

Research Article

## Understanding Acid and Base Concepts among Chemistry and Biology Pre-service Teachers at Faculty of Education in Amran University–Yemen

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### ABSTRACT

This study aimed to find out Yemeni chemistry and biology pre-service teachers' (YCBPSTs) understanding of acid and base concepts. To this end, a cross sectional study was conducted on a sample consisted of 246 subjects that were selected from 590 of CBPSTs enrolled in the preparation program of science pre-service teachers (SPSTs) at faculty of education-Amran university in Yemen. An acid-base test, 24 multiple-choice questions, was developed as an instrument to carry out this study. Content validity as well as reliability of the instrument were calculated. Cronbach alpha coefficient of the instrument was found to be (0.72). Results of this study revealed that the overall scores of all participants were low. Hence the percentages of the average scores achieved on the overall acid-base test and its scales for all participants were respectively (38%, 40%, 36%, and 36%). In addition, it was found that no statistical significant difference in the mean of achievement scores on the test in all groups' comparisons except for the ones that dealt with the academic year. Based on results of the study, it was recommend to widen its scope by conducting different studies that explore the YCPSTs' understanding of other chemistry concepts in different program preparation of YCPSTs.

Key words: Science Education, Chemistry Education, Chemistry Concepts, Chemistry Pre-service Teachers, and Biology Pre-service Teachers.

### INTRODUCTION

All over the world, chemistry education (CE) is known as a key school subject. It forms an important component in the basic school science curriculum and then later in the upper science curriculum of the secondary schools (SSs). Nationally, chemistry is a core subject among the natural sciences and other science related courses in Yemeni education curricula as it is in many countries around the world.

Achieving high level of chemistry concepts (e.g. acids-bases concepts) at all levels of education requires chemistry teachers who have a high competency in chemistry teaching as well as a wide knowledge in chemistry subject matter. Hence, more qualified and knowledgeable teachers are considered to be more able to concentrate on the most appropriate way to teach particular topics such as acid and base to students [1,2].

Consequently, an improvement of any parts of science education (SE), such as CE, is imperative to involve a well-articulated teacher education program that will prepare the teacher for the role of leadership he/she is expected to play [1,3]. Educationally, the importance of science teacher at all levels can be declared in one sentence, there is "no educational system may rise above the quality of its teachers" [1].

An acid-base concepts, i.e. 'the species, molecule or ion, that donates a proton to another species in a proton transfer reaction is called an acid, while the species that accepts a proton to another species is base' [4], are the key and basic concepts in CE. Hence, learning of many chemistry concepts, that are taught to all students, depends on understanding such important concepts (i.e. acid and base). Thus, understanding acid and base concepts is a key point in recognizing the chemistry subject matter. Consequently, these concepts became widely a part of targeted concepts in school chemistry curriculum. However, as many studies revealed that not only most students but also teachers have inappropriate understanding even with the basic chemistry concepts (e.g. mole concept, conservation of atoms and mass, acid, base, chemical equation etc.) [5,6,7,8,9].

In this regard, previous studies reported that students at all levels of education had a lack understanding and hold misconceptions about many basic chemical concepts such as acid and base' concepts [10]. Such a lack of the students' understanding may be referred to textbooks and teaching materials as well as teaching-learning environment [10, 11, 12,13]. On the other hand, literature review on SE indicates that science teachers play a valuable role in helping students to overcome such a lack of understanding, or misconceptions [1,2,6]. But this role depends on the pedagogical content knowledge (PCK) that teachers are exposed to.

It is similar to other science disciplines that chemistry teachers' understanding of subject matter affects how their students understand the chemical concepts; teachers with limited understanding of subject matter may not be able to offer viable explanations to their students [15, 16]. Thus, they must be prepared to reflect the findings of research on chemical subject matter into practice. Furthermore, they must have a sound understanding of fundamental chemistry concepts such as acid and base. Researchers showed that science teacher knowledge about subject matter plays a vital role in enhancing or limiting student's learning [1,2,6,15,16].

Although plentiful studies on SPSTs' understanding of some chemistry concepts have been worldly conducted [17], only a few studies conducted on the understanding of YSPSTs about such concepts [5,6]. Thus, this study was an attempt to find out the YCBPSTs' understanding on a particular chemistry concepts, mainly acid and base concepts.

## **PROBLEM STATEMENT**

The emphasis given to SPSTs' understanding have probably arisen from some assumptions about their key roles in SE. Hence, one of the most outstanding element in the field of human education, i.e. SE, is training the teachers, either pre-service, or in-service preparation. Thus, teachers' understanding about subject matter and science teaching should be concentrated on.

