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What are the Pre-service Chemistry Teachers' Explanations on Chemistry Topics?

Ayla Ç. DİNDAR, Oktay BEKTAŞ & Ayşe Y. ÇELİK
Middle East Technical University & Gazi University, TURKEY

Abstract: Many students at all levels have difficulties in understanding chemistry. Students' constructions of a chemical concept sometimes differ from scientific explanations since they construct their own concepts. Therefore, the purpose of this study was to find out the pre-service chemistry teachers' explanations regarding chemistry topics which are matter and particles, gases, solutions, vapor pressure and boiling point, chemical equilibrium, acids and bases, and electrochemistry. One-to-one semi-structured interviews were administered to a sample of six participants enrolled in the Department of Secondary Science and Mathematics Education at a university in Ankara. During the interviews, participants were questioned to determine their conceptual understanding aforementioned chemistry topics. Coding was made and five main (correct explanation, partially correct explanation, incorrect explanation without misconceptions, incorrect explanation with misconceptions, and no answer) categories were formed to analyze the data. Analysis of the transcribed interviews showed that the majority of the participants explained their ideas as incorrect and hold some misconceptions on aforementioned topics. In order to overcome these misconceptions it is crucial to diagnose and alternative views of them should be discussed in the class via implementing different teaching strategies and methods such as conceptual change, argumentation, and problem based learning.

Keywords: pre-service chemistry teachers, misconception, chemistry concepts

Introduction

In science education, students' alternative conceptions contradictory to scientific knowledge have been variously called misconceptions, prior conceptions, preconceptions, pre-instructional beliefs, alternative frameworks, naive theories, intuitive ideas, untutored beliefs, or children's science in recent years (Griffiths & Preston, 1992; Harrison & Treagust, 1996; Nakhleh, 1992; Nakhleh, 1999; Haidar & Abraham, 1991). In this study, misconceptions term is used. There have been many studies on students' understanding of chemistry conceptions in recent years and these studies reveal that students had some difficulties in understanding of chemistry concepts (Akkuş, Kadayıfçı, Atasoy & Geban, 2003; Canpolat, Pinarbasi, & Sozbilir, 2006; Gomez, Benarroch & Marin, 2006; Sanger & Greenbowe, 1999; Schmidt, 1995).

It is important to determine the conceptions of pre-service chemistry teachers and how they interpret chemistry concepts since they will teach chemistry to future generations their understandings of chemistry take a crucial role; therefore, if they are well educated in the subject of chemistry, then it will be helpful for their students. In the literature, the studies revealed that pre-service chemistry teachers did not understand chemistry concepts very well (Aydemir, Bektaş, Çetin-Dindar, Aydın, & Boz, 2008; Bektas, Cetin-Dindar, & Yalcin-Celik, 2009; Canpolat, Pinarbasi, & Sozbilir, 2006). Some of them are summarized below:

Aydemir et al., (2008) studied with pre-service chemistry teachers in order to determine the pre-service chemistry teachers' understanding of particulate nature of matter. They coded the answers of their participants under the four categories which are correct answers, partially correct answers, incorrect answers, and no answers. Their results showed that pre-service chemistry teachers had misconceptions regarding the particulate nature of matter and were classified under the category of incorrect answers.

Taber (2008) developed an interview questionnaire to explore the extent of conceptual integration in students studying chemistry and physics in the college. Questions regarding mechanics, electricity, chemical reactions, physical changes, and bonding were used in his study. He used in-depth case study in his study and four volunteered students (two females and two males) took part in his case study. He examined the cases under the titles which were forces, force and motion, interactions between charges, energy, and particle models. In the light of his results, Taber concluded that these students had some difficulties in the integration of these concepts.

Bektas et al., (2009) aimed to understand whether the pre-service chemistry teachers achieve the conceptual integration across the some chemistry topics (solubility, acids and bases, atomic models, chemical change, and chemical equilibrium) and between physics, chemistry, and biology concepts during a semester. The analysis of data showed that the participants had some difficulties when they integrate aforementioned chemistry concepts either to the other chemistry topics, to physics, or biology concepts.

