PROSPECTIVE SCIENCE TEACHERS’ CONCEPTIONS OF THE SOLUTION CHEMISTRY

Mustafa Özden

Introduction

Identification and investigation of student misconceptions in chemistry education have been very important for the last two decades. Several researchers in many countries such as Stavy (1988); Peterson and Treaust (1989); Ebenezer and Gaskell (1995); Quiles-Pardo and Solaz-Portolés (1995); Ayas and Demirbaş (1997); Ayas and Coştu (2002); Akın荆州 and Yaşar, (2007); Akpınar, (2007); Ebenezer, (2001); Ebenezer and Gaskell, (1995); Johnson and Scott, (1991); Kabapınar, Leach and Scott, (2004); Kaartinen & Kumpulainen, (2002); Köse (2006); Taylor and Coll, (1997); Lamanauskas, Gedrovics and Raipulis (2004) have been focused on some concepts like dissolution, particulate nature of matter, chemical bonding, reaction rate, acids and bases, electrochemistry, chemical equilibrium and solution chemistry.

Solution chemistry is an important subject in which the students and teachers have common misconceptions in chemistry teaching (Gennaro, 1981; Fensham and Fensham, 1987; Berkheimer and Blakeslee, 1993; Ebenezer and Erickson, 1996; Ebenezer, 2001; Liu, Ebenezer and Fraser, 2002; Pınarbaşı and Canpolat, 2003). Conceptual understanding of solution chemistry is significant since the other subjects in school curriculum depend on this subject. Therefore, identification of misconceptions related to solution chemistry has significant role to overcome misconceptions and develop alternative teaching-learning strategies for better understanding of the concepts. Many researchers investigated conceptual understanding and misconceptions held by students and prospective teachers about solution chemistry. The studies about solution chemistry can be concluded related with different concepts. Dissolution concept (Lee, Eichinger, Anderson, Berkheimer and Blakeslee, 1993; Haidar and Abraham, 1991; Abraham, Gryzybowski, Renner and Marek, 1992, 1994; Longden, Black and Solomon, J, 1991; Ebenezer and Erickson, 1996; Smith and Metz, 1996; Çalış, 2005), the nature of solutions (Fensham and Fensham, 1987; Prieto, Blanco and Rodri-
As can be seen from the literature related to misconceptions about solution chemistry, students and prospective science teachers often have misconceptions about solution chemistry. These misconceptions play negative effects on teaching and learning processes (Lamanauskas et al., 2004; Valanides, 2000; Ebenezer and Fraser, 2002). Especially, if the prospective science teachers have misconceptions, most probably their students may have some difficulties to understand the concepts. For this reason, it is very significant to investigate prospective science teachers’ preconceptions in order to organize teaching and learning activities. The results obtained from this research may provide some keys for science educators and curriculum designers.

This study attempts to focus on the university level for prospective science teachers’ conception of solution chemistry in a wide spectrum with 7 different questions, because if a prospective science teacher does not develop a sound understanding of the concept, their students may not learn much from them. As can be seen from existing literature, there appears to be an absence of what prospective science teachers understand about the subtitles of solution chemistry and this study has tried to fill this gap. The aim of this study was to determine and characterize prospective science teachers’ conception of the concept of solution chemistry and related concepts. The concepts are solubility rate, classification of solutions, boiling point elevation, properties of dissolution, characteristics of the electrical conductivity for solutions and the difference between melting and dissolution. It is very important to learn these concepts for science teachers because they provide prospective teachers a basic vision to explain solution chemistry to the students in a proper way.

Methodology of Research

This study examined prospective science teachers’ understanding of some concepts in solution chemistry. Firstly, fifteen open-ended questions were prepared considering the concepts and misconceptions with respect to literature (Çalık, and Ayas, 2005; Pınarbaşı and Canpolat, 2003; Blanco and Prieto, 1997; Liu and Ebenezer, 2002; Lee, Eichinger, Anderson, Berkheimer and Blakeslee, 1993; Ebenezer and Gaskell, 1995) and solution chemistry course content by the researcher. Previous studies have used many ways of gathering information about students’ misconceptions. Some of them can be considered as drawing (Özden, 2009a; Bahar et al., 2008; Martlew & Connolly, 1996; Prokop & Fančovičová, 2006; Prokop et al., 2007; Tunnicliffe & Reiss, 1999a; Reiss et al., 2002 and Pridmore et al., 1995); lesson preparation task ( Özden, 2008); open-ended questions ( Özden, 2009b; Eisen and Stavy, 1988) and individual interviews about recording pupils’ spontaneous conversations (Tunnicliffe & Reiss, 1999b; Zoldosava & Prokop, 2007).

