Traditional and computer-assisted learning in teaching acids and bases

Inci Morgil*, Soner Yavuz, Özge Özyalçin Oskay and Seçil Arda
Hacettepe University, Faculty of Education, Beytepe-Ankara, Turkey.
e-mail: inci@hacettepe.edu.tr

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Abstract: The traditional and the computer-assisted teaching methods for teaching a fundamental topic within chemistry education, acids and bases, were compared and the influences of the three dimensional spatial visualization abilities, computational attitudes and learning styles of the students on their acquisition of knowledge were investigated. The students were randomly distributed into control and experimental groups and their knowledge about acids and bases was assessed by a test comprising twenty questions. After this test, the experimental group received computer-assisted teaching and the control group was taught by traditional teaching methods for two days on the related subject. After two days of teaching, the students were tested again with the same twenty questions. Parallel to this, the three-dimensional spatial visualization abilities, computational attitudes and learning styles of the students from both groups were assessed. The three dimensional spatial visualization abilities, computational attitudes and learning styles of the students were not found to influence their test scores. However, a 52% improvement was observed in the post-instruction test results of the students of the experimental group whereas the control group only improved by 31%. The independent two-sample *t*-test was applied for the evaluation of the results of the study and there was a significant difference favoring the experimental group. [*Chem. Educ. Res. Pract.*, 2005, **6** (1), 52-63]

Keywords: *acid-base chemistry; computer-assisted education; spatial visualization ability; computational attitudes; learning styles.*

Introduction

Computer-aided instruction

It is possible to acquire information through using computers and the Internet in science, especially by chemistry classes of primary, secondary and higher education. The teaching tools prepared by institutions specializing in such applications could also be used in virtual media. By using such teaching tools, students could learn the subject matter in a better way, as they are provided with a variety of knowledge, and a medium where they can observe the virtual experiments and repeat the same experiments many times if they request. As a result, it is expected that computer-assisted applications affect the students' achievement.

One of the common teaching methods that chemistry teachers prefer today is the lecture method. In this the teacher transmits knowledge to the students who sit passively in the classroom and listen. Another common method is the question-and-answer approach, which was developed in order to avoid the boredom caused by lectures and to provide a more efficient learning environment. On the other hand, case studies allow the students to face the problems that occur in real life. They help to fill the gap between theory and practice through putting the previously learnt concepts and principles into use. The best part of this method is that it enables the students to apply what they have learnt to what they are living through (Sönmez, 1986).

A useful part of instruction in chemistry is the performing of experiments. This can be done by demonstrations when the teacher actively carries out the experiments in front of the class or demonstrates some materials (Bayramlı, 2000) or by the students who learn about a subject by carrying out experiments in the laboratory or classroom, in which case, the role of the teacher is to guide and help them where necessary.

In contrast to the previously described methods, in *Computer-Assisted Instruction* (CAI), the teacher can use computers at different times and places according to the characteristics of the subject matter, the students, and the available software and hardware. Computer programs can be used for practice, revision, one-to-one instruction, problem solving, or simulations during the applications (Demirel, 1996).

In many studies, CAI has been shown to have some benefits, although there are also cases where none were observed. With CAI, there is a form of one-to-one instruction (or two students together at each computer), plus the opportunity for the students to proceed at their own pace, repeating parts of the exercise as they wish. None of these features are easily available in a didactic classroom situation. In addition, there is added variety and, perhaps, novelty in CAI, along with the potential to use vivid and animated graphics, enabling three-dimensional aspects, and other features to be viewed more realistically. Of course, not all computer programs have these features, but the potential is certainly there.

For understanding to occur, students need to have the time to be able to handle new information, to think through ideas and to revisit difficult areas. All of this may reflect features of many computer programs. However, computers lack the human dimension and the ability to provoke thought by spontaneous questions and answers. A good teacher can respond to the way a class is reacting to a lesson by the skillful use of such spontaneous questions and answers. This flexibility is not easy to develop in a computer program and the style of presentation will depend on the ingenuity of the program developer and his/her own understandings of the subject matter.

