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EVALUATING OF PRE-SERVICE SCIENCE TEACHERS' UNDERSTANDING OF GENERAL CHEMISTRY CONCEPTS BY USING TWO TIER DIAGNOSTIC TEST

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Abstract. *This research aimed at evaluating pre-service science teachers' understanding of the subject matters such as "thermochemistry, chemical kinetics, chemical equilibrium, acids and bases and electrochemistry". For this purpose, a two-tier diagnostic test consisting of 44 items (α = 0.84) related to the aforementioned concepts was developed by the researchers. This test was applied on to the first, second, and third year pre-service science teachers in Hasan Ali Yucel Education Faculty, Istanbul University. The results showed that the pre-service science teachers had alternative conceptions about endothermic-exothermic reactions, conservation of energy, reaction enthalpy, calorimeters; rate of reaction, reaction rate constant, effects of some factors on reaction rate and reaction rate constant; effects of some factors on equilibrium, equilibrium dynamics, Le Chatelier Principle; equivalence point, end point, indicators, buffers, titrations, neutralization, strength and properties of acids and bases, pH; effects of concentrations on cell potential, metal electrodes, localization of anode and cathode, plating, galvanization.*

Key words: *acids and bases, alternative conception, chemical equilibrium, chemical kinetic, electrochemistry, thermochemistry, two tier diagnostic test.*

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Introduction

The investigation of students' learning processes has been an important issue in science education. Students come to science classes with their prior knowledge. This knowledge affects how the learners perceive new information. Some part of this knowledge can be different from those generally accepted by scientists and they may stand in the way of learning scientific concepts meaningfully (Sanger & Greenbowe, 1997a). These different conceptions are generally called "alternative conceptions" (Artdej et al., 2010; Boz, 2009; Cakmakci, 2010; Coll & Taylor 2001; Karsli & Ayas, 2013; McClary & Bretz, 2012; Pedrosa & Diaz, 2000; Taber & Tan, 2011) or "misconception" (Barke, 2012; Bilgin & Geban, 2001; Cheung, Ma & Yang, 2009; Duis, 2011; Kariper, 2011; Kolomuc & Tekin, 2011; Kousathana, Demerouti & Tsaparlis, 2005; Yakmaci-Guzel, 2013). Throughout this article, the term "alternative conception" will be used to refer to students' incorrect conceptions because these incorrect conceptions are accepted as alternatives to scientific conceptions by the students in their mind.

There are several sources of alternative conceptions in chemistry. These are daily life experiences, instructional language, teachers, changes in the meaning of chemical terms and textbooks (Hodge, 1993; Kathleen, 1994; Schmidt, 1999; Schmidt et al., 2003). These alternative conceptions create difficulties for students since they are not able to make meaningful connections between their own conceptions and the ones learned newly. As learning involves the construction of new meanings and understandings through linking of new ideas with existing ones, alternative conceptions need to be addressed as they will subsequently influence students' ability to acquire scientific conceptions (Chin, 2001).

Identifying students' understanding of scientific phenomena and alternative conceptions has always been important for meaningful learning of chemistry concepts. So, researchers have been focused on investigating students' understanding of basic chemistry concepts in high school level such as acids and bases (e.g. Acar, 2008; Acar Sesen & Tarhan, 2011; Cetin-Dindar, 2012; Demircioglu, 2003; Demircioglu et al., 2004; Kousathana, Demerouti & Tsaparlis, 2005; Sisovic & Bojovic, 2000; Tarhan & Acar Sesen, 2011, 2012, 2013) chemical kinetics (e.g. Cakmakci, 2009, 2010; Calik, Kolomoc & Karagolge, 2010; Justi, 2002; Van Driel, 2002) chemical equilibrium (e.g. Bilgin & Geban, 2001; Cam & Geban, 2013; Chiu, Chou & Liu, 2002; Ozmen, 2007; Pedrosa & Dias, 2000) electrochemistry (e.g. Acar & Tarhan, 2007; Gedik, Ertepinar, & Geban, 2002; Lin, Yang, Chiu, & Chou, 2002; Niaz, 2002; Niaz & Chacon, 2003; Tarhan & Acar, 2007; Tasdelen, 2011; Thompson & Soyibo, 2002; Yuruk & Geban, 2001) and thermochemistry (e.g. Ayyildiz & Tarhan, 2012; Greenbowe & Meltzer, 2003; Yalcinkaya, Tastan & Boz, 2009). Although there are several researches for investigating alternative conceptions related to aforementioned concepts in high school level, studies in undergraduate level (Ebenezer & Fraser, 2001; Greenbowe & Meltzer, 2003; Mathabatha, 2005; McClary & Bretz, 2012; Nilsson & Niedderer, 2014; Turányi & Tóth, 2013; Yang, Andre & Greenbowe, 2003), in teacher training level (Ahtee, Asunta & Palm, 2002; Cakmakci, Leach & Donnelly, 2006; Cetin-Dindar, Bektas & Celik, 2010; Demircioglu, Ozmen & Ayas, 2001;Ozkaya, 2002; Sozbilir, Pinarbasi & Canpolat, 2010; Yilmaz, Erdem, & Morgil, 2002) and especially in science teacher training (Boz, 2009; Dhindsa, 2002; Karsli & Ayas, 2013; Karsli & Calik, 2012; Ozdemir, Kose & Bilen, 2012; Ozmen, 2008) are limited.