Open ended questions and individual interviews were used to collect data about prospective science teachers’ misconceptions in this study. Then, numbers of the open-ended questions were reduced to seven in order to determine conceptual learning and misconceptions if there were, because only seven questions directly related to solution chemistry subject matter. The seven subject matters for the seven open-ended questions are shown in Table 1. The pilot study for all questions was done and some modifications were made before administration of the test. The content validity of the test was examined by two chemistry professors and two chemistry teachers. The test was administered to 30 undergraduates enrolled in the Primary Science Teacher Training Department in Adiyaman University in Turkey. The subjects took General Chemistry I-II and General Chemistry Laboratories I and II in the first year as this research was being conducted. A traditional instruction was used in the courses. The test was administered under normal class conditions without any warning. Student teachers were informed that the results of the test would be used for research aims and would be kept hidden.
Student teachers’ responses to the diagnostic questions were examined. Misconceptions were identified and percentages were calculated for the responses. The misconceptions determined over % 20 of the subjects are shown in Table 2. In addition, 5 students were interviewed in order to clarify their written responses and to further probe students' conceptual understandings of the questions asked in the test. Interviewees were selected according to their responses on the written test. The student teachers demonstrating a misconception of his/her response were requested to interview. The interviews took almost 15–20 minutes. The interviews were not in detail and they were used to reveal the student teachers’ misconceptions. All interviews were tape recorded after gaining the interviewees’ approval and transcribed for analysis. The interviews were conducted in Turkish; the quotations presented in this paper are translated into English by the author.

Table 2. Prospective science teachers' misconceptions.

<table>
<thead>
<tr>
<th>Misconceptions</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Solubility rate is inversely proportional with temperature.</td>
<td>59</td>
</tr>
<tr>
<td>Saturated solutions are always concentrated and unsaturated solutions are always diluted</td>
<td>61</td>
</tr>
<tr>
<td>Boiling point of a substance increases with height.</td>
<td>42</td>
</tr>
<tr>
<td>Salt solutions have always higher boiling point than sugar solutions.</td>
<td>35</td>
</tr>
<tr>
<td>Dissolution is melting.</td>
<td>42</td>
</tr>
</tbody>
</table>

The results of the student teachers' written responses to item 1 examined the prospective science teachers' understanding of solubility rate and required the correlation between solubility rate and temperature for the substances whose solubility are inversely proportional with the temperature.

Item 2 examined the prospective science teachers' understanding of the statement “saturated solutions are always concentrated and unsaturated solutions are always diluted” and required to give reasons about this statement.

Item 3 examined the prospective science teachers' understanding of the factors affecting boiling point and required to compare the boiling point of the same substance in different places (heights).

The other misconception revealed by item 4 examined the prospective science teachers' understanding of the characteristic properties in dissolution cases and required prospective science teachers to give examples about the dissolution cases.

Item 5 examined the prospective science teachers' understanding of how boiling points of different substances with different concentration can be the same and required prospective science teachers to know the effect of total concentration on boiling points of solutions.

Item 6 examined the prospective science teachers' understanding of electrical conductivity of solutions and required prospective science teachers to know the electrical conductivity of solutions by ion movement.

The results of the student teachers' written responses to item 7 examined the prospective science teachers' understanding of the difference between melting and dissolution processes and required
prospective science teachers to explain in molecular level.

Students were given 50 minutes (1 class hour) to answer open-ended questions. Seven open-ended questions containing related concepts in solution chemistry can be seen in Appendix. The open-ended questions were analyzed with respect to the following categories proposed by Abraham, Gryzybowski, Renner and Marek (1992); Abraham et al. (1994) as shown in Table 3.