In a study that was conducted to find out the effects of the computer on attitudes, motivation or learning, and the possible advantages of computer-assisted test programs (Jackson, 1988), secondary school students were distributed into control and experimental groups. The assessment of the experimental group was done using computers, whereas that of the control group was done through a written test. The statistical evaluations displayed a higher achievement rate for the experimental group that received a computer-assisted test.

Levine and Donitsa-Schmidt (1996) compared the traditional learning strategies with computer-based activities. Applications and the assessment were administered after the students were distributed into control and experimental groups. The results of the evaluations showed that the experimental group was more successful at answering the questions of the Chemistry Achievement Test than the control group. In another study, Demircioğlu and Geban (1996) compared CAI with the traditional teaching method on 6th grade students in science classes. The students of the experimental group were taught with CAI in addition to the traditional teaching method. The students of the control group were taught through problem solving. The topics were static electricity, electrical transmission, electrical wires and Ohm’s laws. The science achievement rates of the two groups were compared through a *t*-test and the group that was taught through CAI was found to be more successful.

The effects of the CAI were assessed by Gerardo (1986). This study compared the effectiveness for learning of the technology-assisted and the traditional method. The students were shown to be more successful in the technology-assisted applications. In another study, the achievement rate increased when the general chemistry applications were made through the CAI (Jackman, Moellenberg, & Brabson, 1990). Lord (1999) in a study of 90 high school students observed that they had difficulty in understanding the “nitrogen cycle” and experienced misconception problems when they were taught through traditional methods.

The students were then distributed into a control and experimental group. The control group was taught through the traditional method with teacher-centered education using models, slides, OHP and the students were not allowed to ask any questions. The experimental group was taught in groups using the question and answer method in an active way. It was reported that the achievement rate of the treatment group was higher.

In another study by Jackman and Moellenberg (1987), the effects of the traditional learning cycles and computer simulations on the achievement of freshmen university students in the laboratory applications on a spectrophotometer were compared. The comparisons were evaluated through *t*-tests. The results of the group that received CAI were found to be higher than that of the group that was taught through the other two methods. No significant difference was found between the post-test results of the groups who were taught through the learning cycle and the traditional method. Ertepınar (1995) conducted a study on the effects of the two different teaching methods involving logical thinking skills, computer-assisted education and students' portfolios on the achievements of 119 high school chemistry students. The results showed that the application with two methods and the logical thinking skills of the students had a significant contribution to the achievement of the students in chemistry. Yıldırım, Özden and Aksu (2001) compared the traditional and hypermedia learning environments on the chosen subjects in a control-treatment group and pre- and post-test design in their study on acquiring and retaining knowledge. Forty-nine 9th grade biology students were distributed into subject (hypermedia learning environment) and control (traditional) groups. Pre-tests, post-tests and retention tests were administered to both groups. The results of the post-test did not display a significant difference between the control and experimental groups about acquiring knowledge. However, the retention tests showed that the experimental group retained knowledge better than the control group. Rivers and Vockell (1987) studied how to develop the problem solving skills of high school biology students by way of using computer simulations. Simulations were administered to the experimental group of students with and without guidance, whereas they were not administered to the control group. In order to study the effects of simulations on the development of the problem solving skills of the students, their performance was assessed through pretests, scientific thinking tests and critical thinking tests. According to the results, the students who used simulations could understand the main subjects as well as the control group students. The students who were guided through simulations could achieve better in the post-tests, scientific and critical thinking tests. In a similar study, Ybarrondo (1984) attempted to find out whether computer-assisted teaching could increase the level of learning in high school biology classes. The treatment group received CAI in addition to the traditional method. The CAI applications were computer simulations. The post-test results of both groups were evaluated through a *t*-test but no significant difference could be observed. The students were more interested in the computer-assisted applications.

A similar study was conducted by Redish, Saul and Steinberg (2000) in the introduction to calculus by distributing the students into two groups and comparing the laboratory class method based on microcomputers and the traditional problem solving method. Multiple-choice and open–ended exam questions were used for the assessment of both groups. Similarly to the study done by Denton (1972), the group that received computer-assisted teaching was found to be more successful than the other group. In a study by Durbin (2002), where computers and the Internet were used as teaching tools in a geography class, an increase in the students' achievement rates and knowledge acquisition was observed.

