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Using Two-Tier Test to Identify Primary Students' Conceptual Understanding and Alternative Conceptions in Acid Base

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The purpose of this study was to identify primary students' conceptual understanding and alternative conceptions in acid-base. For this reason, a 15 items two-tier multiple choice test administered 56 eighth grade students in spring semester 2009-2010. Data for this study were collected using a conceptual understanding scale prepared to include the concepts used in the subject of "Acids and Bases", which is a part of the unit "Structure and Properties of Matter" taught in the eighth grade Science and Technology course. The conceptual understanding scale was developed by the researchers to identify the alternative conceptions students might have concerning this subject. The scale 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. Data were first analyzed by tabulating students' answers to the first tier of each question, and the percentages of the reasons they selected for their answers. Analysis of results showed that students find difficulty about conceptual understanding and they have some alternative conceptions related to in acid-base.

Introduction

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 & Gunstone, 1992; Schmidt, 1997; 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.

Diagnostics tests consist of two sections at least. The first section aims to diagnose how the

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individual interprets scientific knowledge. In the second section, students are asked to state the reason(s) for their answer in the first section (Karataş, Köse & Coştu, 2003).

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 (Karataş, Köse and Coştu, 2003).

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 (Özmen, 2005). 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 students gave to the first tier of each question, and the percentages of the different reasons they cite for their answers (Karataş, Köse & Coştu, 2003). 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 students have can also be reported as percentages (Peterson & Treagust, 1989; Haslam & Treagust, 1987; Odom & Barrow, 1995; Referred: Karataş, Köse & Coştu, 2003).

Method

The purpose of this study was to identify primary students' conceptual understanding and alternative conceptions in acid-base. For this reason, the study was performed as a survey model.

Participants

The study was conducted in the 2009-2010 academic year with the participation of a total of 56 eighth grade students attending a public primary education school in Istanbul, Turkey.

Data Gathering Instruments

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

Conceptual Understanding Scale (CUS)

The conceptual understanding scale 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 (Özmen, 2005). Then, these questions were examined by a number of Science and technology teachers and science education experts in the field, and revised according to their suggestions. The scale was applied to 98 eighth grade school students in the autumn semester of the 2008-2009 academic year. Responses to the items on the conceptual understanding scale 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 multi choose.
One Correct Answer (1 point)	They have only one correct answer.
Two Correct Answer (2 point)	They have two correct answers.

The scale 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 scale consist of two parts. The first part aims to identify the alternative conception, and the second part aims to identify the ways of thinking that led to this alternative conception. Both the first and second parts are multiple choice questions. 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

Diagnostic tests were used and analyzed to measure levels of conceptual understanding among the students and to identify misconceptions.

Data were first analyzed by tabulating students' answers to the first tier of each question, and the percentages of the reasons they selected for their answers. Then, the combination of the responses to the first tier on content and the second tier on reasons was examined, and a second table showing the combination of correct answers both to the first tier on content and the second tier on reasons was created. Students received a score of 1 (one) if they selected the correct answer in both tiers, and a score of 0 (zero) if they selected the incorrect answer in either one or both of the tiers. The misconceptions students have were reported as percentages. This method of analysis is used and recommended by other studies as well (Peterson & Treagust, 1989; Haslam & Treagust, 1987; Odom & Barrow, 1995; Referred: Karataş, Köse & Coştu, 2003).

Findings

Percentages of correct answers given by students to only the first tier of the two-tier questions in the test, and correct answers to both of the tiers were compared. Percentage values are reported in Table 2.

Table 2. Conceptual understanding questions of percentage values

Question Number	First Tier	Two Tier
1	82,14	71,43
2	50	46,43
3	69,52	58,93
4	69,64	58,93
5	48,21	41,07
6	46,43	37,50
7	60,71	39,29
8	53,57	42,86
9	69,64	58,93
10	67,86	55,36
11	85,71	76,79
12	76,79	55,36
13	46,43	39,29
14	62,50	46,43
15	58,93	46,43

One of the most important findings reported in Table 2 is that the percentage of correct answers to both tiers of the questions is lower than the percentage of correct answers to the first tier in the test measurements.

For example, in the test measurement, the percentage of correct answers to the first tier of question 7 is 60,71%, whereas the percentage of corrects answers "*Materials that create H ions when solved in water are acidic*" to both tiers is 39,29%, the percentage of correct answers to the first tier of question 10 is 67,86%, whereas the percentage of corrects answers "*Apple juice is acidic. It would turn pink*" to both tiers is 55,36%. The percentage of correct answers to the first tier of question 12 is 76,79%, whereas the percentage of corrects answers "*T solution is acidic because it contains fewer OH ions than H ions*" to both tiers is 55,36%. The percentage of correct answers to the first tier of question 14 is 62,50%, whereas the percentage of corrects answers "*To increase the pH value of a neutral material, we need to add basic materials that would create OH ions when solved in water*" to both tiers is 46,43%. The percentage of correct answers to the first tier of question 15 is 58,93%, whereas the percentage of corrects answers "Materials with pH values pH<7 are acidic" to both tiers is 46,43%.