<table>
<thead>
<tr>
<th>Understanding Categories and Contents.</th>
<th>Scoring Criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sound Understanding (SU)</td>
<td>Responses that included all components of the validated response</td>
</tr>
<tr>
<td>Partial Understanding (PU)</td>
<td>Responses that included at least one of the components of validated response, but not all the components</td>
</tr>
<tr>
<td>Partial Understanding with Specific Misconception (PUSM)</td>
<td>Responses that showed understanding of the concept, but also made a statement, which demonstrated a misunderstanding</td>
</tr>
<tr>
<td>Specific Misconceptions (SM)</td>
<td>Responses that included illogical or incorrect information</td>
</tr>
<tr>
<td>No Understanding (NU)</td>
<td>Repeated the question; contained irrelevant information or an unclear response; left the response blank</td>
</tr>
</tbody>
</table>

This categorization was selected to classify prospective science teachers’ answers and to compare their different levels of understanding.

**Results of Research**

The results of the open-ended test are shown in Table 4. The percentages of the responses with regard to mentioned categories above are presented below.

<table>
<thead>
<tr>
<th>Item No.</th>
<th>SU</th>
<th>PU</th>
<th>PUSM</th>
<th>SM</th>
<th>NU</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>7</td>
<td>10</td>
<td>17</td>
<td>59</td>
<td>7</td>
</tr>
<tr>
<td>2</td>
<td>10</td>
<td>24</td>
<td>35</td>
<td>28</td>
<td>3</td>
</tr>
<tr>
<td>3</td>
<td>21</td>
<td>10</td>
<td>28</td>
<td>41</td>
<td>0</td>
</tr>
<tr>
<td>4</td>
<td>76</td>
<td>7</td>
<td>7</td>
<td>10</td>
<td>0</td>
</tr>
<tr>
<td>5</td>
<td>38</td>
<td>17</td>
<td>24</td>
<td>17</td>
<td>4</td>
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<tr>
<td>6</td>
<td>48</td>
<td>14</td>
<td>31</td>
<td>7</td>
<td>0</td>
</tr>
<tr>
<td>7</td>
<td>0</td>
<td>28</td>
<td>41</td>
<td>31</td>
<td>0</td>
</tr>
</tbody>
</table>

SU: Sound Understanding  PU: Partial Understanding  SM: Specific Misconceptions  NU: No Understanding  PUSM: Partial Understanding with Specific Misconception

In Item 1, sound understanding contained information that solubility rate is always proportional with temperature for all substances because solubility rate is different from solubility. As can be seen from Table 4, almost 17 percent of prospective science teachers have sound and partial understanding while 83 percent of them have specific misconception and no understanding for item 1. From the
results, it could be stated that many prospective science teachers have specific misconception about
the temperature factor affecting solubility rate. Some of them know that there are some substances
whose solubility in water decreases with increasing temperature like gases and some other substances
but they think that if the solubility of substance decreases with temperature then the solubility rate
of the same substances will also decrease with temperature. They may be confused with the concept
“solubility” and solubility rate. The following excerpt from a student’s interview exemplifies this confu-
sion (R and S stand for researcher and student teacher, respectively):

  R: Are the solubility and solubility rate the same concepts?
  S: Yes, they are similar concepts.
  R: Is there any correlation between them?
  S: Yes, they are proportional with each other. If the solubility of a substance is proportional with
temperature, then the solubility rate of that substance is also proportional with temperature.
  R: Can you give an example?
  S: For example, sugar in water.
  R: Do you know any substance whose solubility is inversely proportional with temperature?
  S: I don’t remember.

For item 2, sound understanding consisted of knowledge that saturated solutions can be diluted
or concentrated while unsaturated solutions can be concentrated or diluted.

   Shortly, there is no direct relation between saturation and concentration of the solutions. As it can
be seen from Table 4, the results show that almost 35 percent of prospective science teachers have sound
and partial understanding; on the other hand, almost 65 percent of them have specific misconception
and no understanding for item 2. Some of the prospective science teachers have not understood the
types and classification of solutions and they have not differentiated saturation and concentration
terms. They think that if a solution is saturated then it means this solution is also concentrated and if
a solution is unsaturated then it is diluted. They have no knowledge that there is no scientific relation
between saturation and concentration of a solution. The following dialogue from an interview indicates
this misconception:

  R: Can a concentrated solution be saturated, unsaturated or supersaturated?
  S: The solutions have limited saturation point. The solutions which are not reached this point are
diluted; on the other hand, the solutions that are reached or over reached this point are classified
as concentrated.