Acids and bases

Since Liebig defined acids as substances that form hydrogen when they react with metals in 1838, many studies have been conducted about ways of teaching acids and bases. While defining acids and bases systematically, Sumfleth (1989) used concept maps; Schmidkunz (1985) used curriculum spirals; Weißenhorn (1994) and Hilbing and Barke (2000) used thinking and visual models. In chemistry education, as in daily life, acids and bases have a special importance. Pfeifer, Häusler and Lutz (1992) used student reflections in education. Also, there are many studies in which traditional education techniques are used in order to improve student performance (Bühler, 1973; Legall, 1977; Bukatsch, 1979; Weskamp, 1993; Kopyciok et al. 1998; Reiners, 2000; Sumfleth, 2001). While teaching acids and bases, demonstrations (Radford et al., 1995; Meyer et al., 2003), and carrying out experiments (Stairs, 1978; Markle, 1984; Thompson, 1998) play an important role. Instead of theoretical learning, learning by doing improves students' performance (Sumfleth, 1987, 1997). In the applications, there are techniques that use constructivism (Hand and Treagust, 1991), problem based learning (Radford et al. 1995) inductive approach (Boeck, 2000) and learning-cycle (Beisenherz and Dantonio, 1996). In the analogy applications, acids and bases are taught by football analogy (Todd, 2000). When computer-assisted applications started, acid-base titrations were taken into the visual medium (Gipps, 1994). The misconceptions and difficulties associated with acids and bases, the factors such as developmental level and disembedding ability that affect learning were investigated by Demerouti et al. (2004a, 2004b) and their effects on achievement was determined. But, in the studies done up to this time, the comparison of the educational techniques used in teaching of acids and bases has not been investigated.

The aim of this study is to identify any possible difference in student achievement when the subject of acid-base is taught using CAI or the traditional methods in chemistry education at the university. Moreover, the effects of the factors such as the students' three-dimensional spatial ability, attitudes towards computers, learning styles and socio-economic status on the students' achievement were investigated.

Method

The subjects

The participants of the study were 84 students who were attending the chemistry education and chemistry education seminar classes at Hacettepe University, Faculty of Education, Department of Chemistry Education.

The test instruments

The data of the study were collected through the following tests, scales and applications.

Purdue Rotation-Orientation Test

The spatial (three-dimensional) visualization skills of the students were evaluated by the Purdue Rotation-Orientation Test (Bodner and Guay, 1997). The students were asked to answer the twenty questions of the test in ten minutes. The results of the evaluation pointed out the relationship between the psychometric structure known as the spatial ability of the students and their achievement in the chemistry classes. The aim of the applied test was to determine the abilities of the students in visualizing the structure in their minds when the pieces of a figure (shape) or picture moved, moving the shapes (spatial structure intact visualization) and maintaining while the changes in the orientation occurred (spatial orientation).

The Scale of Attitude

"The Scale of Computational Attitude" developed by N. Selwyn, consisting of twenty-one questions, was used in order to assess the attitudes of the students towards computer-assisted chemistry education (Selwyn, 1997). The scale focused on four main structures expressed under the four main titles; these were the computational perception of the students, their previous knowledge of computers, their computer related behaviors, and whether they had any difficulties in using computers or not. The five-point likert-type scale was used for the evaluation of the statements (strongly agree, agree, indecisive, disagree, and strongly disagree). The scale consisted of eleven positive and ten negative statements.

The Inventory of Learning Style

The Inventory of Learning Style, developed by Kolb in 1985, determines the learning style of the individuals (Kolb, 1984, 1985; Kolb, Baker, and Dixon, 1985). The identification of the learning style for individuals indicates their choices of profession, attitudes towards problems and objectives. Moreover, it is a scale that identifies the strong and weak parts of the individuals. Kolb defined four learning styles depending on the experimental learning theory. The Inventory of Learning Style applications consists of twelve statements, each with four choices, that require the four learning styles to be ordered as to which describes them best. In Kolb's learning model, the learning styles are cyclical and The Inventory of Learning Style locates the individual in that cycle. There are four learning cycles, which are C*oncrete Experience, Reflective Observation, Abstract Conceptualization* and *Active Experience*. The learning ways that symbolize each learning style are different from each other, which are, in turn, learning by, '*Feeling*' for the Concrete Experience; '*Observing'* for the Reflective Observation; '*Thinking'* for the Abstract Conceptualization and '*Doing*' for the Active Experience. However, there is no single style that identifies the learning style of the individual. The learning style of each individual is a composition of these four basic styles, which are '*Accommodator*', *'Assimilator', 'Diverger' and 'Converger'* (Aşkar, and Akkoyunlu, 1993).

