addition, misconceptions, once embedded in a learner's conceptual schemes, are extremely hard to remove (Novak, 1988; Songer et al., 1994).

Table 2. The percentages of students' misconceptions determined in the pre-tests and post-tests in the experimental and control groups

Student Misconceptions	Experimental Group				Control Group			
	Pre-test		Post-test		Pre-test		Post-test	
	f	%	f	%	f	%	f	%
Acids burn and melt everything	21	48	6	14	25	57	13	30
All acids and bases are harmful and poisonous	16	36	3	7	12	27	4	9
As pH increases, acids become harmless and bases are not harmful	11	25	0	0	9	20	3	7
Different pH solutions have different colors.	11	25	0	0	10	23	5	11
pH is a measure of acidity	22	50	2	5	25	57	12	27
A strong acid doesn't dissociate in water solution, because its intra-molecular bonds are very strong.	20	45	8	18	21	48	10	23
The only way to test a sample whether it is an acid or a base is to see if it eats something away, for example metal, plastic, animal, and us	20	45	0	0	24	55	11	25
All salts are neutral	37	84	8	18	42	95	18	41
Salts don't have a pH value	26	59	3	7	29	66	9	20
In all neutralization reactions, acid and base consume each other completely	32	73	5	11	35	80	13	30
At the end of all neutralization reactions, there are neither H^+ nor OH^- ions in the resulting solutions	26	59	10	23	22	50	19	43
A strong acid is always a concentrated acid	8	18	2	5	10	23	1	2
Bubbles or bubbling is a sign of chemical reaction or strength of an acid or a base	13	30	0	0	16	36	6	14
Indicators help with neutralization	15	34	6	14	15	34	10	23
As the value of pH increases, acidity increases	8	18	3	7	11	25	1	2
While bases turn blue litmus paper into red, acids turns red litmus paper into blue.	12	27	1	2	9	20	1	2
As the number of hydrogen atoms increases in the formula of an acid, its acidity becomes stronger	24	55	0	0	26	59	12	27
Species having formulas with hydrogen are acids and those having formulas with hydroxyl are bases	18	41	1	2	21	48	5	11

If the results are examined in detail, it can be seen that many students explained the testing of an acid based on sensory perceptions, often with statements such as "*The only way to test a sample whether it is an acid or a base is to see if it eats something away, for example*

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metal, plastic, animal, and us". 45 % of the students in the experimental group and 55 % of the students in the control group held this misconception prior to instruction. After the instruction, while 25% of the students in the control group maintained the misconception, none of the students in the experimental group did so. This result showed that when chemistry concepts were related to everyday life during teaching, their retention in the learner's mind was greater. This finding was similar to that of Ross and Munby (1991). They found that the students retain everyday concepts more than are scientific concepts. After the instruction, the most common misconception was that "*At the end of all neutralization reactions, there are neither H^+ nor OH^- ions in the resulting solutions*", with 23% of the experimental group and 43% of the control group holding it. The misconception indicated that most of the students, especially in the control group, failed to realize the central role of water in neutralization reactions. The concentration of H_3O^+ and OH^- ions in the neutral aqueous solution is about 10^{-7} mol/l. Therefore, neutral doesn't mean that the two are not present in the medium. In the literature, Schmidt's (1991, 1995) suggestion for the reason of this misconception was that students misunderstood the concepts of neutralization and neutrality. Another major misconception was that "*All salts are neutral*". This misconception was held by 18% of the experimental group students and 41% of the control group students on the post tests. The misconception indicated that the students had the idea that '*acid and base consume each other completely in all neutralizations*'.

This discussion shows that there are a number of misconceptions that are not confined to students of one nationality only. Therefore methods used to remedy them may, to some extent, be effective in other cultures.

Conclusions and Implications

The results indicate that training with the NTM based on the conceptual change strategy was more successful in remedying students' misconceptions on acids and bases than conventional instruction. This result supported the notion that it is not easy to eliminate misconceptions just by employing traditional instructional methods. The students' participation in the practical activities has caused not only greater understanding but also greater interest in the study of chemistry. So, while teaching acids and bases, teachers should organize activities that encourage students to use their prior knowledge and experience, and also provide them with opportunities to apply the newly acquired concepts in a variety of situations. That is, instructional strategy should focus on: first, what is known or unknown about the concepts of acids and bases, and then the new knowledge should be constructed upon existing knowledge.

We have concluded that the students' misunderstandings of the concepts of the acids and bases generally originated from their experiences in everyday life. So, when preparing a teaching program and student-activities on the concepts, it is very important to include everyday substances in the activities. Additionally, the students in both groups had more difficulty in understanding the neutralization (titration process) and related concepts than the others in the unit, because of the complex structure of the neutralization concept. In the teaching of this concept, in addition to simple titration activities that we used in this study, using different technologies, especially microcomputer-based activities could be suggested as better teaching tools (Nakhleh et al., 1993).

Another important conclusion was that the students in the experimental group attained more positive attitudes toward chemistry than did those in the control group. This result indicated that the NTM achieved success in moving the students' attitudes in the desired direction. This conclusion was not surprising because the experimental group students spent longer time than the control group ones in the laboratory. However, this conclusion may be

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surprising for many science teachers in Turkey because they tend not to use labs and do not believe that the practical activities can influence their students' attitudes towards science. This study is important in emphasizing that the NTM and laboratory activities are quite influential on students' achievement and attitudes.

Teachers should be aware of students' prior knowledge and misconceptions on acids and bases, because they are strong predictors of student achievement. They should be informed about the usage and importance of worksheets based on conceptual change approach. In short, when suitable strategies are used in the teaching of the unit 'acids and bases', they are more likely to cause a significantly better removal of misconceptions and acquisition of scientifically sound concepts. In addition, chemistry teachers should be encouraged to prepare teaching materials related to the other chemistry topics in the light of the models of conceptual change. In this process, we have thought that the present study would be an important source for the chemistry teachers in Turkey as well as that in other countries. Also, current chemistry textbooks should be revised to include the elements of conceptual change.

Pre-service and practising science teachers should be introduced to constructivist ideas of teaching and learning so that they become aware that the teacher's role is not simply to transmit knowledge but to facilitate student learning. Relevant research results about student conceptions should be communicated to teachers, curriculum developers to inform improvement in the practice.

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Appendix A. Interview questions

1. The student was shown a beaker marked ’dilute acid‘, and was asked to describe the solution.
2. The student was shown an unlabelled beaker of liquid and was asked the question “How would you test this liquid without litmus paper whether it is acidic or basic?”
3. The student was first shown four labeled cans of vinegar, lemon, dishwashing detergent, and soapy water. Each example was then discussed as to whether it might contain an acid or a base.
4. The student was first shown four bottles labeled HCl, NaOH, NH_3 and NaCl. Each example was then discussed as to whether the formula indicated an acid or base.
5. The student was shown three beakers marked pH 4, pH 7 and pH 12, and was asked to describe the solutions.
6. The student observed the changes that occurred when the dilute acid and base were mixed. The student was then asked to describe what had happened to the acid and base.

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