Researchers have used different techniques to identify students' understanding about scientific concepts such as traditional multiple choice tests, short answer questions, open-ended questions etc. However, it was reported that although students gave correct responses to a scientific question, they often had difficulties in-depth explanation of their reasons during the learning process (Ben-Zvi et al., 1986; Osborne & Cosgrove, 1983). For example, a traditional multiple choice test has some limitations such as chance success, for this reason using of justifications while answering the test items is an effective way of assessing learning (Tamir, 1989). Moreover, assessing of high level cognitive skills by using traditional assessment techniques is difficult. Especially true-false questions have only two options and this situation causes inadequate assessing of learning process, in-depth. Therefore, alternative assessment methods have gained importance among science educators. Two-tier tests are one of these methods to diagnose students' understanding. Using two tier diagnostic tests provide an opportunity to identify students' understanding and alternative conceptions. In this test, the first tier of each item consists of a multiple-choice question and it includes some specific content knowledge. The second tier of each item contains justifications for responses to the first tier. There is one correct answer and distractors derived from literature, interviews, and open-ended responses to the tests. In this test, each item was considered to be correctly answered both content (the first tier) and reason (the second tier) parts were correctly answered (Treagust, 1988). This scoring ensures that students' chances of obtaining a correct answer by guessing would be very low (Tsui & Treagust, 2010). Two tier diagnostic tests make contribution to the assessment of students' reasoning or interpretation and their relation to alternative conceptions of the target concept (Wang, 2004) and it provides an opportunity to use students' justifications for identifying alternative conceptions and assessing understanding.

There are many tools for assessing students' understanding of chemistry concepts but they have some limitation for identifying alternative conceptions as explained above. In addition, there are limited studies that investigate undergraduates' and pre-service science teachers' understanding of chemistry concepts by using a two-tier diagnostic test.

For these reasons in this research, it was aimed at identifying the pre-service science teachers' understanding of some chemistry concepts such as thermochemistry, chemical kinetics, chemical equilibrium, acids-bases and electrochemistry in the context of General Chemistry course in the second semester of university.

Methodology of Research

In this research, a descriptive research design was conducted by participation of 151 pre-service science teachers. It was aimed to investigate pre-service science teachers' understanding of some chemistry concepts by using a two tier diagnostic test developed by researchers and their responses to each item were analysed by the following Treagust method (1988).

Participants

This research was conducted with 151 pre-service science teachers (between 18 and 21 years of age) at Istanbul University, Hasan Ali Yucel Education Faculty, Turkey. The pre-service science teachers' socio- economic statuses were similar and they were from different cities in Turkey. They achieved Turkish University Entrance Exam to enrol in the faculty of education, and their scores were similar. All the participants achieved first semester General Chemistry course and they learned basic chemistry concepts such as atom, periodic table, chemical reactions, mole, chemical bonds and solutions.

Instrument

In this research, a two-tier diagnostic test consisting of 44 items related to the chemistry concepts such as thermochemistry, chemical kinetics, chemical equilibrium, acids-bases and electrochemistry was developed by the researchers, basically following Treagust's (1988) methods (Mutlu & Acar Sesen, 2015). In the first step, content boundaries and learning objectives were determined. Concept maps for each subject were developed and all the maps were validated by five chemistry educators. Alternative conceptions were identified according to both literature review (as indicated in the introduction) and the pre-service science teachers' semi-structured interviews. Later, a multiple-choice test with an open ended part, in which the pre-service science teachers were required to explain their reason for their answers to the first part, was constructed. The test was applied on to 68 pre-service science teachers. Their responses to the open-ended part of each item were analysed. Distractors for the second tier containing alternative conceptions were constructed according to those responses and the literature review. Hence, the two-tier test was constructed in a way that the first tier included the conventional multiple choice step and the second tier included possible reasons of the given answer for the first tier. In order to check the content validity, the test was reviewed by 5 chemistry educators who work at different universities, have a PhD degree and teach General Chemistry, General Chemistry Laboratory and Teaching of General Chemistry courses. The two-tier diagnostic test was applied on to 151 pre-service science teachers. They were required to make a choice in the first-tier, and to choose an appropriate explanation in the second tier. According to the item analysis results, two items were removed from the test because their discrimination indices were negative. For reliability analysis, SPSS data file was constructed. The final version of the two-tier diagnostic test consisted of 44 items. The Cronbach α reliability coefficient was found to be 0.84 (Table 1) and this value was high and acceptable when compared to the literature values (e.g. Chandrasegaran, Treagust & Mocerino, 2007; Tsui & Treagust, 2010).

Table 1. Test topics, items and Cronbach's alpha reliability coefficient.

Topic	Items	α-reliability coefficient
Thermochemistry	Q6, Q15, Q24, Q35, Q41, Q44	0.85
Chemical Kinetics	Q1, Q4, Q7, Q8, Q10, Q11, Q12, Q14, Q16, Q18, Q38	0.88
Chemical Equilibrium	Q27, Q30, Q32, Q34, Q36	0.82
Acids and Bases	Q2, Q5, Q9, Q13, Q17, Q19, Q20, Q21, Q23, Q25, Q28, Q29, Q31, Q37, Q42, Q43	0.86
Electrochemistry	Q3, Q22, Q26, Q33, Q39, Q40	0.79

Data Analysis

For the reliability analysis, SPSS data file was constructed. While analysing this data, the answer was considered to be correct if both tiers were correctly answered (Treagust, 1988) because it decreased the percentage of students' obtaining a correct answer by chance (Tsui & Treagust, 2010) and evaluated meaningful understanding, deeply. Therefore, one point was given for items only when both parts of the item were correctly answered, and zero point was given for items when either part was incorrectly answered. Cronbach's alpha reliability coefficient was reported because coefficient alpha is equivalent to the Kuder-Richardson 20 coefficient for dichotomous data (Green & Salkind, 2005).