The computer software

The software that was used in the computer-assisted applications is the CCI Project Software program (Creative Chemistry on the Web) prepared by ETH (Eidgenossiche Technische Hochschule Zurich/Switzerland). The software is available through the Internet (CCI-Project (Creative Chemistry on the Internet) by ETH (Eidgenössische Technische Hochschule, Zurich; http://www.cci.ethz.ch). The software includes some experiments on the subject of concepts, which can be viewed on Real Player. Moreover, there are explanations and parts where the students can watch the detailed information and reactions during the experiment show.

Chemistry achievement test

The chemistry achievement test was prepared by the researchers according to the CCI_Project (creative chemistry on the web) applications. The chemistry achievement test consists of 20 open-ended questions on concepts related to the subject of acid-base. The opinions of specialists were asked in order to determine which concepts were to be asked on the test; after the experts' views were taken into consideration, the inner validity of the chemistry achievement test was achieved. The questions are shown in Table 1.

Table 1. The chemistry achievement test on acids and bases.

The Chemistry Achievement Test

1. When a NaOH solution was added to an $AlCI_3$ solution that had a pH of 3.5, the pH of the solution increased to 12.0. Later, when the HCI solution was added, the pH decreased to 1.6 Write the chemical reactions of the processes.
2. What is an amphiprotic property of a substance? Explain with an example.
3. Complete the following chemical reactions
   $Al + H_2O \longrightarrow$
   $Al + HCl \longrightarrow$
   $Al + HNO_3 \longrightarrow$
   $Al + NaOH \longrightarrow$
4. Identify the oxidizing agent and the reducing agent in the following reaction.
   $3C + 2KNO_3 \longrightarrow K_2CO_3 + N_2 + CO + CO_2$
5. Complete the following chemical reaction.
   $NH_4Cl + H_2SO_4 \longrightarrow$
   What happens when NaOH is added to the solution at the end?
6. Complete the following chemical reactions. Explain the reasons for the effect of an acid on copper and aluminum
   $Cu + HCl \longrightarrow$
   $Cu + HNO_3 \longrightarrow$
   $Al + HCl \longrightarrow$
   $Al + HNO_3 \longrightarrow$
7. What is a masking reagent? How does it mask in a given chemical reaction?
8. What kind of reagent can be used in the masking of $[Al(H_2O)_{6}]^{+3}$ ion. Write the equation.
9. Explain the identification reaction of ammonia.
10. How does the oxidizing power of $KMnO_4$ vary according to the pH? Explain.
11. Which gases evolve at the anode and at the cathode during the electrolysis of the water?
12. What is the proportion of the volumes of the gases that evolve at the anode and the cathode during the electrolysis of the water?
13. What colour solution results if phenolphthalein is added to the following?
    a) Concentrated H_2SO_4, b) 1M H_2SO_4, c) 0.1M NaOH, d) 1M NaOH.
14. Write boric acid (H_3BO_3) in the Lewis acid form.
15. Write the reaction between HCl/H_2O and $Na_2S_2O_3$ in aqueous solution.
16. Explain the reactions that take place when
    a) 12M HCl, and b) 6M NaOH are added separately to acetic acid-sodium acetate buffer solution.
17. Write the chemical reaction between gaseous NH_3 and HCl. What is the name of the solid substance formed?
18. Describe the dependence of the equilibrium between the CrO_4^{-2} and $Cr_2O_7^{-2}$ ions on the pH of the solution?
19. Explain the electron-pair acceptor property of a Lewis acid with an example.
20. Explain the electron-pair donor property of the Lewis base with an example.

