USING TWO-TIER TEST TO ASSESS THE FOURTH YEAR STUDENTS′ LEARNING AND ALTERNATIVE CONCEPTIONS IN ACID-BASE

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ABSTRACT
Since the chemistry concepts are complex and abstract, thought of by students as complex as understanding, identifying and investigation of misconceptions is important because misconceptions is considered as one of the preventives to perpetual and meaningful students′ understanding. The purpose of the present study was to identify and assessing the fourth year students' misconceptions of acid–base chemistry in high schools of Marivan using a two-tier multiple choice diagnostic instrument. In pilot study, a test with 30 multiple-choice diagnostic questions was written concerning to the goal-content's table according to Bloom s taxonomy. Thirty participants were selected by using attainable sampling the high school fourth year students in Marivan city. With attention to the obtained amount of Cronbakh's Alpha (α=0.74), it was specified that designed questions verified with mentioned instructional objectives of goal-content' s table. With using Difficulty Coefficient, Distinction Coefficient and Internal Consistency coefficients, 12 unfit questions deleted and 18 questions remained. The main test was run on 120 students who were chosen by attainable sampling in the high school fourth year students in Marivan city. Data were analysed with use of descriptive statistics examinations (frequency, percent, average and standard deviation) and χ^2. Results showed that students had misconceptions in acid and base chemistry concepts: acid–base theories application, acid-base reactions, conjugate acid–base pairs, monoprotic and polyprotic acids, strong and weak acids/bases, pH and pOH concepts, ionization constant and kind of salts. Notably, no significant difference in the amount of misconceptions was found between the experimental and mathematical branches.
Keywords: Acid, Base, Chemistry, Misconceptions, Students, Two-Tier Test

INTRODUCTION:

Sometimes the concepts that students can perceive are not able to explain properly scientific phenomena and finally deviate from scientific phenomena. These differences between the student's points of view and the accepted scientific theories which prevent the students from meaningful and permanent learning is named misconception. In other sources, misconception is named as alternative conception, naïve belief, previous idea and etc. Researches have shown that students' previous experience, their prior knowledge, the surrounding environment and the global theory effect on the interpretation of their observations and even concepts that make. Therefore, it is possible that students come to class with misconceptions about subject taught (Çetingul, 2005). Misconceptions much impact on students learning with prevention of acquisition of the new scientific concepts.

The first step for preventing misconceptions is the recognition of the students' misconception. For misconception recognition, various discreteness tools have been developed and are used. Interviews, multiple choice exams, concept maps and multiple part exams can be listed as the discernments tools for misconception finding in science education field. Between these tools, interview has benefits such as: more flexibility and encompassing deeper information and also has disadvantage of limitation of the number of participants. Also, concept mat needs spend time for student and teacher training, scoring and interpretation of results. Although multiple chose exam can be performed for a large group but it is unable of deep probing of the students' response. For example, it occurs very much that students with wrong ratiocination correctly answer.

To compensate the limitations of these tools, researchers designed double and triple questions by improving the multiple questions. By using these developed tests for misconceptions identification researchers can gain valuable information about people misconceptions and discriminate between misconceptions and mistakes and lack of knowledge (Kaltakci & Erylmaz, 2007)

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Employing two steps multiple choice exams has doubled benefit provided teachers are aware of the students' learning of the intended subject, their thought process and also their imagery (Kao, 2007).

Many studies on student's misconception about chemistry of acids and bases have been done. Demircioglu and Ayas, 2005, believe that acid-base chemistry has been known as a difficult concept in high school. Misconceptions that students have in this topic are because the acid-base chemistry learning includes understanding of many topics such as: general chemistry, chemical equilibrium, chemical reactions, stoichiometry, the nature of matter and solutions.

In recently performed researches by Drechsle and Schmidt (2005) and Furio-Mas et al. (2007), some misconceptions and alternative concepts were reported about chemistry of acid-base between the students. Some common misconceptions of acid- base chemistry are observed on topics such as: pH, conjugate acid-base pair, salts, titration, neutralization and buffer solutions (Demircioglu et al., 2005; Sheppard, 2006).

Considering the high risk of the students' misconceptions of scientific concepts and its bad effect that influences the continuity of learning at higher levels, in new educational methods diagnostic of the common students' false conceptions and misconceptions and try for its correction is very important. Finding of this project is important because it is going with investigation of the students' comments evaluate their common misconceptions related to acid-base and offer strategies for conceptual change and correction of these types of misconceptions.