To evaluate the pre-service science teachers' understanding, their responses to each item were analysed by the following Treagust method (1988). Therefore, the percentage of the pre-service science teachers' choices to each option was calculated. The percentage of correct answers and alternative conceptions were considered for incorrect items which scored 20% or more to aforementioned concepts, which were reported. An example item related to thermochemistry was presented to illustrate how the item worked and how the data were used by the pre-service science teachers.

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Which of the following is true about an endothermic equilibrium reaction?

a) Activation energy for the forward reaction is greater than activation energy for the reverse reaction.
b) Activation energy for the reverse reaction is greater than activation energy for the forward reaction.

Because:

A) It gains the required activation energy faster because of taking out energy.
B) The reactants' energy is greater than the products' energy.
C) The activation energy of exothermic reactions is greater than that of endothermic.
D) The products' energy is greater than reactants' energy.

This item assessed the pre-service science teachers' understanding of endothermic reactions and some of their features. While analysing this item, percentage of choosing each option in each tier was calculated (Table 2).

Table 2. Analysis of a thermochemistry-related item for identifying understanding.

N	First Tier (%)	Second Tier (%)				
		A	B	C	D	No reason
151	a (73%)	12	20%	10	31*	0
	b (27%)**	1	9%	0	17	0
	No choice (0%)	-	-	-	-	-
	Total	13	29**	10	48	0

*Note * The correct choice and reason response*
*** Alternative conceptions were considered for incorrect items, which scored 20% or more*
- No responses in this category

The majority of the pre-service science teachers (73%) correctly responded to the first tier "Activation energy for the forward reaction is greater than activation energy for the reverse reaction". Also, some of the pre-service science teachers (48%) correctly responded to the second tier. However, only 31% selected the correct choice for each tier: (a) for the first tier and (D) for the second tier, so only 31% correctly understood endothermic reactions, some of their features and why activation energy for the forward reaction is greater than activation energy for the reverse reaction. Moreover, some of the pre-service science teachers selected choices (b) 27% in the first tier and (B) 29% in the second tier, respectively. According to the results, these pre-service science teachers had the following alternative conceptions;

- Activation energy for the reverse reaction is greater than activation energy for the forward reaction (27%).
- The reactants' energy is greater than the products' energy in endothermic equilibrium reactions (29%).

Results of Research

Q6, Q15, Q24, Q35, Q41 and Q44 in the two-tier diagnostic test related to thermochemistry. The results showed that, the first tier of Q15 had the highest percentage as a correct answer (Table 3).

Table 3. Percentages of the pre-service science teachers' correct answers for thermochemistry-related items.

		Percentages of correct answers		
Item	Educational objectives of item	First tier	Second tier	Both tiers
Q6	Be able to explain endothermic reactions.	73	48	31
Q15	Be able to explain conservation of energy.	82	53	50
Q24	Be able to explain reaction enthalpy.	62	38	28

	Percentages of correct answers			
Item	Educational objectives of item	First tier	Second tier	Both tiers
Q35	Be able to explain bond energy.	36	41	23
Q41	Be able to compare different reactions' enthalpy by using calorimeter.	62	58	47
Q44	Be able to calculate reaction enthalpy	30	56	11

Moreover, generally, the first tiers were correctly answered with more than 50% percentage by the pre-service science teachers, but the percentage of correct answers to the second tiers and both tiers decreased. In addition, alternative conceptions obtained from those items were presented in Table 4.

Table 4. Alternative conceptions related to thermochemistry.

Category	Alternative conceptions	Percentage
Reaction enthalpy	Reaction enthalpy is the difference of temperature between before and after reaction.	30
	Reaction enthalpy is the difference of temperature between the system and the environment.	26
	Reaction enthalpy is the difference of temperature stored in the product's and reactant's chemical bonds.	28
Endothermic reactions	The reactants' energy is greater than the products' energy in endothermic equilibrium reactions.	29
	Activation energy for the reverse reaction is greater than activation energy for the forward reaction in endothermic equilibrium reactions.	27
Exothermic reactions and bond energy	The energy stored in chemical bonds is released by reactions.	36
	The energy required to break the bonds in the reactants' molecules is greater than the energy required for the formation of bonds in the products' molecules in exothermic reactions.	32
	The energy stored in products' bond is less than energy stored in reactants' bonds in exothermic reactions.	27
Hess's law	The reaction enthalpy only depends on stoichiometric coefficients in the balanced reaction equation.	22

The results obtained in this research indicated that the pre-service science teachers had 9 alternative conceptions related to thermochemistry and these alternative conceptions were classified under the subheadings of "Reaction enthalpy, endothermic reactions, exothermic reactions, bond energy and Hess's Law". In addition, the alternative conception "*The energy stored in chemical bonds is released by reactions"* had the highest percentage in this research.

Q1, Q4, Q7, Q8, Q10, Q11, Q12, Q14, Q16, Q18 and Q38 related to chemical kinetics in the two-tier diagnostic test (Table 5).