Sound understanding for item 3 can be concluded as boiling point of a substance is proportional
with atmospheric pressure. Almost 31 percent of prospective science teachers have sound and partial
understanding, while 69 percent of them have specific misconception for item 3. Many of the prospec-
tive science teachers think that boiling point of a solution is inversely proportional with atmospheric
pressure by memorization and some of them cannot realize that boiling point is proportional with the
time period of boiling process of solution at the same temperature by using identical heater. The fol-
lowing quotation from an interview dialogue emphasizes this misconception:

  R: Which factors affect boiling point of a substance?
  S: Height, atmospheric pressure, type of a liquid etc.
  R: How is the boiling point of a substance change with atmospheric pressure and height?
  S: It changes inversely proportional with atmospheric pressure and height because vapor
pressure of a liquid decreases when height increases, so boiling point increases when vapor
pressure decreases by the effect of decreasing temperature.

In item 4, sound understanding included information that dissolution process can be only physical
change. For example, dissolution of sugar in water categorized as physical change; on the other hand,
reaction of sodium (Na) metal with water can not be classified as dissolution. As it can be seen from Table 4, the high percentage of the sound or partial understanding (83 %) indicates that minority of the respondents (17 %) hold specific misconception about the characteristics of dissolution. They think that some dissolution processes can be chemical and they do not know active metal with acid or water is a chemical reaction resulting in the "disappearing" of the metal as this is the case in many other reactions, and it is not a dissolving process. The following excerpt indicates this correct view:

R: Is the dissolution process physical or chemical change?
S: It is always physical change, because there is no change in the internal structure and it is reversible; For example, sugar in water.
R: What about reactions of some metals in acid solutions?
S: Some metals react with strong acids but it is not a dissolution process.

For item 5, sound understanding consisted knowledge that boiling point elevation is proportional with total concentration of solution. As it can be seen from Table 4, almost 55 percent of prospective science teachers have sound and partial understanding while 45 percent of them have specific misconception and no understanding for item 1. From the results, it could be stated that many of respondents know that boiling point elevation is proportional with total concentration of solution. On the other hand, some of the respondents have a specific misconception that salt solutions always have higher boiling points compared to sugar solutions. They are not aware of total concentration factor determining boiling point elevation of a solution.

R: Does concentration of a solution affect the boiling point of a solution?
S: Yes.
R: In which way?
S: If the concentration of a solution is increased then the boiling point also increases.
R: Do the different type of solutions in the same conditions have same boiling points? For example, Can sugar and table salt (NaCl) solutions have same boiling points in the same conditions?
S: No, They can not. Table salt solutions always have higher boiling points than sugar solutions, because table salt (NaCl) dissolve in ionic form in water.

Sound understanding for item 6 can be concluded as electrical conductivity of solutions occur by ion movement while electrical conductivity of metals occur by electron movement. The high percentage of the sound or partial understanding indicates that many of the respondents (%62) know the characteristic properties of electrical conductivity in solution chemistry. On the other hand, 38 percent of respondents have some specific misconceptions or misconceptions with partial understanding as can be seen from Table 4. Many of the respondents who have specific misconception think that electrical conductivity occur by electron movement in the solutions. They may be confused with the electrical conductivity of metals as clearly indicated in the following quotation:

... R: Which one of them is electrolyte solution, sugar in water or table salt in water?
S: Of course, table salt in water, because electrons in table salt disperses in water and transfer charge from one side to another.

In item 7, sound understanding included information that dissolution is the process of attraction and association of molecules of a solute with molecules of a solvent; on the other hand, melting is a process that results in the phase change of a substance from a solid to a liquid. The results show that almost 28 percent of prospective science teachers have sound and partial understanding; on the other hand, almost 72 percent of them have specific misconception and no understanding for item 7. The low percentage of the sound or partial understanding indicates that many of the respondents hold specific misconception about differentiating between melting and dissolution processes. Some of the respondents used the term of “melting of sugar in water" for dissolution process. This can be interpreted...
as some respondents think that sugar melts for the dissolution of sugar in water, as can be seen in the following quotation:

\[ R: \text{When the sugar is put in water, what happens to sugar in water?} \]
\[ S: \text{It melts in water and disperses everywhere in the water.} \]

**Discussion**

This study is aimed at determining prospective science teachers’ conception of the solution chemistry. Since there are a few studies about prospective science teachers’ conceptions of the solution chemistry on a narrow spectrum of solution chemistry with specific items the results of this study may provide a wider vision into the prospective science teachers’ understanding of different concepts compared to the related literature in solution chemistry. Many of the prospective science teachers have not developed sufficient conceptual understanding of the solution chemistry and related concepts. The results of this study is similar as in the study of Ebenezer and Gaskell (1995); Akınoglu and Yaşar, (2007); Akpınar, (2007); Ebenezer, (2001); Ebenezer and Gaskell, (1995); Johnson and Scott, (1991); Kabapınar, Leach and Scott, (2004); Kaartinen and Kumpulainen, (2002); Taylor and Coll, (1997). Most prospective teachers had no meaningful understanding of concepts and they used unrelated correct ideas to answer the questions about the concepts related to solution chemistry. They mostly used the statements concerning mere memorization of the concepts’ definitions as stated by Valanides (2000).