Test-administration procedure

In our study of computer-assisted learning in chemistry education, the first step was to assess the knowledge of the students about acids and bases through the above test. This topic had been taught to all the students three semesters earlier. The second step was the formation of the control and the experimental groups, and the subject matter of acids and bases was taught to the experimental group through the computer assisted teaching method and to the control group through the traditional learning method. The students all took the same test after the teaching period of two days and the changes in the students' performance were observed. The post-test was administered one week after the application of the pre-test. The attitudes of the students towards computers, their spatial visualization abilities, learning styles, and socio-economic profiles were also studied as the factors that may affect learning. Eighty-four students of Hacettepe University, Faculty of Education, Department of Chemistry Education, who were attending the Internet, Chemistry Education and Chemistry Education Seminar classes were randomly chosen and distributed into the experimental and control groups of forty-two each.

Results

When the effects of the traditional and the computer-assisted methods of teaching on students' achievement in acid-base in chemistry education were compared, the average increase scores of the experimental group students was found to be 52%. The average increase with the control group, however, was found to be 32%. The average score of the control group students at the pretest was found to be 36%, whereas that of the experimental group was found to be 28%. However, when the post-test results were examined the average grade of the control group was 68%, whereas that of the experimental group was 80%. When the results of the Rotation-Orientation test were examined, the average values of the control and treatment groups were found to be similar, in which more than 50% of the students were found to have adequate three-dimensional spatial visualization abilities in the Rotation-Orientation tests.

When the attitudes of the students towards computers were assessed and the attitude statements were evaluated, the students in the experimental group were found to have a better understanding in computer-assisted teaching than the students in the control group and it was observed that they could use computers. In other words, students in the experimental group were observed to have adequate knowledge and skills to use computers. However, the students did not have much experience related to technology, concerning the computers. After the Kolb Learning Style Inventory was administered, the students were observed to display all four different learning styles. Twenty-six students from each group belonged to the assimilator learning group that could make reflective observations and abstract conceptualizations and ten students from each group belonged to the diverger learning group that could think, make abstract conceptualizations and create active experiences. Two students from the treatment group and three from the control group displayed the converger learning style, and four students from the treatment group and three from the control group displayed the accommodator learning style.

Similar results were observed with students of Science and Technology Education (Aşkar and Akkoyunlu, 1993). As a result, the students commonly possessed the assimilator and diverger learning styles. The pre- and post-test results of the control and treatment groups that consisted of eighty-four students were statistically evaluated and independent two-sample *t*-tests were administered. In the study, first the pre- and post-test results of the control and experimental groups were statistically evaluated (a), then the pre- and post-test results were compared for the control and the experimental groups (b). The results are displayed in Table 2.

Table 2. The statistical evaluation of the pre- and post-test results of the experimental and the control groups

(a)

	Control Group					Experimental Group				
	N	*x*	*s*	*t*	*p*	*N*	*x*	*s*	*t*	*p*
Pre test	42	36.3	9.62	-21.41	0.000	42	28.2	7.07	-47.63	0.000
Post test	42	68.0				42	80.2			
	Significant difference was observed favoring the post-test.					Significant difference was observed favoring the post-test.				

(b)

	Pretest					Post-test				
	N	*x*	*s*	*t*	*p*	*N*	*x*	*s*	*t*	*p*
Experimental Group	42	28.2	11.05	-4.72	0,000	42	80.1	14.13	5.22	0.000
Control Group	42	36.2				42	68.7			
	Significant difference was observed favoring the Control Group the pretest results.					Significant difference was observed favoring the Experimental Group in the post-test in the results.				

N: number of students; *x*: average, *s*: standard deviation, *t*: significance factor, *p*: significance,

Discussion

When all the instruments on learning styles, attitudes towards computers, rotation-orientation abilities, and increases in the achievement rates between the pre- and post-test that was administered on 84 students, in which chemistry education Internet class students were evaluated altogether, the following results could be acquired. Table 3 demonstrates the learning styles of the students.

Table 3. Correlation of learning styles with improvement between the two tests, the students' Rotation-Orientation Test scores and their computational attitude scores.