Cetin-Dindar, Bektas, Aydın, Aydemir, & Boz (2008) searched the pre-service chemistry teachers' ideas regarding evaporation, boiling, and vapor pressure. The participants were classified under the four categories based on the data analysis. The researchers stated that the pre-service chemistry teachers had some wrong explanations about the aforementioned concepts. Therefore, they coded their participants under the category of incorrect answers.

Ausubel (1968) stated that the new knowledge should be related with the students' prior knowledge for the meaningful learning. Thus, if teachers know about the pre-knowledge of their students, then this can be important for the meaningful learning. At this point, science educators have understood the importance of exploring the students' existing ideas to inform teaching in recent years (Taber, 2003). Hence, the focus of this research was to investigate the pre-service chemistry teachers' explanations regarding chemistry topics which were matter and particles, gases, solutions, vapor pressure and boiling point, chemical equilibrium, acids and bases, and electrochemistry. The research question of this study is presented below:

1- What are the pre-service chemistry teachers' explanations regarding chemistry topics which are matter and particles, gases, solutions, vapor pressure and boiling point, chemical equilibrium, acids and bases, and electrochemistry?

2- Method

2.1 Sample

Semi structured interviews were administered to a sample of six pre-service chemistry teachers (4 females and 2 males) enrolled in the course of Basic Chemistry Laboratory at a university in Ankara. All the participants volunteered to be interviewed. These students were selected according to their academic achievement (2 lower achiever students, 2 middle achiever students, and 2 higher achiever students). These students theoretically took basic chemistry, basic biology, and basic physics while they are studying at this laboratory session. Each interview was audio typed. The interviews were transcribed by the researchers.

2.2 Interview Process

The interviews took place in a comfortable private location. Each interview was audio taped with the students' awareness and permission. The interviews began with the explanation of the purpose of the study and the collection of some personal data (such as which courses they took) and they were all transcribed for further analysis. It was envisaged that the interview process should be completed within a one-hour time frame.

In order to form interview questions, literature review was made and some concepts and subjects were determined by researchers. Most questions were taken directly or adapted from the related literature (Bektas, 2003; Canpolat, Pinarbasi & Sözbilir, 2006; Novick and Nussbaum, 1981; Powers, 2000; Schmidt, Marohn, and Harrison, 2006) whereas some were developed by the researchers. These questions were piloted with a group of eight pre-service chemistry teachers in the previous semester. For the content validity, the objectives of questions were written and the table of specification was composed. Finally, these questions were examined by five experts in science education. The interview questions were related to matter and particles, gases, solutions, vapor pressure and boiling point, chemical equilibrium, acids and bases, and electrochemistry. The questions are given in the Appendix.

3- Results and Interpretation

Coding was made and categories were formed in order to analyze the data. Five main categories were formed, which were correct explanation, partially correct explanation, incorrect explanation without misconceptions, incorrect explanation with misconceptions, and no answer. Analysis of the transcribed interviews showed that the majority of the participants explained their ideas as incorrect and hold some misconceptions on aforementioned topics.

3.1 Matter and particles

Four pre-service chemistry teachers defined the matter as everything that has mass and volume. They did not think about that a matter has particles, takes up spaces, and is mobile. Thus, these students were classified in "partially correct explanation" category. All students stated that just an atom is a particle. Therefore, a molecule and an ion are not particles for these participants. Half of the interviewees made the correct definition about an element, a compound, and mixtures; but the rest of them gave only examples regarding them. The analyses of the data also reveal that the pre-service chemistry teachers had some misconceptions regarding physical and chemical changes. For instance, they explicated that chemical changes are related with the nucleus of an atom, but physical changes are related with the number of orbit in an atom. In addition, they stated that while chemical changes are irreversible, physical changes are reversible. Table 1 shows the classification of pre-service teachers in terms of explanations for matter.