Table 5. Percentages of the pre-service science teachers' correct answers for chemical kinetics-related items.

	Percentages of correct answers			
Item	Educational objectives of item	First tier	Second tier	Both Tier
Q1	Be able to explain the reaction rate.	63	62	27
Q4	Be able to interpret effect of concentration on the reaction rate.	60	60	38

Percentages of correct answers				
Item	Educational objectives of item	First tier	Second tier	Both Tier
Q7	Be able to explain effect of temperature on the reaction constant.	60	40	39
Q8	Be able to explain effect of surface area on the reaction rate.	72	72	67
Q10	Be able to interpret effect of catalyst on the reaction rate.	60	51	44
Q11	Be able to interpret effect of catalyst on the reaction rate.	37	30	5
Q12	Be able to compare values of reaction constants in multiple-step reactions.	46	32	30
Q14	Be able to compare effect of temperature on endothermic and exothermic reactions' rate.	40	44	31
Q16	Be able to interpret effective collisions.	56	47	29
Q18	Be able to compare effect of temperature on endothermic and exothermic reactions' rate	32	30	27
Q38	Be able to explain effect of surface area on the reaction rate.	75	66	45

The results showed that the first tier of Q38 had the highest percentage as a correct answer. According to the findings, generally, the first tiers were correctly answered in higher percentages by the pre-service science teachers, but the percentage of correct answers to the second tiers and both tiers decreased. These alternative conceptions related to chemical kinetics obtained from the two-tier diagnostic test were presented in Table 6.

According to the finding, the pre-service science teachers had 18 alternative conceptions related to reaction rate, concentration effect, temperature effect, catalyst effect, surface area effect, collision theory, reaction mechanism and reaction rate constant.

Table 6. Alternative conceptions related to chemical kinetics.

Category	Alternative conceptions	Percentages
Reaction rate	The reaction rate indicates how much time a reaction takes to complete.	25
	Reaction rate is a process of conversion from reactants to products.	23
Concentration effect	As reactants concentration increases, the reaction duration increases.	26
	As concentration increases, the number of particles in per unit volume also increases; as a result particles' motion area decreases and their collision becomes difficult.	25
Temperature effect	The effect of temperature on reaction rate is an enhancer line in endothermic reactions and in a detractive line in exothermic reactions.	58
	When temperature increases the reaction rate increases very much in endothermic reactions but in exothermic reaction it at first increases but later decreases. .	33
Catalyst effect	Catalysts do not affect reaction	32
	Reactants' energy is increased by catalysts.	22
	Catalysts provide more yielding reactions.	29
	Catalysts do not affect reaction rate because they do not run out in reaction.	28
Surface area effect	Powder of a subtance and equal amount of the same substance in crystals complete reaction in the same time because they engage in the same reaction.	23
	When surface area increases, the reaction rate decreases for the same substances' equal amount.	24
Collision theory	Each atom in a molecule should come into a collision with any other atom in the other molecule for an effective collision.	26

Category	Alternative conceptions	Percentages
Reaction mechanism	Reaction rate constants are equal in a reaction which has two-steps and the first step is slow and the second step is fast.	15
	In a reaction, in which the first step is slow and the second one is fast, reaction rate constants on each of step are equal.	40
Reaction rate constant	The slow step's reaction rate constant is high because the reaction rate depends on to the slow step.	38
	When concentration increases, effective collision increases and thus the reaction rate constant increases.	23
	In a reaction, in which reactant and product are in gas phase, the reaction rate constant depends on the reactant concentration.	25

Q27, Q30, Q32, Q34 and Q36 related to chemical equilibrium in the two-tier diagnostic test (Table 7).

According to the findings, generally, the first tiers were correctly answered with more than 40% percentage by the pre-service science teachers, but the percentage of correct answers to the second tier and both tiers decreased. Then alternative conceptions related to chemical equilibrium obtained from the two-tier diagnostic test were presented in Table 8.

According to the findings, the pre-service science teachers had 7 alternative conceptions related to Le Chatelier Principle, temperature effect, concentration effect and equilibrium constant. *"If making an effect to a reaction is at equilibrium and has stable temperature, equilibrium is established by concentration of products and reactants are equalled". It had the* highest percentage as an alternative conception (32%).

Table 7. Percentages of the pre-service science teachers' correct answers for chemical equilibrium-related items.

		Percentages of correct answers		
Item	Educational objectives of items	First tier	Second tier	Both tier
Q27	Be able to explain Le Chatelier Principle.	72	36	19
Q30	Be able to explain equilibrium dynamics on a reaction.	41	34	11
Q32	Be able to explain effect of temperature on equilibrium.	63	50	39
Q34	Be able to explain effect of temperature on equilibrium.	59	31	24
Q36	Be able to explain effect of concentration on equilibrium.	42	32	17

Table 8. Alternative conceptions related to chemical equilibrium.

Category	Alternative conceptions	Percentages
Le Chatelier Principle	If making an effect to a reaction is at equilibrium and has stable temperature, equilibrium is established by concentration of products and reactants are equalled.	32
Temperature effect	When temperature increases, concentration of reactants increases but concentration of products decreases in endothermic reactions.	22
	If temperature increases, the reaction will always favour the product.	27
Equilibrium constant	When temperature decreases, equilibrium constant increases in endothermic reactions.	23
	Temperature does not affect equilibrium constant.	28
Concentration effect	If a substance is added to products which are on at the stable temperature, reaction will not change.	26
	If a substance is added to products which are on stable a temperature, reaction will favour the products.	31

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Q2, Q5, Q9, Q13, Q17, Q19, Q20, Q21, Q23, Q25, Q28, Q29, Q31, Q37, Q42 and Q43 related to acids and bases in the two-tier diagnostic test.