It was determined many misconceptions produced by the prospective science teachers in this study. Some of them were supported by the literature. For example, most of the prospective science teachers thought that how the solubility of a substance change with temperature, then the solubility rate of that substance change with temperature in the same way. Many of them have confused the term “solubility” and “solubility rate” (Ebenezer and Erickson, 1996; Gennaro, 1981; Pınarbaşı and Canpolat, 2003; Çalık, 2005). Besides, more than half of the prospective science teachers held the view that saturated solutions are always concentrated and unsaturated solutions are always diluted solutions (Çalık, 2005; Pınarbaşı and Canpolat, 2003; Liu and Ebenezer, 2002). Furthermore, a significant number of the prospective science teachers thought that boiling point of a solution is inversely proportional with atmospheric pressure (Costu, Ayas, Niaz, Calik, 2007; Pınarbaşı and Canpolat, 2003; Pınarbaşı, Canpolat, Bayrakçeken and Geban, 2006). Some of the misconceptions are not reviewed in the literature. For instance, some of the prospective science teachers believed that salt solutions always have higher boiling points compared to sugar solutions and some of them thought that electrolyte solutions conduct electricity by electron movement.

Almost 40 % of the prospective science teachers thought that electrical conductivity occur by electron movement in the solutions (Çalık, 2005) and a significant numbers of prospective science teachers held the view that sugar melts for the dissolution of sugar in water (Goodwin, 2002; Kabapınar et al. 2004).

**Conclusion and Educational Implications**

In general, the results indicated that many prospective science teachers could not learn the concepts related to solution chemistry well enough. Teaching methods, memorization of the concepts, making science lessons without laboratory, insufficient curriculum and traditional learning activities may be the reasons. The teaching of elementary chemistry begins with a brief introduction of matter and properties as a part of science lesson at the age of 10–11 (in grade 4). Then, introductory chemistry concepts such as mole concept, atoms and chemical reactions are taught at age 13–14 (in grade 7–8). More formal chemistry lessons start with secondary education at age 14–15 (in grade 9) (Ayas, Özmen and Genç, 2001).

The results may contribute to perceive some difficulties which prospective science teachers can be faced in their science classes. These results also imply that more effective teaching strategies need to be developed to prevent misconceptions about the subject. If the science teachers have some misconcep-
tions about solution chemistry, then their students can be faced with difficulties in problem solving by using concept of learning.

Furthermore, scientific researches and studies should be done to assess prospective science teachers' misconceptions about solution chemistry. Science teachers' in-service training should include pedagogical content knowledge and conceptual learning in problem solving deeply. Science curricula should also be developed with respect to the common misconceptions related to solution chemistry. Teaching strategies should be arranged according to the recent misconceptions held by prospective science teachers about solution chemistry.

References


promote development in understanding about conservation of mass on dissolving. Research in Science and Technological Education, 9(2), 193-212.


APPENDIX

Solution Chemistry Conceptual Open-ended Questions

1. How does the solubility rate change when the temperature increases for the substances whose solubility are inversely proportional with the temperature? Explain in brief.
2. Can you say that saturated solutions are always concentrated and unsaturated solutions are always diluted? Why?
3. Explain why it takes shorter to cook an egg in Malatya, a city of Turkey in the east (atmospheric pressure = 720 mm Hg) than in Muğla, a city of Turkey in the west (atmospheric pressure = 755 mm Hg)?
4. Are the dissolution cases physical or chemical? Give examples.
5. How can be equal the boiling points of 0.2 M glucose solutions and 0.1 M NaCl solutions in the same place? Explain.
6. Electrical conductivity of solutions occurs by electron movement or ion movement? Explain.
7. What is the difference between dissolution and melting process? Explain in molecular level.

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