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Effects of Problem-Based Learning in a Web Environment on Conceptual Understanding: The Subject of Acids and Bases

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Abstract

This study aims to design a learning environment supported with problem-based learning in a web-environment, with the purpose of providing a more meaningful and to examine the effects of this learning environment on students' conceptual understanding. The study uses a pretest posttest control group experimental design. A total of 56 eighth grade students attending a public primary school in Istanbul, Turkey participated in the study. Diagnostic tests were used to measure the level of conceptual understanding among students concerning the subject of acids and bases, and to identify misunderstandings. It was found that the posttest conceptual understanding scores of the control and experimental groups differed significantly from one another, with the experimental group students receiving higher scores (t_{54}= 6,63 p< ,05).

Key Words: Web environment, problem based learning, science education, acid-base, conceptual understanding

Introduction

Educational studies conducted in recent years emphasize constructivism as an approach to be used in studying and designing education programs. Problem-Based Learning (PBL) is a constructivist-based approach to teaching, defined by Torp and Sage (2002) as an effort by students to solve complex real-life problems by living and personally experiencing them. Problem-based solving encourages students to make more frequent use of their higher level thinking skills, compared to traditional learning environments, by giving them an opportunity to practice what they have learnt, and requiring them to organize and to present information and materials for the solution of the problem at hand.

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The widespread use of educational technologies in recent years has resulted in a surge of interest in studies on the use of PBL in web environments. Various studies find that online learning environments are more effective in facilitating learning and problem solving among students (Oliver and Omari, 1999), and that an exchange of ideas over various communication and cooperation tools such as e-mail, chat rooms, and discussion groups facilitates learning (Taradi et all, 2004). The web is used as a tool that provides students with easier access to different sources of information. In using the web, students are able to search for sources effectively, solve problems freely, and structure their own knowledge.

Jonassen and Kwon (2001) argue that in computer-assisted communication environments, students participate more and engage in more communication with one another compared to face-to-face communication environments. Sage (2000) emphasizes that web-based technologies are very powerful tools for the organization, distribution and presentation of information.

Problem-Based Learning in a Web Environment and Conceptual Understanding

Problem-based learning focuses on an experience-based learning environment that involves the identification and solution of real-life problems. Web-based technologies assist in the creation and implementation of such environments. Instructional designers can create effective, lively and functional environments by combining PBL and web-based learning (Oliver and Omari, 1999).

During the teaching process, students learn about a number of important abstract concepts for the first time. If the course proceeds without the students understanding some of these basic concepts, learning processes in following tiers are negatively affected. The conceptions students have, no matter how well-founded in their own thinking, frequently conflict with scientific facts. These student conceptions that are at variance with what is accepted in scientific circles are variously referred to in the literature as misconception, misunderstanding, alternative conception, children's science, preconceptions, or spontaneous knowledge. Misconception can be defined as an inconsistency between the knowledge or ideas of an individual and scientific knowledge (Blosser, 1987; Treagust, 1988).

The subject of acids and bases has an important place in primary and secondary chemistry education. Concepts concerning acids and bases are inter-related. Frequently thought of by students as too complex to learn, these concepts need to be taught using appropriate methods and misconceptions need to be prevented. When students have difficulty understanding one of these concepts, they also experience difficulties in related subjects (Kauffman, 1988) and have misconceptions (Cros et al., 1986), which are known to affect their learning in later grades.

Measuring Levels of Understanding and Identifying Misconceptions among the Students

Measuring levels of understanding and identifying misconceptions among the students is just as important as teaching the concepts. Although many different techniques are used in the measurement of levels of understanding and identification of misconceptions among students, one or a combination of concept mapping, prediction- observation-description, interviews on facts and events, interviews on concepts, word association, and diagnostic tests are among the most frequently used (White and Gunstone, 1992; Schmidt, 1997; Ayas et al., 2001; Kabapınar, 2003).

One of the techniques used for the identification of misconceptions, as was mentioned above, is diagnostic tests (Peterson et al., 1986; Treagust, 1988; Kabapınar, 2003). These tools have two functions (Taber, 1999):

1. They can be used as a pretest to identify misconceptions in a class.

2. Students can be motivated to find the correct answer after they complete this activity.

Diagnostic tests consist of a minimum of two sections. The first section aims to diagnose how the individual interprets scientific knowledge. In the second and following sections, students are asked to state the reason(s) for their answer given in the first section.