METHODOLOGY

The aim of this project was to identify students' achievements and misconceptions in acid-base topic. Therefore, the study was done as a survey model. The study was performed with descriptive-analytic method. For this purpose, at first in the pilot study, a preliminary questionnaire containing 30 multiple-choice diagnostic questions was written concerning to the goal-content's table according to Bloom s taxonomy. Then prepared questionnaire was presented to 30 high school fourth year students, so they must answer to the question within a specified time. Notably, negative score was not included for questions to easily and without any stress students answer them. Questions were related to the third section of the fourth year of high school textbook in acid-base chemistry topics. It includes concepts such as: acid-base theory, pH concept, pOH and related subjects to it, single-protic and polyprotic acids, ionization constant, acid-base power, acid-base reactions and acidic and basic salts. In order to validate the questionnaire, it was administrated to 5 high school expert chemistry teachers of Marivan city-Kurdistan Province and 10 chemistry teachers which were chemical education master students at Shahid Rajaee Teacher Training University (SRTTU) and also science education professors of SRTTU and their evaluations was collected. Then, average scores of each question were calculated. Regarding to obtained average scores of the each question and average scores of the total questions which were greater than 3 (average amount), validity of the questionnaire was confirmed.

After evaluation and calculation of the difficulty and discrimination indexes, 12 questions were omitted and 18 questions remained. The main two-tier diagnostic test was run on 120 students who were chosen by attainable sampling in the high school fourth year students in Marivan - Kurdistan Province. Each question contained 2 sections. First part was included multiple-choice questions employed in preliminary exam in which one option was the correct answer and the others were incorrect. Second part was multiple choice tests and it has been prepared so that the students should select one choice regarding the reason they chose the particular option in the first part. Notably, in the send section of each question one option was correct and others targeting the students' misconceptions which undoubtedly they were incorrect. This research was conducted in the 2016-2017 academic year with 120 participations, chosen by attainable sampling; of the high school fourth year students of the Marivan city attended to the boys government gifted Farzanegan and girls talented high schools who studied the experimental science and mathematics and physics fields. For simplicity of the data analysis was performed using SPSS software which by using that the absolute and relative frequency of the students for various options of the questions was obtained. Statistical characteristics related to holding exam have been shown in table 1.

RESULTS AND DISCUSSION

Data were analysed with use of descriptive statistics examinations (frequency, percent, average and standard deviation) and χ^2.

Table 1. Statistical characteristics related to multiple-chose exam of the acid-base concept

Exam Type	Studied city	Total Questions	Total students	Gender		Educational field study	
				Girls	Boys	Mathematics and physics	Experimental science
Preliminary	Marivan	30	30	17	13	13	17
Main (to tier)	Marivan	18	120	80	40	80	40

The evaluation of the students' response to the two-tier multiple- choice exam was performed by Bayrak (2013) classification method. To accomplish this ail, both sections of the question including response for first part and reasoning for the second part were considered. Classification was as follow:

1- Sound understanding (SU): for each question both of the response and its argument is correct.
2- Partial understanding (PU): for each question only one part is correct. Correct response or correct argument.
3- Partial understanding with Specific alternative conception (PS): includes correct response with false reasoning or correct argument with false responses.
4- Specific Alternative conception (SA): both response and arguments are incorrect.
5- No understanding (NU): leave empty options or selecting more than one option for each section of question.

This classification enables the researchers to obtain information based on two important points of view (Romklao et al., 2010).

Students' answers to the options on the conceptual understanding scale were scored based on the assessment criteria stated in Table 2.

Table 2. Assessment criteria

The degree of concept learning	Assessment criteria
0 point	No answer
0 point	Marked multiple choices
1 point	Only one correct answer
2 point	Two correct answers

Table 3. The percentages of the students' response according to the Çhalik and Ayas classification

Concept	Students responses (percentage value)									
	SU		PU		PS		SA		NU	
	Girl	Boy	Girl	Boy	Girl	Boy	Girl	Boy	Girl	Boy
Application of acid-base theories										
Q 1	27.1	33.3	0	5.6	0	0	62.5	51.4	10.4	9.7
Q 2	35.4	23.6	0	2.8	0	0	56.3	63.9	8.3	9.7
Q 3	33.3	40.2	0	1.4	14.6	16.7	43.8	37.5	8.3	4.2
Single-protic and polyprotic acids										
Q4	35.4	25	0	0	12.5	8.3	45.8	59.8	6.3	6.9
Q11	25	18	0	1.4	10.4	5.6	54.2	69.4	10.4	5.6
pH and pOH										
Q5	41.7	30.6	0	0	12.5	5.6	43.7	61.1	2.1	2.7
Q8	18.7	29.2	0	0	2.1	5.6	72.9	56.9	6.3	8.3
Q9	12.5	26.4	0	0	6.3	5.6	81.2	68	0	0
Q10	16.7	29.2	0	4.2	29.2	13.9	45.8	45.8	8.3	6.9
Conjugated acid-										