According to the finding, the pre-service science teachers gave correct answer in higher percentages to Q9, Q13, Q17, Q21, Q25, Q28, Q31, Q37, Q42, Q43; the percentages of correct answers given to those items' second tiers and both tiers decreased (Table 9). Moreover, the first tier of Q38 had the highest percentage as a correct answer. Also, alternative conceptions related to acids and bases were identified and these alternative conceptions were classified under the subheadings of "strength of acids and bases, pH, neutralization, titration, indicator, buffers, acid-base equilibrium and equivalence point". The pre-service science teachers had 33 alternative conceptions and the alternative conception about pH had the highest percentage (Table 10).

Table 9. Percentages of the pre-service science teachers' correct answers for acids and bases-related items.

Percentages of correct answers				
Item	**Educational objectives of items**	**First tier**	**Second tier**	**Both tier**
Q2	Be able to explain properties of end point.	60	60	47
Q5	Be able to explain titration.	59	62	22
Q9	Be able to interpret buffers mechanism	46	30	27
Q13	Be able to explain pH.	50	34	30
Q17	Be able to interpret neutralization.	73	63	59
Q19	Be able to explain strength of acids and bases.	30	32	19
Q20	Be able to interpret neutralization.	30	32	9
Q21	Be able to describe buffers.	63	27	21
Q23	Be able to explain indicators and principles of their use.	30	33	10
Q25	Be able to explain properties of equivalence point	46	30	25
Q28	Be able to interpret acid-base equilibrium.	37	36	21
Q29	Be able to compare end point and equivalence point.	46	46	37
Q31	Be able to explain titration.	59	57	52
Q37	Be able to interpret buffers mechanism	32	31	22
Q42	Be able to choose best indicator for titration.	45	32	7
Q43	Be able to explain strength of acids and bases.	55	41	21

Table 10. Alternative conceptions related to acids and bases.

Category	Alternative conceptions	Percentages
Buffers	If acid/base is added to buffer, solution pH will be fixed at 7.	37
	If acid/base is added to buffer, pH doesn't change because the buffers show fully resistance to pH change.	22
	If little amount of strong base is added to buffer, strong base and base component of buffer will combine and pH will be close to 14.	44
	If little amount of strong base is added to buffer, base component of buffer will be proton receiver.	23
	If acid/base is added to buffer, pH will be fixed at 7 because buffers neutralize to acid and base.	36
	To prepare a buffer, strength of acid or base is not important. Its combination with salt is enough.	21
	Acid and its conjugate base should neutralize each other in buffers.	44

Category	Alternative conceptions	Percentages
Acid-base equilibrium	If base is added to acid solution at equilibrium, the reaction will favour the side the products.	35
	If base is added to acid solution at equilibrium, the reaction equilibrium will not change.	28
Indicator	Indicators increase rate of reaction.	24
	Indicators decrease rate of reaction.	35
	Indicators provide an alternative way for the reaction to happen which has a lower activation energy.	28
Equivalence point	pH is always 7 at the equivalence point.	39
	Solutions are always neutral at the equivalence point.	32
	Weak acids and weak bases do not reach to the equivalence point because they are partially ionized.	23
Strength of acids and bases	If pH decreases, strength of acids will increase.	36
	Strength of acids is determined by pH meter.	49
	pH of strong bases is close to 14.	32
	Ranking of strength of acids is follow respectively HF >HCl>HBr> HI.	45
	Electronegativity of atom X increases, it will attract to bond electrons very much and H will move away from the molecule very easily inside the acid in form of HX.	28
	Electronegativity of atom X increases, it will attract H to itself very much and H will move away from the molecule very hardly in the acid in form of HX.	30
	If pH is close to 1, strength of acids will increase.	46
pH	pH is a measure of strength of acidity.	50
Neutralization	If equal amount acid and base react, pH is always 7.	26
	Acids always form water by giving their H to OH of base.	30
	If acid solution at equal volume and concentration is added to base solution, salt and water are always formed.	46
	If acid solution and base solution are mixed, pH is always 7.	21
	Neutralization reaction does not occur between weak acids and weak bases	25
Titration	pH is 7 at equivalent point in the titration of strong base and weak acid.	23
	Weak acids/weak bases cannot be titrated.	28
	Titration depends on only neutralization of acid and bases, indicator is not important in the titration.	23
	Neutral salt is formed at the equivalent point in the titration of strong base and weak acid.	22
	Weak bases cannot be titrated with weak acids.	29

In the two-tier diagnostic test, Q3, Q22, Q26, Q33, Q39, Q40 related to electrochemistry. The results showed that, the first tier of Q40 had the highest percentage as a correct answer (Table 11). According to findings, the percentage of the first tier was greater than the percentage of the second tier on only for Q39. In all of the other items, the pre-service science teachers were correctly answered with more than 50% percentage, the percentage of correct answers to those items' second tiers and the both tiers decreased.

In addition to these findings, the pre-service science teachers had 9 alternative conceptions related to anode-cathode, metal electrodes, galvanization, platting and cell potential and alternative conception about determining of anode place had the highest percentage (Table 12).