The first section of diagnostic tests is similar to multiple question and categorization tests. It consists of a question item or a premise that is called the stem and a set of options, one of which is the correct answer and the rest are distractors. What differentiates diagnostic tests from multiple choice tests is the second section. In this section, students are asked to state the reason why they selected a particular option. The second tier of the test can have a multiple choice format with options containing common student misconceptions identified in the literature or via interviews, or a multiple choice format where one of the options is open-ended.

In open-ended tests, students are given the opportunity to state in writing everything they know about the subject. Because students will also state the reason for their selections, they allow the teacher to identify possible misconceptions. Distractors in multiple choice tests are prepared on the basis of student responses to test questions and to other open-ended questions.

Development of multiple choice tests on concepts commonly misunderstood by students not only contributes to studies on the subject, but it also allows teachers to plan their instruction on the basis of the findings of these studies. Many teachers are unable to prepare their own versions of these tests due to lack of time or lack of knowledge on test development (Taber, 1999). Thus, teachers can make use of multiple choice tests containing items specially designed to unearth misconceptions students have. Such diagnostic tests would also help the teachers to spot misconceptions resulting from earlier instruction.

Two-tier multiple choice diagnostic tests are usually analyzed via tables showing the answers of students gave to the first tier of each question, and the percentages of the different reasons they cite for their answers. Once student answers are thus shown on tables, the combination of the first tier responses on the content and the second tier responses on the reasons are examined, and a second table showing the combination of the correct answers students gave in the first tier and correct answers they gave in both tiers is created. Students receive a score of 1 (one) if they marked the correct option in both tiers of a question, and they receive a score of 0 (zero) if they marked an incorrect option in either one or both of the tiers. Besides these scores, misconceptions that students have can also be reported as percentages (Peterson and Treagust, 1989; Haslam and Treagust, 1987; Odom and Barrow, 1995).

Due to the opportunities provided by web environments for the creation, storage, distribution and sharing of the information required for PBL applications, this study used PBL and a web-based education environment together. Although there are many studies on conceptual understanding, very few take up the issue of the effects of a learning environment supported by problem-based learning in a web environment on conceptual understanding. This study examined the effects of a learning environment supported by problem-based learning in a web environment on conceptual understanding, and conducted concept analyses using diagnostic tests.

Method

This section presents information on the research design, participants, and data gathering instruments of the study, and the statistical analyses used.

Research Design

As part of the study, teaching materials were prepared by the researcher and presented over the web to conduct the PBL activities. These materials included animations on five problem situations concerning acids and bases, prepared by using the Adobe Flash CS4 software. During the five-week implementation phase, the loop on a different problem situation was activated each week.

The software developed by the researcher using hypermedia tools in a web environment aimed to help the students to learn about acids and bases by using interactive animations and simulations. Working in cooperation, students had the opportunity to interact with other group members and share information.

The study used a pretest posttest experimental design, with randomly assigned control and experimental groups. Measurements were made in each group both prior to and after the application. The study was conducted in the 2009-2010 academic year with the participation of eighth grade students attending a public primary school. A total of five problems were developed to be used during the application, which the students were asked to solve. Teaching materials were developed on the basis of the Harper-Marinick (2001) model. The cycle developed to include the six sequences of learning in the Harper-Marinick (2001) model (Figure 1) was used by students in the solution of problems.