As an educator of curricula and science teaching methods, unfortunately, the researcher explored that many CBPSTs had a lack of understanding many basic concepts of chemistry. In addition, there are number of studies showed that SPSTs had a lack of understanding, perceptions, skills and practices of different chemical concepts in different countries. Nonetheless, there is a lack of literature review on YSPSTs' understanding of acid and base concepts. This study, therefore, focuses on CBPSTs' understanding, those who enrolled in faculty of education-Amran university, about acid-base concepts according to their academic years, and majors variables.

Thus, to address the problem of this study, YCBPSTs must be well prepared, and must have a well understanding of fundamental chemistry concepts such as acid and base concepts. Therefore, this study aimed to answer the following questions:

1. What is the level of YCBPST's understanding of acid and base concepts?
2. Are there any statistically significant differences between YCBPST's understanding of acid and base concepts according to the year of the university, and major variables?

## IMPORTANCE OF THE STUDY

Referring to the internet survey, plenty of the articles deal with the SPSTs' understanding and perception of the chemistry concepts. A few of those articles dealt with the SPSTs' understanding of acid and base concepts. According to YSPSTs' perception on the topic of acid and base concepts, a relative lack of studies have been conducted on such topic. Therefore, conducting such study may provide an indication about the level of YSPSTs' understanding on acid-base concepts in order to inform Yemeni policy makers and educational researchers about how realistic they are in their understanding related to the CPSTs' knowledge to achieve science goals curriculum.

When shaping the science teacher education programs according to science curriculum goals for SS, the need for evidence-based research becomes crucial. Thus, freshman and senior PSTs (i.e. 1st and 4th university academic year) were selected for comparing their understanding on acid-base concepts as an indicator about how CE is presented to Yemeni secondary school (YSS), and how it is presented to SPSTs through the preparation programs at the faculty of education-Amran university.

In this study, CBPSTs at faculty of education-Amran university were chosen as a population for conducting the study because of two main reasons: (1) they took chemistry courses before and after they enter into undergraduate programs so they, particularly the 4th CBPSTs, were expected to achieve a high level of understanding of chemistry concepts, and (2) they will become chemistry teachers in YSS so for their understanding and knowledge of chemistry will be reflected in their future classes.

In addition, this study is important because it is a developmental study researching into the understanding of SPSTs at the beginning and at end of their college education, hence its result explores the understandings about acid-base concepts of YSS outcomes (i.e. 1st year of YSPSTs at faculty of education- Amran university) as well as the understandings of the outputs of the YSPSTs' program on such concepts (i.e. 4th year YSPSTs at faculty of education- Amran university).

## LITERATURE REVIEW

SPSTs' understanding of chemistry concepts, including acid and base concepts, have been studied by numerous researchers in diverse educational researches for different purposes [7, 16, 17]. Concerning YSPSTs' understanding acid and base concepts, even more limited studies existed in the literature.

In this regard, Dindar et al. [18] used one-to-one semi-structured interviews to interview a sample of six secondary CPSTs at a university in Ankara in order to find out the CPSTs' explanations regarding chemistry topics including acids and bases. Concerning acid and base, all CPSTs' did not do any explanation about either Bronsted-Lowry or Lewis acid and base definitions. In addition, they could not understand whether a matter is an acid or a base using a litmus paper. On the other hand, some misconceptions regarding the relationship between pH and the strength of the acids were shown by the results of this study, hence some participants thought that the pH of a strength acid was always higher than a weak acid. Some students also said that when the pH value increased the strength of acid increased, too.

Tan et al. [19] conducted a study aimed to determine PSTs' understanding of the concepts involved in the kinetics of acid reactions that involves understanding of stoichiometry, chemical equilibrium and graphical representations. To achieve this aim, researchers developed four multiple-choice items to determine the understanding of 217 SPATs in Singapore on the kinetics of acid reactions. Results revealed that Singaporean SPSTs had difficulties in explaining the properties of different common acids, including the dissociation of the acids and how these affect the rates of the different acid reactions.

Also, Pan and Henriques (2015) [20] conducted a review study of the literature associated with secondary and postsecondary students' ideas about acids and bases. They

found that there are six types of alternate ideas about acids and bases that students hold. Those alternate ideas are: macroscopic properties of acids and bases, microscopic properties of acids and bases, neutralization, acid strength, pH, and titration.