Control Group				
Kolb classification	*N*	The increase in the success rates of the pre- and post- tests	The rotation-orientation test	Attitude
Assimilator	26	32%	64%	70
Converger	3	33%	86%	73
Accommodator	3	30%	68%	74
Diverger	10	32%	51%	74

Experimental Group				
Kolb classification	*N*	The increase in the success rates of the pre and post tests	The rotation-orientation test	Attitude
Assimilator	26	51%	58%	71
Converger	2	49%	40%	69
Accommodator	4	58%	76%	71
Diverger	10	51%	56%	77

As Table 3 illustrates, the achievement increases of the students from all four learning style groups were observed to be somewhat higher with computer-assisted teaching.

Moreover, it was observed that the other factors shown above do not have a great effect on achievement. However, because of the small number of participants, this study could be repeated with more participants and the results can be subsequently compared. Similar results were found in the researches done with students who participated in science lessons (Aşkar and Akkoyunlu, 1993). Table 4 displays the combined above stated results for the experimental and the control groups.

Table 4. Comparison in the improvement in the test scores, the Rotation-Orientation Test and Attitude test scores between the two groups.

	The Increase In The Success Rates Of The Pre- And Post- Tests	The Rotation-Orientation Test	Attitude
Control	31%	62%	71
Experimental	52%	58%	73

As Table 4 illustrates, the increase in the success rates of the experimental group students is higher than that of the control group students. This finding proves the superiority of the computer-assisted teaching method over the traditional one in this exercise. However, the results of the Rotation-Orientation Test or the Attitude Scale did not display any difference between the students of the control and experimental groups according to the *t*-test results. When students' learning styles were not taken into consideration, the averages of the Rotation-Orientation test in the control group and the averages of the items for students' attitudes towards computers in the experimental group were found to be higher. The point being, although the results of the three-dimensional spatial visualization abilities of the control group were higher, their achievement increase at the end of the traditional applications was not high at all.

The increase in the test scores of the experimental group was higher despite their slightly lower three-dimensional spatial visualization ability results. This shows that the attitudes towards computers and the ROT Test results were not a significant factor in the students' achievement concerning computer-assisted education. The superiority of the computer-assisted teaching method over the traditional one stems from the students' learning the subjects as a whole on the computer.

Some questions on the chemistry achievement test on acid-base could be considered. For example, on question number 3, the students were asked to explain the reactions of aluminum with H_2O, HCl, concentrated HNO_3 and NaOH. The students of the experimental group with the computer-assisted teaching watched the above-mentioned reactions in the virtual media as dynamic experiments followed by the equations that explained the reactions. The presentations were repeated as many times as the students wished. The control group learnt the same subject directly from the teacher using transparencies at the OHP. There was not a live presentation and the revision could only be done through questions and answers. Another example could be question number 19. In the computer-assisted application, in order to explain the acceptor characteristic of the Lewis acid, a virtual experiment was done and DMF, CH_2Cl_2, CH_3CH_2OH, CH_3COOH and concentrated H_2SO_4 were dropped in turns into the experiment tubes in which there was [Fe (phen)$_2$ (CN)$_2$] complex.

The solutions in different colors could be observed and the experiment was followed by explanations of the characteristics of each solvent calculating the number of acceptors. The traditional application consisted of the explanations of the teacher using the OHP transparencies. If the teacher had done the same experiments in test tubes in the class in the traditional way, that would also not helped because the students would not have the chance to see the experiments several times. Although some constructivist applications such as question-answer, meaningful learning, and conceptual understanding are administered in the control group in order to enable them to learn the subject though the process of the study, the complex knowledge that could be presented through computer-assisted teaching could not be fully acquired.

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References

Aşkar P. and Akkoyunlu B., (1993), Kolb learning style inventory, *Science and Education,* **87**, 37-47.

Bayramlı D.Y. (2000). *Teachers lecture methods in chemistry education*, Hacettepe University Science Institute, Master Thesis, pp. 8, 12, 15, 20.

Beisenherz P. and Dantonio, M. (1996), *Using the learning cycle to teach physical science: a hands-on approach for the middle grades*, U.S. New Hampshire, 145.

Bodner G. M.and Guay R., (1997), The Purdue visualisations of rotations test, *The Chemical Educator,* 2.

Boeck C.H. (2000), Try the inductive approach, *Science Teacher*, **67**, 24.