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Table 11. Percentage of the pre-service science teachers' correct answers for electrochemistry-related items.

Item	Educational objectives of items	Percentages of correct answers: First tier	Second tier	Both tier
Q3	Be able to explain effect of concentration on cell potential.	72	62	35
Q22	Be able to explain metal electrodes.	61	51	43
Q26	Be able to explain plating and galvanization.	74	32	26
Q33	Be able to explain plating and galvanization.	67	59	45
Q39	Be able to determine anode and cathode according to several variables	47	63	43
Q40	Be able to determine anode and cathode according to several variables	77	66	59

Table 12. Alternative conceptions related electrochemistry.

Category	Alternative conceptions	Percentages
Anode -cathode	Determining of anode in electrochemical cell depends on amount of anode.	53
Metal electrodes	If metals' activity is high, their reduction potential is high but their oxidation potential is low.	32
	High reactive metals reduce, low reactive metals oxidize.	36
Galvanization	Galvanization depends on principle of voltaic cell.	26
	In galvanization, it must be energized for reduction of iron electrode at anode and oxidation of zinc electrode at cathode at.	30
	In galvanization, during the process of reducing reduction of iron electrode at cathode and oxidation of zinc electrode at anode energy releases.	21
Plating	In the process of covering of a copper plate with tin of which oxidation potential greater than copper, tin is positive and copper is negative pole.	33
Cell potential	Cell potential depends on concentration because ion concentration and speed of electron motion increase when electrolyte concentration increases.	22
	The potential of an electrochemical cell potential is independent from concentration of electrolyte in half cell.	28

Discussion

The present research aimed at investigating the pre-service science teachers' understanding of chemical concepts related to thermochemistry, chemical kinetics, chemical equilibrium, acids and bases and electrochemistry topics. According to the results related to thermochemistry, the first tier of Q15, which examined the conservation of energy, had the highest percentage as a correct answer. It means that the pre-service science teachers had the best understanding related to conservation of energy. Moreover, generally, the first tiers were correctly answered with more than 50% percentage by the pre-service science teachers, but the percentage of correct answers to the second tiers decreased. This situation underlined that the pre-service science teachers had content knowledge, but they could not interpret their justifications for their responses. Moreover, both tiers of Q44 in which the pre-service science teachers were steered to interpret reaction enthalpy based on given reaction had the smallest percentage as a correct answer (%11).This situation showed that the pre-service science teachers had the worst understanding in reaction enthalpy. Reaction enthalpy is a complex topic for learning and understanding because it includes complex concepts and formulas. Many researchers indicated that students and undergraduates have many learning difficulties in this subject (Nilsson & Niedderer, 2014; Sozbilir, 2004; Sreenivasulu & Subramaniam, 2013). Also, the pre-service science teachers had 9 alternative conceptions and these alternative conceptions were classified under the subheadings of "Reaction enthalpy, endothermic reactions, exothermic reactions, bond energy and Hess Law". According to Cohen and Ben-Zvi (1992), students' understanding of thermal phenomena has been an important subject in the science education literature and alternative conceptions can develop because of large number of abstract concepts involved. However, there has been a lack of research related to thermochemistry and understanding of thermochemistry topics was investigated as a subheading of thermodynamic topics in the previous studies. The obtained results in this research indicated that the pre-service science teachers had some alternative conceptions related to thermochemistry and many studies illustrated that students had difficulties in understanding of energy of chemical reactions (Ayyildiz & Tarhan, 2012; Ebenezer & Fraser, 2001; Tastan, Yalcinkaya & Boz, 2008), bond energy (Boo & Watson, 2001; Teichert & Stacy, 2002; Yalcinkaya, Tastan & Boz, 2009), calorimeter (Greenbowe & Meltzer, 2003; Yalcinkaya, Tastan & Boz, 2009), reaction enthalpy (Nilsson & Niedderer, 2014; Sozbilir, 2004; Sreenivasulu & Subramaniam, 2013), conversation of energy (Tatar & Oktay, 2007), exothermic and endothermic reactions (Sreenivasulu & Subramaniam, 2013; Turk & Calik, 2008; Yalcinkaya, Tastan & Boz, 2009) and their finding was coherent with our results. In addition to this, the alternative conception of *"The energy stored in chemical bond is released by reactions"* had the highest percentage in this research. This alternative conception showed that the pre-service science teachers might have confused stored energy with bond breaking energy. Similar alternative conceptions about bond formation, bond breaking and stored energy in bonds were also found in the previous studies (Boo, 1998; Boo & Watson, 2001; Ross, 1993; Teichert & Stacy, 2002; Yalcinkaya, Tastan & Boz, 2009).