Regarding to the basic education students' understanding of acid-base concepts, a study was conducted by Harizal (2012) [21] involved 179 of 9th grade students from six different schools in Medan selected based on their accreditation. An acid-base chemistry misconception test containing 12 open-ended multiple choices was used as an instrument for collecting data of this study. results of Harizal's study revealed that students had fifteen misconceptions and eleven sub-misconceptions. From five main concepts investigated in acid-base chemistry, percentage of students' responses categorized as specific misconceptions are acid and base concepts, pH and pOH concepts, ionization degree and equilibrium constant concepts, acid-base indicators concept, and acid-base titration concept.

Other study conducted by Ciogl (2009) [22] used the concept achievement test, in a semi-experimental design, to examine the effective of conceptual change texts' application on 10th Turkish grade students' conceptual understanding and alternative conceptions about acids and bases. The result of Ciogl's study revealed that there were no significant differences among the groups with respect to the students' understandings of the concepts of the acids and bases before the treatment. On the other hand, this result revealed that statistically significant differences were found between the experimental groups and control groups with respect to the students' understandings of the aforementioned concepts after the treatment.

## METHODOLOGY

This study aimed to find out YCBPSTs' understanding of acid-base concepts. It was conducted as a cross sectional study, i.e. a study involves studying groups of participants in different age groups at the same point in time [23]. Hence, its sample, 246 participates, was selected randomly from 590 CBPSTs of the 1st and 4th academic years enrolled in pre-service education program at faculty of education-Amran university in Yemen, as it is illustrated in Table 1. Due to all of CBPSTs are being prepared to teach chemistry in YSS, sample of the study was selected from the majors of CBPSTs.

**Table 1 Population and sample of the study**

Population	1st year			4th year			Total
	Chemistry	Biology	Total	Chemistry	Biology	Total	
	166	180	346	98	146	244	590
<b>Sample</b>	77	73	150	71	25	96	246

## Instrument

An acid-base test was (i.e. multiple choice questions) developed by the researcher himself as instrument to achieve the objectives of this study. The test's items were based on the acids and bases topics. Because these topics are part of the curriculum of all SSs, every chemistry teacher could reasonably be expected to hold Content Knowledge and PCK about them. On the subject of the knowledge content of the test's items, it was collected from different respectful chemistry resources [24, 25]. Every item of the test has four alternative choices but only one of them is a correct answer.

For further testing applicability and comprehensives of the test, validity and reliability were figured out. For validity, the test was given to 12 experts, educators of the chemistry/science teaching methods and curricula subject in Yemeni universities, to figure out its content validity. Experts were asked to evaluate the test's items in terms of the clarity and accuracy of each item. they were also asked to be free in adding, removing, or modifying any of its items. 80% of consensus amongst the experts were taken as criteria to accept the item.

As regard the reliability, Cronbach alpha reliability coefficient was calculated. It was found to be (.722). Moreover, to insure the suitability of the instrument for achieving its objectives, difficulty and discrimination coefficients of every items were calculated, too. Thus, the final version of the test consists of 24 items that were categorized in three categories (see table 2).

**Table 2 items' distribution amongst acid-base test's categories**

Domain /Area	Items	Total items
<b>Acid</b>	1,3,4, 5, 7, 8, 10, 15, 16, 23, and 25	11
<b>Base</b>	2, 9, 11, 12, 17, and 27	6
<b>Miscellaneous</b>	13, 20, 21, 22, 26, 29, and 30	7

The test was administered during the second semester of academic year, 2015/2016. It was conducted by the author himself. Before the test, the subjects were given the instructions of how to answer the test's items. Additionally, the subjects were asked to write down some necessary information related to the study (i.e. academic year, and major). The subjects responded to each item of the test by ticking the symbol "√" either A, B, C, or D in the answer sheet. Therefore, maximum scores of test is 24 scores, while the minimum scores is zero. For analyzing data of the study, a descriptive statistics was conducted using SPSS, version 23.

## RESULTS

According to the first question of the study, the results show that the overall scores of the participants to the acid-base test were low, as it is illustrated in table 3.

**Table 3 means and percentages of all participants as well as the 1<sup>st</sup> and 4<sup>th</sup> of their academic years on all acid-base test and its scales**

Group	N	All test's items		Acid		Base		Miscellaneous	
		Mean	%	Mean	%	Mean	%	Mean	%
<b>1<sup>st</sup> year</b>	150	7.65	32	3.84	35	1.17	29	2.09	30
<b>4<sup>th</sup> year</b>	96	11.22	46	5.18	47	2.84	47	3.20	45
<b>All</b>	246	9.04	38	4.36	40	2.16	36	2.52	36

As illustrated in table 3, percentages of the average scores achieved in the overall acid-base test and its scales for all participants were respectively (38%, 40%, 36%, and 36%). For the 1st academic year, percentages were (32 %, 35%, 36%, and 30%), while they were for the 4th year (46%, 47%, 47%, and 45%) respectively. Obviously, the percentages of the 1st year's scores were the lowest percentages in contrast to scores percentages of the 4th year.