Bukatsch F. (1979), *Ein Motivationsversuch zum Thema "Universalindikator* (Praktische Winke), In: *Praxis der Naturwissenschaften Chemie,* no. 28, p. 49.

Bühler A.E. (1973), Strukturen und Lernziele der Chemie - Versuch einer lernpsychologischen Analyse des Denkprozesses am Beispiel der Neutralisation / Kompensation, In: *Zeitnahe Schularbeit,* **26**, 1.

Creative chemistry on the web, ETH (Eidgenössische Technische Hochschule Zürich/Switzerland) http://www.cci.ethz.ch

Demerouti M., Kousathana M. and Tsaparlis, G. (2004a), Acid-base equlibria, Part I. Upper secondary students' misconceptions and difficulties, *The Chemical Educator,* **9**, 122-131.

Demerouti, M., Kousathana, M., Tsaparlis G., (2004b), Acid-base equlibria, Part II. Effect of developmental level and disembedding ability on students' conceptual understanding and problem-solving ability, *The Chemical Educator,* **9**, 132-137.

Demircioğlu H. and Geban Ö. (1996), Comparison of computer assisted and traditional problem solving activities in science, *Journal of Hacettepe University Faculty of Education,* **12**, 183-185.

Demirel Ö. (1996), *Teaching methods*, Usem Publications, Ankara, p.55.

Denton J.J. (1972), *A methodological study of a computer-managed instructional program in high school physics*, p.245.

Durbin J.M., (2002), The benefits of combining computer technology and traditional teaching methods in large enrollment geoscience classes, *Journal of Geoscience Education,* **50,** 56-63.

Ertepınar H. (1995), The relationship between formal reasoning ability, computer assisted instruction, and chemistry achievement, *Journal of Hacettepe University Faculty of Education***,** **11**, 21-24.

Gerardo A. (1986), Computer based learning in the engineering technology curriculum: how effective is it*? Engineering Education,* **76**, 759-761.

Gipps J. (1994), Acids, bases and computers, *Australian Science Teachers Journal*, **40,** 48-52.

Hand B. and Treagust, D.F. (1991), Student achievement and science curriculum development using a constructive framework, *School Science and Mathematics*, **91**, 172-176.

Hilbing C. and Barke H.D. (2000), Male dein Bild von der Chemie. Zum Image von Chemie und Chemieunterricht bei Jugendlichen, *Chemie in unserer Zeit,* **34**, 17.

Jackman L.E., Moellenberg W.P. and Brabson D. (1990), Effects of conceptual systems and instructional methods on general chemistry lab. achievement, *Journal of Research in Science Teaching,* **27**, *699-709.*

Jackman L.E. and Moellenberg W. (1987), Evaluation of three instructional methods for teaching general chemistry, *Journal of Chemical Education*, **64**, 794-96.

Jackson B., (1988), A comparison between computer-based and traditional assessment tests, and their effects on pupil learning and scoring, *School Science Review,* **69**, no. 249, 809-815.

Kolb D., (1984), *Experimental learning: experience as the source of learning and development,* Englewood cliffs.

Kolb D., (1985), *Learning style inventory: self-scoring inventory and interpretation booklet,* Boston: McBer&Company.

Kolb D., Baker R. and Dixon, N. (1985), *Personal learning guide self-study booklet*, Boston.

Kopyciok C. and Echtermeyer S., Hildebrandt, H., Becker, H.J. (1998), Begriffe lernen: Beispiel "Säuren" -wie Studentinnen sich mit chemiedidaktischer Theorie auseinandersetzen, In: *Praxis der Naturwissenschaften-Chemie*, no. *5,* **47**, *2.*

Legall W.D., (1977), Behandlung der sauren, basischen und neutralen Reaktion unter Beachtung der Motivation, In: *Chemie in der Schule*, no. 5, p. 206.

Levine T. and Donitsa-Schmidt S. (1996), Classroom environment in computer-integrated science classes: effects of gender and computer ownership, *Research in Science and Technological Education,* **14**, 163-78.

Liebig J., (1838), Über die Constitution der organischen Säuren, *Ann. Chem. Pharm.* **26**, 113.