These results show that students are more successful in finding the correct answer to the first tier of the questions, but less so in stating, in the second tier, the reasons for their correct answers, which indicates that their learning is not meaningful learning, but superficial and rote learning. In some of the questions, students know the correct answers, but they do not have any idea why these are correct.

Measuring Levels of Understanding and Identifying Misconceptions among the Students

Two-tier multiple choice diagnostic tests are usually analyzed via tables showing the answers students gave to the first tier of each question, and the percentages of the different reasons they cite for their answers. Alternative conceptions students have can also be reported

as percentages (Peterson & Treagust, 1989; Haslam & Treagust, 1987; Odom & Barrow, 1995; Referred: Karataş, Köse and Coştu, 2003). The method of assessment for each question on the scale is explained below using a sample question.

Findings Concerning Question 6:

In what follows, findings concerning one of the questions on the conceptual understanding scale that aimed to identify students' ideas concerning the general characteristics of acids and bases, reproduced in Figure 1, are presented.

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 1. Question 6 on the conceptual understanding scale

Table 3 reports the answers given by students to question 6, which is one of the two-tier questions on the conceptual understanding scale, and the numbers and percentages of students who selected each answer.

Table 3. The answers of sixth question

6 Which of the following statements is TRUE concerning NH_3, CH_3COOH, and HCl?		**N *(%)***
A1- CH_3COOH is a base.	a NH_3, CH_3COOH and HCl contain only H^+ ion in their structures. *b CH_3COOH is a base because it contains OH^- ion.* c NH_3 is an acid because it contains H^+ ion. d *pH values of bases are greater than the pH values of acids.* e Blank	2 *(3,6)* 4 *(7,2)*
	TOTAL	**6 *(10,7)***
A2- All are acids.	a NH_3, CH_3COOH and HCl contain only H^+ ion in their structures. b CH_3COOH is a base because it contains OH^- ion. c NH_3 is an acid because it contains H^+ ion.. d *pH values of bases are greater than the pH values of acids*. e Blank	4 *(7,2)* 3 *(5,4)* 4(7,2) 3 *(5,4)*
	TOTAL	**14 *(25)***
A3 NH_3 is an acid.	a NH_3, CH_3COOH and HCl contain only H^+ ion in their structures. b CH_3COOH is a base because it contains OH^- ion. c NH_3 is an acid because it contains H^+ ion. d *pH values of bases are greater than the pH values of acids*. e Blank	 2 (3,6) 6 *(10,7)*
	TOTAL	**8 *(14,3)***
B- The pH value of NH_3 is greater than the pH value of CH_3COOH.	a NH_3, CH_3COOH and HCl contain only H^+ ion in their structures.. b CH_3COOH is a base because it contains OH^- ion c NH_3 is an acid because it contains H^+ ion. *d pH values of bases are greater than the pH values of acids.* e Blank	 2 (3,6) *2(3,6)* 16 (28,6) 2(3,6)
	TOTAL	**22 *(39,3)***
C (Blank)	a NH_3, CH_3COOH and HCl contain only H^+ ion in their structures. b CH_3COOH is a base because it contains OH^- ion. c NH_3 is an acid because it contains H^+ ion. d *pH values of bases are greater than the pH values of acids* e Blank	 6 *(10,7)*

TOTAL	**6 *(10,7)***
TOTAL	**56 (100)**

Table 3 shows that the incorrect answers selected by the students in the A2, "All are acids", with 25%. Of the reasons, those selected by the largest number of students were "NH_3, CH_3COOH and HCl contain only H^+ ion in their structures".

Table 4 reports the answers given by students to two-tier questions on the conceptual understanding scale.

Table 4. Students' misconception

Question Number	Alternative Answer	Selected Reason
7) The aqueous solutions of which of the following materials are acidic? I. CH_3COOH II. NH_3 III. HCl	b- II ve III	Materials that contain H^+ ions only are acidic.
10) Ceyda boils red cabbage and obtains purple-coloured water. When she mixes this purple-coloured water with lemon juice, it turns pink; and when she mixes the purple-coloured water with soap, it turns blue. What color would emerge if she were to mix the purple-coloured water of the red cabbage with apple juice?	b- Blue	Apple juice is basic. It would turn blue.
12) In his measurements with the pH paper, Ahmet finds the following values for the solutions X, Y, Z and T. X → 6, Y → 5, Z → 13 T → 1 Which of the following conclusions can Ahmet reach on the basis of these observations? a) Z is a acid. b) T is a acid c) Y is a base	Z is a acid.	Z is an acid because the pH value of Z is 13, which is greater than 7.
Material / **pH**: Blood 7.0-8.0; Vinegar 2.0-3.0; Baking powder 8.0-9.0; Tomato 4.0-5.0 *15*) On the basis of this table, which of the following is correct? *a- Vinegar is acidic.* b- Blood would not change the color of blue litmus paper. c- Tomato would turn red litmus paper blue. d- Baking powder would turn blue litmus paper red	Tomato would turn red litmus paper blue.	Materials with pH values pH<7 are basic

Conclusion

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.

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 & Holding, 1986; Griffiths & 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 & Abraham,1995; Burke et al., 1998; Ebenezer, 2001; Marcano et al., 2004; Sırabaşı, 2006; Kelly & Jones, 2007).

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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