base pair										
Q6	31.2	36.1	0	0	22.9	15.3	39.6	47.2	6.3	1.4
Acid-base power										
Q7	20.8	12.5	0	0	22.9	15.3	43.8	62.5	12.5	9.7
Q12	39.6	27.8	6.3	5.6	2.1	0	33.3	41.6	18.7	25
Q14	20.8	30.6	0	0	0	0	66.7	48.6	12.5	20.8
Q16	29.2	47.3	4.2	0	10.4	8.3	47.9	37.5	8.3	6.9
Q18	35.4	30.6	0	0	6.3	4.2	47.9	58.3	10.4	6.9
Acid-base reaction										
Q13	20.8	27.8	0	1.4	18.8	27.8	50	23.6	10.4	19.4
Q15	14.6	29.2	0	2.8	12.5	11.1	56.2	45.8	16.7	11.1
Ionization constant										
Q17	22.9	38.9	0	4.3	8.3	2.8	64.6	43	4.2	11.1

Regarding to table 3, it is obvious that almost in all evaluated subjects misconceptions are observed in both gender (boy and girl students). Tsai proposed that if the total percent of misconceptions in a subject is more than 10 %, such a subject should be evaluated (Tsai et al., 2007).

Questions 1 -3 evaluate the students learning about application of the acid-base theory. In question 1, 60 % of the boy students and 50 % of girl students believed that every chemical formula containing OH in its structure is a base. That is not correct in all situation as there is an OH in the phenol (C_6H_5OH) structure but carbon electro-negativity is not enough to obtain electron from oxygen and release its OH, while most of the students did not know that.

Questions 2: in question 2 the structural formula of the boric acid (H_3BO_3) had been given in which hydrogen atoms connected to the oxygen. 32.5 % of the boy students and 43 % of the girl students incorrectly selected it as base.

Even though higher percentage of the students were able to select the correct response but obtained results shows that students do not enough contemplate and do not use their previous experience and learning or indeed they do not take the help of their prior knowledge about the property of electro-negativity of the elements.

Question 3: Arrhenius acid-base theory of oxy-acids has been questioned. As it is obvious from table 3, 20 % of boy students and 40 % of girl students mistakenly thought that all of the nonmetal oxides are acid. But some of the nonmetal oxides are neutral oxides (not acids!!!) such as CO, NO, N_2O and they are molecularly dissolved in water. Meantime, nonmetal oxides do not have H^+ in their structure that they can to release it while they produce it and this mistake is obvious in 35 % of the boy students' response and 13 % of the girls.

Questions 4 and 11: These questions aimed at the identification of the polyprotic acids from single protic ones. 37.5 % of the boy students and 17 % of the girl students only look at the formula appearance and they chose false option with misconception. Most of the students believed that hypophosphorous acid (H_3PO_2) is a polyprotic acid and can donate three protons to water molecule. In deed this acid despite having 3 protons but only has one detachable proton and is single proton acid. As a result, for identifying multiprotoic acid the number of the detachable protons is important not the number of H in structural formula. Also, 55 % of the boy students and 54 % of the girl students believed that basic species such as OH^- do not presence in acidic solutions and do not attend to aqueousity of the acidic solution and presence of hydroxide ion produced from ionization water.

Questions 5 and 8: have been stated about pH and pOH concepts that 13 % of boy students and 27 % of girl students considered the pH and pOH as a measure of the acidic and basic environment, respectively, and this is due to the same wrong idea of the acid-base definition in their mind. Furthermore, acidic power is only one of the factors that effect on pH amount and most students were neglected acid concentration and results show that 55 % of boys and 60 % of girls unable to correctly answer to the question 8.

Question 6: Plans specify conjugate acid-base pairs in following reaction,

$$NH_{3\,(aq)} + HPO_4^{2-}{}_{(aq)} \rightleftarrows NH_4^{+}{}_{(aq)} + PO_4^{3-}{}_{(aq)}$$

Students should diagnose that compounds or ions are considered conjugate acid-base that one of them to be proton donor while another is proton acceptor. Such as: HPO_4^{2-} and PO_4^{3-} or NH_3 and NH_4^+. Results show that both group of students, boys and girls, did not correctly learn this concept. About 33 % of boys and 17 % of girls was unable to identify conjugate acid-base pairs and truly argue their option. Most of them had such a misconception that considered conjugate acid-base pairs containing positively and negatively charged ions which can neutralize each other.

Question 7: Here basic power of some compounds is measured. About 27 % of boy students and 20 % of girl students incorrectly answered the both section of the question. They thought that power of bases is related to their solubility in water and also to the number of the OH group in their structures. For example, they considered $Mg(OH)_2$ stronger base than RbOH. While the power of an acid or base depends on its dissociation and ionization in water.

Question 9: it shows the pH definiation using its famus relation as $-\log[H^+]$. Here, 40 % of boy students and 50 % os girl students used this relation, unaware that in very low concentration this relation is not correct and H_3O^+ ion concentration genereted from self ionization of water should be added which lower the solution pH. Teaching method of teachers and permanent use of this equation for solving the sample questions without taking sides, have high impact on students' learning and understanidng.