Lord T.R., (1999), A comparison between traditional and constructivist teaching in environmental science, *Journal of Environmental Education,* **30**, 22-27.

Markle S., (1984), Do-it-yourself science labs, *Instructor*, **93**, *46-47, 50.*

Meyer L.S., Schmidt S., Nozawa F. and Panee D., (2003), Using demonstration to promote student comprehension in chemistry, *Journal of Chemical Education*, **80**, 431-435.

Pfeifer P., Häusler, K., Lutz, B. (1992), *Konkrete Fachdidaktik Chemie*, München (Oldenburg)

Radford D., Ramsey, L., &Deese, W. (1995), Demonstration assessment: measuring conceptual understanding and critical thinking with rubrics, *Science Teacher*, **62**, 52-55.

Redish E.F., Saul, J.M., Steinberg, R.N. (2000), *On the effectiveness of active-engagement microcomputer based laboratories,* US, 16p. Maryland

Reiners C.S., (2000), Das Donator-Akzeptor-Prinzip in der Schulpraxis Zur Möglichkeit, durch eine besondere Sichtweise zu allgemeinen Erkenntnissen zu gelangen, In: *Der Mathematische und Naturwissenschaftliche Unterricht* **53**, 306.

Rivers R. and Vockell, E., (1987), Computer simulations to stimulate scientific problem solving, *Journal of Research in Science Teaching,* **24**, 403-415.

Schmidkunz, H., Büttner, D. (1985), Chemieunterricht im Spiralcurriculum, *Naturwissenschaften im Unterricht-Physik/Chemie* 33, 19.

Selwyn N., (1997), Students' attitudes toward computers: validation of a computer attitude scale for 16-19 education, *Computers Education,* **28**, 35-41.

Sönmez V. (1986), *Teachers' handbook in program development*, Yargı Publications, Ankara, 287p.

Stairs R.A., (1978), Unified calculation of titration curves, *Journal of Chemical Education,* **55**, 99.

Sumfleth E. (1987), *Über den Zusammenhang zwischen Schulleistung und Gedächtnisstruktur-eine Untersuchung zu Säure-Base-Theorien*, *Naturwissenschaften im Unterricht-Physik/Chemie,* no. 35, .21-29.

Sumfleth E. u. a. (1989), Stoffe: Eigenschaften und Reaktionen, Modelle: Teilchenanordnungen und -Umordungen. Eine mit Lernhilfen gestützte Einführung in die Chemie, *Der Matematische und Naturwissenschaftliche Unterricht,* **42,** 411.

Sumfleth E., Geisler, A. (1997), Untersuchung zur Veränderung von Schülervorstellungen im Lauf der Schulzeit im Bereich Säure/Base, *Gesellschaft für Didaktik der Chemie und Physik* **2**, 265.

Sumfleth E., Geisler, A. (2001), Entwicklung von Schülervorstellungen im Laufe der Schulzeit am Beispiel der Säure-Base-Thematik, In: *Chimica Didactica.* **27,** 122.

Thompson R.Q. (1998), Identification of weak acids and bases by titration with primary standards. A modern version of an old analytical chemistry experiment, *Journal of Chemical Education*, **65**, 179-180.

Todd P.S. (2000), Weak vs. strong acids and bases: the football analogy, *Journal of Chemical Education*, **77**, 849-850.

Weißenhorn R.G. (1994), Verteilungs- und Säure-Base-Gleichgewichte Lernprozesse an einem "Chemischen Kabinettstück", In: *Praxis der Naturwissenschaften Chemie,* **43***,* 2.

Weskamp R. (1993), Schüleraktivität fördern Selbständiges Arbeiten im Chemieunterricht der gymnasialen Oberstufe am Beispiel der Vermittlung von Säure-Base-Gleichgewichten, In: *Naturwissenschaften im Unterricht-Chemie,* **14**, 46.

Ybarrondo B.A. (1984), *A study of the effectiveness of computer assisted instruction in the high school biology classroom,* Idaho, 20p.

Yıldırım Z., Özden M.Y. and Aksu M., (2001), Comparison of hypermedia learning and traditional instruction on knowledge acquisition and retention, *Journal of Educational Research***,** **94**, 207-214.