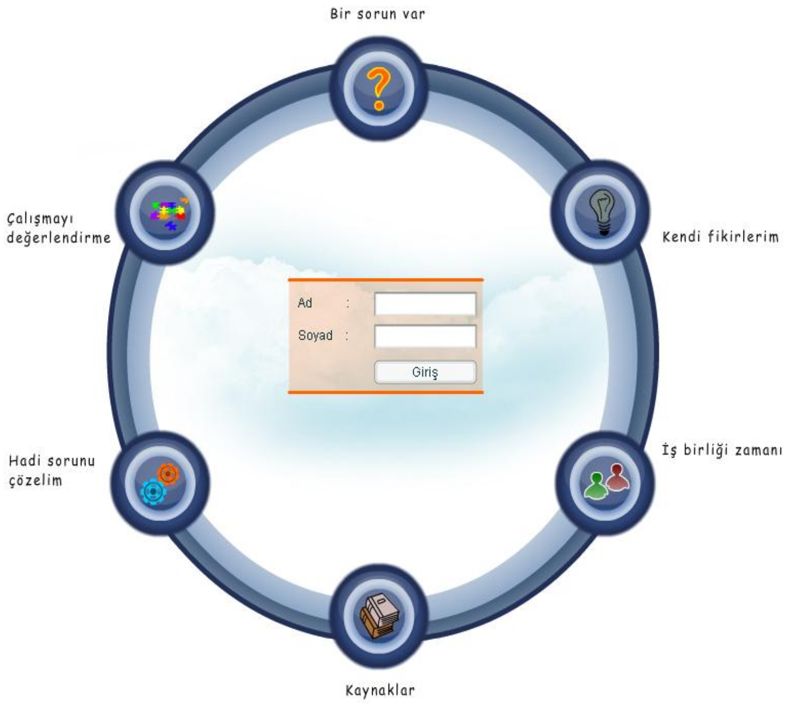

Figure 1. Learning cycle

The Harper-Marinick (2001) model is based on the following learning sequences:

1. *Presentation of Introductory Information*: The new learning environment is introduced, students' tasks are stated, and information is given on what they need to achieve learning goals.

2. *Presentation of an Ill-Structured Problem*: A problem appropriate for use in PBL is presented. Presentation of the problem needs to be made in such a way as to generate curiosity, raise interest among the students, and to motivate them.

3. *Online Collaboration*: They identify their existing information, what additional information they need, and what needs to be known to be able to solve the problem. During this process of collaboration, the teacher acts as a guide, facilitator, and enabler. The teacher observes and manages the whole process.

4. *Accessing Resources over the Web*: The software includes links to necessary resources. Students search these resources and obtain the information they need. This practice is crucial for the students to acquire the skill of "learning to learn", which is an important part of problem-based learning.

5. *Follow-up Online Collaboration*: Following independent and individual research, groups continue discussing in the web environment. At this tier, each group member presents what he or she learnt and how it might help solve the problem. The hypothesis is re-examined in the light of this new information.

6. *Solution of the Problem*: Processes 4 and 5 are repeated until the group is satisfied that answers to the problem are found. Group members decide how they will present the solution that they came up with using the tools provided.

Using this cycle, a different problem situation was activated each week over a five-week period.

The control group was provided with a traditional learning environment, and the experimental group was provided with a learning environment based upon teaching material prepared using problem-based learning in a web environment.

Participants

A total of 56 eighth grade students attending a public primary school in Istanbul, Turkey participated in this study. The same Science teacher taught both the experimental and control groups to prevent teacher-based differences.

Data Gathering Instruments

Data for this study were collected using a conceptual understanding test prepared to include the concepts used in the subject of "Acids and Bases", which is a part of the chapter "Structure and Properties of Matter" taught in the eighth grade Science and Technology course.

Conceptual understanding test (CUT). The conceptual understanding test was developed by the researchers to identify the misconceptions students might have concerning this subject. To develop this test, studies on the misconceptions concerning the subject of acids and bases were examined. A total of 32 diagnostic questions were prepared on the basis of the misconceptions identified in the literature. Then, these questions were examined by a number of Science teachers and experts in the field, and revised according to their suggestions. The test was applied to 98 first-year high school students in the autumn semester of the 2008-2009 academic year. Responses to the items on the conceptual understanding test were scored on the basis of the assessment criteria presented in Table 1, distributions of scores for each question were entered into the SPSS 13.0 software package, and the reliability coefficient of the test was found to be .783 with 15 items.

Table 1. Assessment criteria

The Degree of Concept Learning	*Assessment Criteria*
No Answer (0 point)	They don't have any answer.
Not Mark Answer (0 point)	They marked multiple choices.
One Correct Answer (1 point)	They have only one correct answer.
Two Correct Answer (2 point)	They have two correct answers.

6) Which of the following statements is TRUE concerning NH_3, CH_3COOH, and HCl?

a- CH_3COOH is a base.

b- The pH value of NH_3 is greater than the pH value of CH_3COOH.

c- All are acids.

d- NH_3 is an acid.

Reason:

1- NH_3, CH_3COOH and HCl contain only H^+ ion in their structures.

2- CH_3COOH is a base because it contains OH^- ion.