Question 10: this question targeted the effect of temperature on pH but unfortunately the percentage of the correct answers to this question was very low that shows low learning level in this subject.

Question 12: Evaluated the properties of the hydrohalic acids considering their power. Students have a general idea about acids and bases in their mind and they always include the point that acids are sour and bases are bitter in their definition.

Question 13 and 15: It has been propound about acid-base reactions. About a quarter of girl and boy students in responding to question 13 have considered their learning in relation to salt definition in second and third year of high school in which salt has been defined as a compound that is product of the acid and base reaction or natural compound having equal charges of cations and anions. May be these definition be considered right in their own place. However, apart from natural salts that are widely used in our lives, we also have acidic and basic salts in nature while students do not look at the subject with a comprehensive view but they suffice to their partial information. Question 15 has propounded the esterification reaction. Ester and water are produced from the reaction of a carbocyclic acid and an alcohol in which proton (H) of the produced H_2O is supplied by alcohol and OH by acid. About 53 % of boy students and 50 % of girl students were unable to find the correct answer. Functional group of alcohols and acids is as R-OH and R-COOH, respectively. Probably, students answered to this question regarding to functional groups and jumbled topics.

Question 14: It asked ionization steps of a multropotic acid. Phosphoric acid (H_3PO_4) is a three protonated acid which has three dissociation steps and loses one proton in each step. Students thought multropotic acids are strong acids and do not know that these acids cannot completely dissociate and they do not change much in practice. 25 % of boy students and 40 % girl students had clear misconception in this subject.

Question 17: The students were asked to show as chart the K_w change of an aqueous solution based on $H_3O^+(aq)$ concentration at constant temperature. The highest percentage which shows lack of learning of the students is related to question 14 and about 8 % of boy students and 7 % of girl students did not have any comment on this question. In this question, the lack of relation between learning levels of macroscopic, microscopic and symbolic can be considered important factor in the lack of learning. Some of the students were unable to describe the existing sentences in the textbook in the form of chart.

Questions 16 and 18:
These questions asked students to specify the order of the acid-base strength of several various substituted compounds. 40 % of boy students and 34 % of girl students had misconception about question 16. Some of the students considered the alkyl groups as electron acceptor. Some others were not aware of relation between basic strength and K_b. Question 18 had almost similar situation with question 16. 33 % of boy students and 34 % of girl students had clear misconception in this question. Presence of halogens increases the acidic strength and conversely,

increasing the number of carbon reduced the acid strength. From the students response it seems that they were confused in this question and they took wrong the acidic strength with basic strength.

Finally, some students' misconceptions related to questions of acid- base concept were detected as below:

- Every chemical formula having OH represents a base.
- Every nonmetal oxide is Arrhenius acid (oxy-acid).
- Every compound with any number of H in its structure can release all of them.
- pH is a measure of the acidity of the environment and pOH is a measure of the basicity of the environment.
- The conjugate acid-base pair includes ions with positive and negative charge which can neutral each other.
- Strong acids are sourer, more caustic and have strong bond between their molecules compared to weak acids.
- When the pH increases, acidic strength enhances.
- pH of the hydrochloric acid solution (HCl) with 10^{-8} M concentration is equal to 8.
- Equilibrium systems, including acidic and basic solutions are not affected by temperature and pH=7 is the characterization of the neutral aqueous solution.
- All salt are neutral or salts that are reaction result of a strong acid and a weak base are considered as neutral salts.

CONCLUSION

In total, present research findings showed that the high school fourth year students have high misconceptions in case of acid-base chemistry concept. They cannot to have clear and accurate understanding of the intended concept. Various factors can be introduced as the origin of such misconceptions. Pre-learning of the students in previous years, abstract concepts, complexity of chemical content and disproportion of the presented scientific content with the level of the students' cognitive development, inappropriate organization of educational content without observing prerequisite, appropriate longitudinal and transverse links, inappropriate analog simulation use by teachers, lack of laboratory work and discussion, lack of connection between the three levels of learning: sensory (macroscopic), atomic and molecular (microscopic) and symbolic (formulas and algorithms), inappropriate teaching methods and instill concepts by teachers, all of them are considered as the genesis misconceptions in students. Investigating the source of misconceptions and ways of correcting them requires a separate research. When planning and writing textbooks, all the challenging concepts and prone to misconceptions in students should be examined. The use of diagnostic and genetic assessments and teachers' awareness of the views and opinions of students toward challenging concepts, towards helps to adopt appropriate teaching methods. The findings of this study can help to course planners, the authors of the chemistry and science textbooks of the middle school and also chemistry teachers proceed to improve the quality of teaching process - learning the concepts related to acid-base chemistry.

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