On statistical analysis that deals with the second question, An independent-samples t-test was conducted to compare scores of the participants' groups on acid-base test. Results of this analysis revealed that there was no statistical significant difference in acid-base achievement between variables of the study in all groups' comparisons except for the comparison of academic year groups.

As it can be seen from Table 4, there were statistically significant differences between participants' scores means on acid-base test of the 1st academic year group and the 4th year group either in the means on the whole test's items, or each of its scales.

**Table 4 t-test for comparing scores' means of the all participates on acid-base test in terms of their academic year**

Group	N	Mean	S.D	t	Df	P
1 <sup>st</sup> /acid scale	150	3.84	1.773	-5.671-	198.363	0.005
4 <sup>th</sup> / acid scale	96	5.18	1.824			
1 <sup>st</sup> / base scale	150	1.17	1.101	-6.918-	244	0.005
4 <sup>th</sup> / base scale	96	2.84	1.453			
1 <sup>st</sup> / Miscellaneous scale	150	2.09	1.287	-5.892-	222.475	0.005
4 <sup>th</sup> / Miscellaneous scale	96	3.20	1.631			
1 <sup>st</sup> / total scale	150	7.65	0.857	-8.317-	244	0.005
4 <sup>th</sup> / total scale	96	11.22	0.3944			

On the other hand, results of this study revealed (see table 5) that there were no statistical significant differences in acid-base test achievement between participants can be referred to the major variable either on the whole test's items, or on each of its scales.

**Table 5 t-test for comparing scores' means of the all participates on acid-base test in terms of their major**

Group	N	Mean	S.D	t	Df	P
Chemistry /acid scale	147	9.04	3.725	0.001	210.600	0.999
Biology / acid scale	99	9.04	3.720			
Chemistry / base scale	147	2.18	1.355	0.41	207.333	.0685
Biology / base scale	99	2.11	1.384			
Chemistry / Miscellaneous scale	147	2.48	1.585	-0.53-	222.475	0.600
Biology / Miscellaneous scale	99	2.58	1.450			
Chemistry / total scale	147	4.37	1.855	0.12	200.570	0.903
Biology / total scale	99	4.34	1.988			

Similarly, these results revealed, see table 6, that there were no statistical significant differences in acid-base test achievement of the 4th academic year's participants can be referred to the major variable whether on the whole test's items, or on each of its scales.

**Table 6 t-test for comparing scores' means of the 4<sup>th</sup> year on acid-base test in terms of their major**

Group	N	Mean	S.D	t	Df	P
Chemistry 4 <sup>th</sup> /acid scale	56	5.91	1.975	-0.177-	92.773	0.860
Biology 4 <sup>th</sup> / acid scale	40	5.98	1.577			
Chemistry 4 <sup>th</sup> / base scale	56	1.32	0.855	-0.021-	85.727	0.984
Biology 4 <sup>th</sup> / base scale	40	1.33	0.829			
Chemistry 4 <sup>th</sup> / Miscellaneous scale	56	1.48	1.190	-1.148	88.702	0.254
Biology 4 <sup>th</sup> / Miscellaneous scale	40	1.75	1.080			
Chemistry 4 <sup>th</sup> / total scale	56	3.11	1.448	0.760	91.494	.449
Biology 4 <sup>th</sup> / total scale	40	2.90	1.215			

Also, as it is showed in Table 7, results revealed that there were no statistical significant differences in acid-base test achievement of the 1st academic year's participants which can be referred to the major variable either on the whole test's items, or on each of its scales.

**Table 7 t-test for comparing scores' means of the 1<sup>st</sup> year on acid-base test in terms of their major**

Group	N	Mean	S.D	t	Df	P
Chemistry 1 <sup>st</sup> /acid scale	91	10.97	3.206	-0.278-	121.645	0.781
Biology 1 <sup>st</sup> / acid scale	59	11.12	3.291			
Chemistry 1 <sup>st</sup> / base scale	91	2.71	1.336	0.301	117.524	0.764
Biology 1 <sup>st</sup> / base scale	59	2.64	1.436			
Chemistry 1 <sup>st</sup> / Miscellaneous scale	91	3.01	1.484	-0.224-	129.124	0.823
Biology 1 <sup>st</sup> / Miscellaneous scale	59	3.15	1.391			
Chemistry 1 <sup>st</sup> / total scale	91	5.15	1.639	-0.578-	115.378	0.565
Biology 1 <sup>st</sup> / total scale	59	5.32	1.805			

## DISCUSSION

Results of this study revealed that the achievement of the participants on overall acid-base test was less than the accepted achievement (i.e. cut-point that is 80%). Percentage of the score achieved in the overall acid-base test and its scales for all participants was respectively (38%, 40%, 36%, and 36%). While the percentages of the 1st academic year, were (32 %, 35%, 36%, and 30%), they were (46%, 47%, 47%, and 45%) for the 4th year, respectively.