Based on the findings related to chemical kinetics, it was found that although the pre-service science teachers correctly answered the first tiers in higher percentages, but the percentage of correct answers to the second tier decreased. These results showed that although the pre-service science teachers had chemical kinetics content knowledge, they had difficulties to interpret a reason for their responses. Moreover, the first and the second tiers of Q8, which related to effect of surface area on reaction rate, had the highest percentage correct (67%). It means that the pre-service science teachers had the best understanding related to effect of surface area on reaction rate. Moreover, both tiers of Q11 in which the pre-service science teachers were required to explain catalyst based on given reaction had the smallest percentage as a correct answer (%5). This situation showed that the pre-service science teachers had the worst understanding about catalyst effect. It was also found out that the pre-service science teachers had 18 alternative conceptions related to reaction rate, concentration effect, temperature effect, catalyst effect, surface area effect, collision theory, reaction mechanism and reaction rate constant. One of these conceptions was "*The effect of temperature on reaction rate in an enhancer line in endothermic reactions and in a detractive line in exothermic reactions"* and its percentage was the highest one (58%). According to Hackling & Garnett (as cited in Karsli & Ayas, 2013, p.302), this alternative conception may be a result confusing of reaction rate with chemical equilibrium laws. In the literature, many alternative conceptions related to temperature effect on reaction rate were reported by Bektasli & Cakmakci (2011), Cakmakci et al. (2006), Calik et al. (2010), Karsli & Ayas (2013), Kolomuc (2009), Kolomuc & Tekin (2011), Nakiboglu et al. (2002), Van Driel, (2002). Chemical kinetics is a central part of chemistry. It is one of the hardest topics for teachers and students in terms of teaching and learning (Justi, 2002). For this reason, alternative conceptions about chemical kinetics have been important place in the literature (Bektasli & Cakmakcı, 2011; Cakmakci et al., 2006; Calik et al., 2010; Justi, 2002; Karsli & Ayas, 2013; Kaya, Geban, 2012; Kolomuc, 2009; Kolomuc & Tekin, 2011; Nakiboglu et al., 2002, Sozbilir et al., 2010; Tastan et al. 2010; Turányi & Tóth, 2013; Van Driel, 2002) as it is our research.

Based on the finding obtained from the two-tier diagnostic test items related to chemical equilibrium, generally, the first tiers were correctly answered with more than 40% percentage by the pre-service science teachers, but the percentage of correct answers to the second tiers decreased. This situation showed that the pre-service science teachers had content knowledge about related to chemical equilibrium topic, but they could not interpret their justifications for their responses. Also, both tiers of Q30 in which the pre-service science teachers were steered to interpret equilibrium dynamic based on given reaction had the smallest percentage as a correct answer (%11). This result showed that the pre-service science teachers had the worst understanding about equilibrium dynamic. Moreover, it was found that the pre-service science teachers had 8 alternative conceptions about Le Chatelier Principle, temperature effect, concentration effect and equilibrium constant. Although the pre-service science teachers had the best understanding about *"If making an effect to a reaction is at an equilibrium and has stable temperature, equilibrium is established again"* (72%), they had alternative conception of *"If making an effect to a reaction is at an equilibrium and has stable temperature, experience a change, equilibrium is established by concentration of products and reactants is equalled"* and it had the highest percentage (32%). It means that the pre-service science teachers did not know how equilibrium had been established. This situation showed that the pre-service science teachers had learning difficulties about equilibrium dynamic and Le Chatelier Principle so they interpreted it as equalling concentration of products and reactants. According to Russo & Silver (2006) this alternative conception is a result of explaining when the rates of forward and reverse reactions become equal, dynamic equilibrium is established, and there are no further changes in concentrations and students interpret this as a concentration of reactants and products become equal at equilibrium (Ozmen, 2008). In the previous research, similar alternative conceptions were reported related to Le Chatelier Principle as it is our research (Ozmen, 2007; Solomonidou & Stavridou, 2001). Chemical equilibrium is an important subject because of its essential role in learning and understanding of other areas of chemistry (Voska & Heikkinen, 2000). There have been numerous studies focused on the students' understanding of chemical equilibrium subject matter in different age groups (Bergquist & Heikkinen, 1990; Bilgin & Geban, 2001; Cam & Geban, 2013; Cetin- Dindar, Bektas & Celik, 2010; Cheung, Ma & Yang, 2009; Chiu, Chou & Liu, 2002; Huddle & Pillay, 1996; Kousathana & Tsaparlis, 2002; Ozmen, 2007, 2008; Pedrosa & Dias, 2000; Piquette & Heikkinen, 2005; Ouilez, 2004; Quilez-Pardo & Solaz-Portoles, 1995; Solomonidou & Stavridou, 2001; Thomas & Schwenz, 1998; Turányi & Tóth, 2013; Tyson et al, 1999; Van Driel, 2002; Voska & Heikkinen, 2000) it is also coherent with our research.