Table 1: The classification of pre-service teachers in terms of explanations for matter

Coding	Matter
Correct explanation	• In chemical reactions, the numbers of electrons changes (2 participants) • True definition for the elements and compounds (3 participants) • Giving correct examples regarding physical and chemical change (all participants)
Partially correct explanation	• Everything that has mass and volume is a matter (4 participants) • Particles of a matter are only atoms (5 participants) • Matter has the particulate nature since there are some spaces between particles (1 participant-there is not enough explanation in terms of a reason-result relation)
Incorrect explanation without misconceptions	• Matter is a smallest unit of inanimate structures (1 participant) • There is no exact definition about pure matter and mixtures, but there are some examples about them (2 participants) • Mixtures can be classified as pure and impure mixtures. Pure mixtures also can be classified homogeneous and heterogeneous (1 participant) • During the chemical change, particles in the inner structure of matter can be damaged (4 participants)
Incorrect explanation with misconceptions	• Physical changes are reversible, but chemical changes are irreversible (5 participants) • Physical changes relate with the number of orbit in an atom (1 participant)
No answer	• Definition of pure matter (1 participant) • The relationship between chemical change and particle-atom (1 participant)

3.2 Gases

In terms of question 3, five pre-service chemistry teachers gave the correct explanation and they thought that gases homogeneously distribute in the closed container. However, when the researcher asked them to draw a figure representing the distribution, some participants made wrong drawings about the distribution. One pre-service teacher explained that all particles that were in the bottom of the flask traveled into the balloon. The other of two participants thought that when particles (atoms) are heated, they expand. Therefore, these three students had misconceptions on this topic.

3.3 Solutions

All students made the correct explanation regarding the solubility of salt and sugar. They stated that salt dissolves in water as ionic and sugar dissolves in water as molecular. However, when researchers asked them to draw the figure of sugar-water solution, they could not draw the correct figures considering particles. Three students stated that pressure and temperature affect the solubility of gases in liquids, but they could not explain why pressure and temperature affect the solubility, which expressed that they had some misconceptions about this topic. For instance, one student said that dissolution was the same thing with melting. Another student stated that as the temperature is increased, gases usually became more soluble in liquids. Also, the other participant stated that as the pressure is increased, gases usually became less soluble in liquids. Table 2 shows the classification of pre-service chemistry teachers in terms of explanations for solubility.

Table 2: The classification of pre-service teachers in terms of explanations for solubility

Coding	Solutions
Correct explanation	• The dissociation of salt in water is ionic and the dissociation of sugar in water is molecular (all participants)
Partially correct explanation	• Solubility is the homogenous distribution of two matters (an explanation only at macroscopic level)-(4 participants) • Temperature affects the solubility of gases in liquids, but how temperature affects the solubility are not explained (3 participants)
Incorrect explanation without misconceptions	• Temperature affects the solubility of gases in liquids since the volatility of the gases increases (2 participants).
Incorrect explanation with misconceptions	• Dissolution is the same with melting (1 participant) • As the temperature is increased, gases usually become more soluble in liquids (1 participant) • As the pressure is increased, gases usually become less soluble in liquids (1 participant)
No answer	• There is no drawing on molecular dissolution (3 participants) • There is no explanation about the “bonds” (4 participants)

3.4 Vapor pressure and boiling point

Three pre-service chemistry teachers had partially correct explanation regarding the definition of evaporation and vapor pressure. They defined that evaporation occurs on the surface of liquid since the particles of matter increase their rate. They also defined that vapor pressure was the pressure that when the matter evaporated. On the other hand, four pre-service teachers had incorrect explanation without misconceptions regarding the definition of boiling. For the question 9, two pre-service teachers made correct explanations and said that the shape of the container and the volume of the container did not affect the vapor pressure of liquid. However, the other four pre-service teachers had misconceptions regarding this question and they stated that the vapor pressure of liquid, which was in bigger volume container, is larger than smaller ones.

3.5 Chemical Equilibrium

All pre-service chemistry teachers explained that they understand there was a chemical equilibrium when they see the double arrow in a reaction equation. However, they did not give any answer regarding the dynamic equilibrium or physical equilibrium. Thus, they did not completely understand the meaning of the equilibrium concept. They had misconceptions regarding for the question 11-d. Three pre-service teachers thought that the reactants occur from the products when enough amount of energy was given to the reaction. In conclusion, they had some misconceptions regarding this topic and lack of knowledge since they did not give any answer to some questions.

3.6 Acids and bases

All pre-service chemistry teachers made the Arrhenius acid-base definition for the question 12-a. They did not do any explanation regarding either Bronsted-Lowry or Lewis acid-base definitions. Four pre-service chemistry teachers did the correct explanation regarding the strength of acid-base. Five participants also did correct explanations regarding the question 13 and all pre-service teachers stated that they could understand whether a matter is an acid or a base with the help of a litmus paper. On the other hand, they had some misconceptions regarding the relationship between pH and the strength of the acids. Some students 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.