Only 6 items of acid-base test (i.e. 1,2,3,7,23, and 29) got  $\geq 50\%$ . Item 1,2,3, and 23 belonged to acid scale and item 7 belonged to base scale, while item 29 belonged to miscellaneous scale items. Noticeably, the lowest percentage was (17%) of item (17) which belonged to base domain items. This item was about the conjugated acid-base pairs. On the other hands, the highest one was (69%) of item (29) that belonged to miscellaneous domain items, and which was about the kinds of acid-base reactions.

These results might indicate that Yemeni chemistry education have not successfully been carried out the aims of chemistry teaching in YSS, particularly teaching dealing with acid-base concepts. Similarly, deficiency of the achievement CE's aims in Yemen can be inferred from the results illustrated in table 3, hence the achievement percentage of the 1st year was less than 50%. Likewise, it can be concluded about the results of the 4th year participants, hence their achievement percentage was less than 50%, too.

The results are expected as CBPSTs were exposed to chemistry subject in which the topic of acid and base were covered during their studies, either at SS or university. Yet, most of them still do not understand a lot of concepts dealing with acid and base concepts.

Results of this study are in line with the results of some previous studies [18, 19]. According to the study of Dindar et al (2010) [18], as regard acids and bases concepts, results revealed that all CPSTs explained incorrectly the acid and base definition regarding Bronsted-Lowry and Lewis acid-base definitions. Besides, all of them stated that they could not understand neither a matter is an acid nor a base using a litmus paper. Furthermore, some of them thought that increasing the value of pH leads to increasing the strength of acid, too. Similarly, results of Tan et al. (2010) [19] study indicated that SPSTs had difficulties in explaining the properties of different common acids, including the dissociation of the acids and how these affect the rates of the different acid reactions.

Regarding the difference between the groups of the sample of the study, results of independents-samples t-test comparisons revealed that there was no statistical significant difference in acid-base achievement between groups of the participants in all groups' comparisons except for the comparison of academic year groups (1st and 4th year) in favor of the 4th academic year. These results are logic, but this is not really the case, hence all scores' percentages of all groups were less than the accepted percentage (i.e. cut-point that is 80%).

Though the value of eta squared for the effect size of (0.22) is a large effect [26], it does not mean that difference between the academic year groups (i.e. 1st and 4th years) was due to the preparation program which CBPSTs have been exposed to; hence all means comparisons between groups in terms of major variable indicated that there were no statistical significant differences in acid-base test achievement of participants can be referred to this variable. At this point, one can say that pre-service education program contributed to the CBPSTs' understanding about acid and base concepts but, obviously, not sufficiently. This may be the case due to the insufficiency of the CBPSTs' preparation program.

## CONCLUSION

This study aimed to find out CBPSTs' understanding about acid-base concepts. To this end, an acid-base multiple choice test was developed to collect data from a sample selected randomly from CBPSTs who enrolled in science program preparation at faculty of education-Amran university.

Results of this study revealed that the participants did not show an accurate understanding of the acid-base concepts. Though results showed that the CBPSTs of the 4th academic year had more understanding about the acid-base concepts than their peer of the 1st year, their understanding on such concepts still inaccurate. Results also indicated that there was no statistical significant difference in acid-base achievement between groups of the participants in all groups' comparisons except for the comparison of the academic year groups in favor of the 4th year. Based on this results, one can conclude that there is an urgent need for revising, evaluating and development the science program preparation of CBPSTs to ensure a sound understanding of chemical concepts, particularly acid-base concepts. Moreover, as this study dealt with the CBPSTs' understanding about only acid-base concepts, therefore, its results are restricted to only these concepts, too.

## RECOMMENDATIONS

Based on the above results, the following recommendations should be taken in consideration:

1. The lack of CBPSTs' understanding of the 4th academic year about acid-base concepts indicates that preparation program of CPST at faculty of education-Amran university needs to evaluate and develop in light of developed theories of teaching and learning science, particularly chemistry discipline;
2. As a future study, it is recommended to conduct different studies that explore the CPSTs' understanding of other chemistry concepts in a larger sample.

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