3- NH_3 is an acid because it contains H^+ ion.

4- pH values of bases are greater than the pH values of acids.

5- None of the above; I selected the option because: ………………………

Figure 2. Question 6 on the conceptual understanding scale

The test consists of diagnostic tests (n=15) designed to measure levels of understanding among students concerning the subject of acids and bases, and to identify their ways of thinking and rationales. Items on the test consist of two parts. The first part aims to identify the alternative idea, and the second part aims to identify the ways of thinking that led to this alternative idea. Both the first and second parts are multiple choice questions (Figure 2). They have only one correct answer. Options presented in the second part are possible reasons for the answer given in the first part. Only one of these options is correct.

Data Analysis

To decide which analysis to use (parametric or non-parametric), the Kolmogorov-Smirnov coefficient was calculated. Kolmogorov-Smirnov Z values showed that all data from the tests had normal distributions (p>.05), and *parametric analysis techniques* were used in the analysis of the data.

Results and Interpretation

First, dependent samples and independent samples t-tests were conducted to see if conceptual understanding pretest and posttest scores of the experimental and control group students differed significantly from one another.

1-Findings concerning whether there is a significant difference between the pretest conceptual understanding scores of the experimental group and the control group

To see whether there was a significant difference between the pretest conceptual understanding scores of the experimental and control groups, an independent sample t-test was conducted, the results of which are reported in Table 2.

Table 2. t-test results of pre-test conceptual understanding scores according to control-experimental groups

Group	N	X	s	sd	t	p
Control	28	9,42	5,28	54	1,26	,226
Experimental	28	11,53	7,40			

t_{54}= 1,26 p> ,05

Table 2 shows that the mean pretest conceptual understanding score among the experimental group students was 11.53, and the mean pretest conceptual understanding score among the control group students was 9.42. This difference between the pretest conceptual understanding scores of the experimental and control group students, however, is not a significant one [t_{54}= 1.26 p>.05]. Thus, it was established that conceptual understanding scores of the experimental and control group students prior to the application were close to one another.

2-Findings concerning whether there is a significant difference between the posttest conceptual understanding scores of the experimental group and the control group

T-test results for the posttest conceptual understanding scores of the control and experimental groups are reported in Table 3.

Table 3. t-test results of post-test conceptual understanding scores according to control-experimental groups

Group	N	X	s	sd	t	p
Control	28	12,60	5,97	54	6,63	,001
Experimental	28	22,92	5,67			

t_{54}= 6,63 p< ,05

Table 3 shows that the mean posttest conceptual understanding score among the experimental group students was 22.92, and the mean posttest conceptual understanding score among the control group students was 12.60. This difference between the posttest conceptual understanding scores of the experimental and control group students is statistically significant, with the experimental group students receiving significantly higher scores [t_{54}= 6.63 p<.05].

3-Findings concerning whether there is a significant difference between the pretest and posttest conceptual understanding scores of the control group

A dependent samples t-test was conducted to see if the pretest and posttest scores of the control group students differed significantly from one another.

Results of the t-test on the pretest and posttest conceptual understanding score of the control group students are reported in Table 4.

Table 4. t-test results of pre-post conceptual understanding scores according to control group

	N	X	s	sd	t	p
Pre Test	28	12,60	5,97	27	2,93	,007
Post Test	28	9,42	5,28			

t_{27}= 2,93 p< ,05

Table 4 shows that the mean posttest conceptual understanding score among the control group students was 12.60, and the mean pretest score was 9.42. This difference between the pretest and posttest conceptual understanding scores of the control group students is statistically significant [t_{27}= 2.93 p< .05].

4-Findings concerning whether there is a significant difference between the pretest and posttest conceptual understanding scores of the experimental group

A dependent samples t-test was conducted to see if the pretest and posttest scores of the experimental group students differed significantly from one another.

Results of the t-test on the pretest and posttest conceptual understanding scores of the experimental group students are reported in Table 5.

Table 5 shows that the mean posttest conceptual understanding score among the experimental group students was 22.92, and the mean pretest score was 11.53. This difference between the pretest and posttest conceptual understanding scores of the experimental group students is statistically significant [t_{27}= 12.042 p< .05].