3.7 Oxidation-reduction reactions

All pre-service chemistry teachers did not give any information about the role of a salt bridge in the voltaic cell. Moreover, one pre-service teacher had a misconception about the role of salt bridge. This participant thought that a salt bridge conducted the electricity since salts conduct the electricity. Although they did partially explanations about anode, cathode, oxidation, and reduction, they did not give any answer about the direction of the flow of electrons in the cell.

4- Conclusion and Recommendations

Misconceptions defined in science education are a reflection of poorly differentiated concepts that have developed naturally rather than through carefully planned instruction, which's reason is confused (Herron, 1996). The reasons may be student originate because of lack of knowledge, inexperience in science education, or naïve thoughts; or may be teacher originate because of inadequacy in content knowledge or pedagogy (Coştu, Ayas, & Ünal, 2007). For this reasons, it is crucial to determine pre-service or in-service teachers' misconceptions or their pedagogical content knowledge.

In this research, the results showed that pre-service chemistry teachers had some misconceptions or difficulties in explaining some chemistry concepts. They also had partial understanding of aforementioned chemistry concepts. The most challenging topic for the pre-service chemistry teachers was one of the basic topics in chemistry which was the particulate nature of matter. When learners have difficulties in such fundamental topics, it is much more difficult for them to understand and illustrate the other subsequent topics meaningfully. The next topics which were more challenging for the pre-service chemistry teachers were chemical equilibrium and acids and bases topics. During the inquiry it was observed that the pre-service chemistry teachers had no difficulties in recognizing and defining the concepts, but they commonly have difficulties in the way to express the background knowledge and explaining the concepts. Even the participants related some topics such as gases, evaporation and boiling point, and solubility into their daily life, they had misconceptions or no ideas about aforementioned topics.

These findings also corroborate with the previous studies (Aydin, Aydemir, Boz, Cetin-Dindar, & Bektas, 2009; Canpolat, Pinarbasi, & Sozbilir, 2006; Powers, 2000). The particulate nature of matter is an important topic in chemistry since it is the basic topic of chemistry and if students do not understand this topic very well, they cannot understand other chemistry topic meaningfully (Bektas, 2003; Gabel, Samuel, & Hunn, 1987). It can be concluded that participants of this study had difficulties in understanding of matter and particles. Hence, they could not explain meaningfully other topics such as gases and electrochemistry because of their inadequate knowledge about particulate nature of matter (Gabel, 1999; Griffiths, & Preston, 1992).

The other finding obtained from this study is that the pre-service chemistry teachers had difficulties in expressing the concepts in terms of sub-microscopic level. Different from other sciences chemistry has three basic levels which are macroscopic, sub-microscopic, and symbolic level (Treagust, Chittleborough, & Mamiala, 2003). These three levels are crucial in learning and teaching chemistry. If the learners could not relate these three levels during the learning process, they can find chemistry more challenging and this may promote learners to hold misconceptions (Teichert, Tien, Anthony, & Rickey, 2008; Treagust et al., 2003). In this study, the pre-service chemistry teachers were asked to draw the related concepts in terms of sub-microscopic level; however, they could not draw the correct representations since they had misconceptions or lack of related knowledge. This study also support the other studies in the literature (Jaansoon, Coll, & Somsook, 2009; Teichert et all, 2008; Mirzaie,Shahmohammadi, & Kouhi, 2010) regarding students hold misconceptions in case of having problems in representing concepts in sub-microscopic level.

There is no relationship between misconceptions and grade level. Researchers are also finding chemical misconceptions in advanced courses. These are called "school made misconceptions" because they are caused by inappropriate teaching methods and materials (Barke, Hazari & Yitbarek, 2009). Thus, there is a need for understanding the pre-service teachers' chemistry conceptions in order to educate well-informed teachers because if the pre-service teachers know about chemistry concepts very well, they can teach their students the concepts in the future.