18 items of the two tier diagnostic test were about acids-bases topic and the pre-service science teachers were correctly answered 10 of them in higher percentage. However, percentage of correct answers to those items' second tiers was decreased. It means that although the pre-service science teachers had content knowledge about acids-bases, but they had difficulties to interpret their responses' reason for these items. Also, the first tier of Q38 had the highest percentage as a correct answer. This tier related to neutralization of strong acids and strong bases and the results underlined that the pre-service science teachers had the best understanding in this subject. Moreover, both tiers of Q42 in which the pre-service science teachers were required to choose indicator based on given reaction had the smallest percentage as a correct answer (%7). This situation showed that the pre-service science teachers had the worst understanding about choosing indicator. Furthermore, alternative conceptions related to acids and bases were identified and these alternative conceptions were classified under the subheadings of "strength of acids and bases, pH, neutralization, titration, indicator, buffers, acid-base equilibrium and equivalence point". The pre-service science teachers had 33 alternative conceptions and *"pH is a measure of strength of acidity"* had the highest percentage (50%). This alternative conception was common and the students mostly described the pH concept as the strength of an acid/base or the amount of acid/base as mentioned by researchers (Acar-Sesen & Tarhan, 2011; Demircioglu, Ayas & Demircioglu, 2005; Ross & Munby, 1991; Sheppard, 2006) and these finding were coherent with our findings. Acid and bases are important concepts from primary to undergraduate education. This topic make students understand a lot of chemistry subject such as nature of matter, stoichiometry, solutions, chemical reactions, chemical equilibrium and electrochemistry (Acar-Sesen & Tarhan, 2011). However, acids-bases subjects are abstract and hard topics for students (Demircioglu, Ayas & Demircioglu, 2005; Sisovic & Bejovic, 2000). For this reason, many researchers have focused understanding of these concepts (e.g. Acar, 2008; Acar Sesen & Tarhan, 2010, 2011; Aggul-Yalcin, 2001; Artdej et al., 2010; Botton, 1995; Boz, 2009; Bradley & Mosimege, 1998; Cetin-Dindar, Bektas & Celik, 2010; Cokelez, 2010; Demircioglu, 2003; Demircioglu et al, 2004; Demircioglu, Ozmen & Ayas, 2001; Dhindsa, 2002; Drechsler & Van Driel, 2009; Kariper, 2011; Kousathana, Demerouti & Tsaparlis, 2005; McClary & Bretz, 2012; Muchtar- Harizal, 2012; Nakhleh & Krajcik, 1994; Orgill & Sutherland, 2008; Ross & Munby, 1991; Schmidt, 1991; Sheppard, 2006; Sisovic & Bojovic, 2000; Tan et al., 2010; Tarhan & Acar Sesen, 2012, 2013; Toplis, 1998) and they have identified similar alternative conceptions in this research.

In the two-tier diagnostic test, 6 items related to electrochemistry. Based on the findings, the first tier of Q40 had the highest percentage as a correct answer. This result showed that the pre-service science teachers had the best understanding about charge of anode and cathode. Also, the pre-service science teachers gave correct answers to the items with more than 50% percentage except Q39, but the percentage of correct answers to those items' the second tiers decreased. It was interpreted that although the pre-service science teachers had content knowledge, they had difficulties to interpret reason of their responses. Moreover, both tiers of Q26 about galvanization of iron and copper had the smallest percentage as a correct answer (%26). This situation showed that the pre-service science teachers had the worst understanding about galvanization. Furthermore, the pre-service science teachers had 9 alternative conceptions related to anode-cathode, metal electrodes, galvanization, platting and cell potential. There are many researches about understanding these subjects from different education levels (e.g. Acar-Sesen & Tarhan, 2007; Ahtee, Asunta & Palm, 2002; Aydeniz & Kirbulut, 2011; Cetin-Dindar, Bektas & Celik, 2010; Ekiz et al., 2011; Garnett & Treagust, 1992a, 1992b; Gedik, Ertepinar, & Geban, 2002; Karsli & Ayas, 2013; Lin, Yang, Chiu, & Chou, 2002; Mamlok-Naaman et al., 2003; Niaz, 2002; Niaz & Chacon, 2003; Ozkaya, 2002; Sanger & Greenbowe, 1997a, 1997b, 1999; Rahayu et al., 2011; Sia, 2010; Sia, Tragust & Chandrasegaran, 2012; Tarhan & Acar, 2007; Tasdelen, 2011; Thompson & Soyibo, 2002; Yang, Andre & Greenbowe, 2003; Yilmaz, Erdem, & Morgil, 2002; Yuruk & Geban, 2001). In the present research, the alternative conception of "*Determining of anode in electrochemical cell depends on amount of anode*" was identified and this alternative conception was also similar to the conception reported in the literature. Many researchers underlined that students have difficulties about determining the nature of anodes and cathodes, identifying anodes and cathodes and their functions (Acar-Sesen & Tarhan, 2007; Garnett & Treagust, 1992a, 1992b; Sanger & Greenbowe, 1997a; Tarhan & Acar, 2007; Yilmaz et al., 2002) since textbooks are sources of alternative conceptions and errors in electrochemistry (Sanger & Greenbowe, 1999), most students just memorize these subjects from textbooks without doing any experiments so they cannot associate with between anode-cathode and reactivity of metals (Karsli, 2011; Karsli & Ayas, 2013; Karsli & Calik, 2012; Yilmaz et al., 2002).

Conclusion

In the present research, it was found that pre-service science teachers have many alternative conceptions on chemistry concepts. The results of this research underlined that, although the pre-service science teachers learned the aforementioned chemistry concepts from primary school to undergraduate level, they could not construct correct conceptions by using their existing knowledge.

In conclusion, identifying alternative conceptions is very important, because students' prior knowledge is the most effective factor for their learning (Ausubel, 1968). Assessing the pre-service science teachers' conceptions by means of a diagnostic tool is inevitable to succeed in overcoming the alternative conceptions. For these reasons, diagnosing the pre-service teachers' alternative conceptions with alternative assessment methods like a two tier diagnostic test makes a major contribution to the literature. Also, alternative conceptions which were determined in this research will be guide researchers, instructors and science educators. Furthermore, two-tier diagnostic test which was developed in this research will make major contributions for future research and it will provide with opportunities to educators and teachers to assess pre-service teachers' alternative conceptions and understanding of the target concepts. Researchers can use all test or the sub-topics included in two-tier diagnostic test independently of each other, and they can also use as pre-test and post-test for evaluating of effect of different learning environments on students' achievement and conceptual understanding.

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