Table 5. t-test results of pre-post conceptual understanding scores according to experimental group

	N	X	s	sd	t	p
Pre Test	28	11,53	7,40	27	12,042	,001
Post Test	28	22,92	5,67			

t_{27}= 12,042 p< ,05

Conclusion and Discussion

Paralleling the findings of previous studies in the literature (Ross and Munby, 1991; Vidyapati and Seetharamappa; 1995; Demircioğlu et al., 2002; Uzuntiryaki et al., 2001; Çil, 2000), it was found in the present study that there were a number of misconceptions among the students concerning the subject of acids and bases, which can be summarized as follows:

Table 6. Misconceptions among the students concerning the subject of acids and bases

All acids taste bitter.
All materials that have a sharp and strong smell are acids.
All acids are poisonous.
Fruits are bases.
Soil is not acidic because many things grow on it.
pH value is greater among stronger acids.
A neutral solution emerges after all neutralization reactions.
All acids and bases conduct electricity in the same manner.
The strength of an acid is determined by the number of H^+ atoms it contains.
Materials that contain H^+ are acidic, and those that contain OH^- are basic.

The posttest results of the experimental group show that the percentage of correct answers to both tiers of the questions is equal or close to the percentage of correct answers to the first tier of the questions only. Percentages of correct answers to questions five, six, seven, eight, twelve, and fifteen, which were very low in the pretest, increase by a significant margin in the posttest. These results show that students achieved meaningful learning, not superficial or rote learning.

Answers to the questions on the conceptual understanding test showed that misconceptions students had at the pretest tier concerning concepts related to acids and bases were removed in the posttest tier among the experimental group students either completely or to a significant extent compared to the control group. For example, the number of students who had the misconception that "A neutral solution emerges every time an acid and a base are mixed" increased among the control group students in the posttest, whereas only three of the experimental group students had this misconception.

The misconceptions that "Level of acidity increases with the increase of the pH value" and that "Solutions with a pH value of 14 have the highest level of acidity" were still prevalent among control group students, but they were removed among the experimental group students. The number of control group students who had the misconception that "All acids contain (H^+) and all bases contain (OH^-)" remained the same, whereas only two of the experimental group students still had this misconception on posttest. The misconception that "solutions with a pH value of 7 are the most acidic" was held by even a greater number of control group students in the posttest, whereas it disappeared among the experimental groups students. The misconception that "We should add acid to increase the pH value of neutral materials" was still prevalent among the control group students even after the teaching, whereas it disappeared among the experimental group students.

These findings parallel the findings of other studies on the effects of a learning environment supported by a problem-based learning in a web environment. Spinello and Fischbach (2008) found that students who use a web-based simulation attain higher levels of understanding compared to students who use traditional methods. Kumar and Sherwood (2007) found that the use of problem-based simulations increases levels of understanding science concepts among students. Chen (2006) found that use of unstructured daily life problem situations in a web environment improves students' conceptual understanding.

Concepts that are abstract and difficult to understand are sometimes structured in students' minds in ways that are at variance with what was targeted. Many recent studies show that students develop beliefs and ideas on certain concepts and events prior to receiving any science education, and that they bring these beliefs into the classroom (Amir & Tamir, 1994).

Various researchers argue that when students learn the basic concepts well, it affects their future learning, and that previous misconceptions sometimes prevent not only the interpretation but also the acquisition of new knowledge, and may even cause new misconceptions (Andersson, 1986; Briggs and Holding, 1986; Griffiths and Preston, 1992).

Use of information and communication technologies is considered to be an alternative method and an efficient tool in science instruction. Use of information and communication technologies in science education can help overcome some problems that traditional teaching methods fail to address (difficulties in understanding and conception, misconceptions, etc.) (Williamson and Abraham,1995; Burke et al., 1998; Ebenezer, 2001; Marcano et al., 2004; Sırabaşı, 2006; Kelly & Jones, 2007).

This study examined levels of conceptual understanding and alternative conceptions among students concerning the subject of "Acids and Bases", which is a part of the chapter "Structure and Properties of Matter". Future studies can examine the interaction of web environment problem based learning method with various variables among students from different age groups or grades, or in different chapters or courses (math, social sciences, English language, etc.).

Subjects covered in science and technology courses are directly or indirectly related to daily life. Thus, it is important that students retain what they learn in this course. There should be more of an effort to make sure that students participate in teaching activities, make use of the information they learn in their daily lives, and apply it to different situations.

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