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Appendix – Interview Questions

Matter and particles:

1- What do you understand the meaning of the matter? How is the nature of matter?

a. If they give true answer, what are the particles of matter?
b. If there is no answer, have you ever heard something about "atom", "molecule", and "ion"?
c. What do these particles form at macroscopic level?
d. If there is no answer, how can we classify the matter?
e. How would you classify the pure matters?
f. From which particles consist of the elements and compounds?

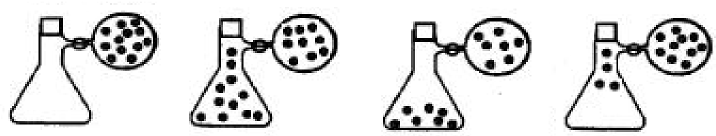
2- What is the physical and chemical change?

a. Which part of an atom, do you think, is responsible for the chemical change?

Gases

3- There is a flask filled with air, attached with a balloon, and closed by a stopper as shown in the figure below. As the flask is heated, the tap is opened. During this process, how will be the distribution of the particles? (Black dots represent air particles).

If there is no answer, which of the following figures explain the distribution?



Solutions

4- Draw the figure of salt-water solution and sugar-water solution via considering particles.

a. If there is no drawing, what is the definition of solubility? How many types of solubility are there? Please explain.

5- What are the factors affecting the solubility? Please explain.

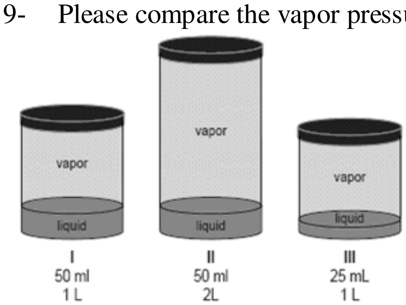
6- How does temperature affect on solubility of gases? Please explain.

Vapor pressure and Boiling point

7- What is the vapor pressure and vaporization? Explain your answer as carefully as you can.

8- What is the boiling? Explain your answer as carefully as you can.

9- Please compare the vapor pressure of three systems at 25^0C. Explain your answer.



Chemical Equilibrium

10- Is there any difference between physical and chemical equilibrium? Please explain.

11- What do you think happens once chemical equilibrium is reached? Explain.

a. If there is no answer, does the reaction stop during the equilibrium?
b. What would you think about the rates of forward and backward reactions?
c. What would you think about the concentrations of matters in the reaction?
d. When do the reactants from products occur?

Acids and bases

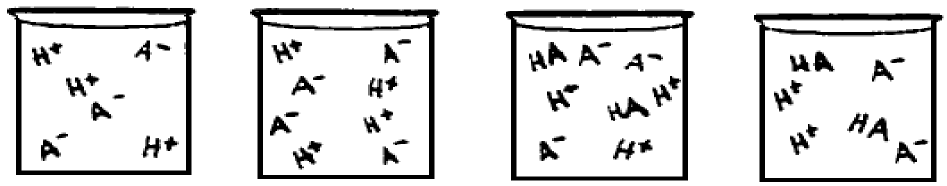
12- What is definition of an acid and a base? Please explain.

a. How many types of definitions of acids and bases are there? Please explain.

13- How would you decide which matter is an acid and which matter is a base?

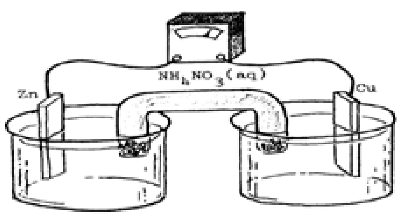
14- Which of the acidic solutions below have the highest pH value? (All solutions have the same volume and HA represents the acidic solution). Explain why?

A) B) C) D)



Oxidation-reduction reactions

15-



$ZnSO_4$ 1M

$CuSO_4$ 1M

Zn/Zn^{2+} = 0,76 V

Cu/Cu^{2+} = -0,34 V

a. What is the purpose of an each piece of an apparatus shown here? (Do the metal strips always react?)
b. How would you determine which electrode is the anode and which is the cathode?
c. How is the current produced in the cell?
d. What is happening in the solutions? What does the salt bridge do?
e. In which direction do the charges (positive and negative) flow in this cell to complete the circuit?
f. What reactions are taking place in each cell? Can you predict the E value for this set-up?