ISSN 1648-3898

PROSPECTIVE SCIENCE TEACHERS' CONCEPTIONS OF THE SOLUTION CHEMISTRY

Mustafa Özden

Abstract. *This study investigated to determine and characterize prospective science teachers' conception of the concept of solution chemistry and its related concepts. An instrument containing open-ended questions was built by the researcher first and administered to 30 prospective science teachers. In addition, semi-structured interviews were administered by researcher with 5 students from the sample in order to clarify their written responses. The results indicated that the prospective science teachers' understandings of most of the concepts were in specific misconception level. Particularly, prospective science teachers showed good understanding on electrical conductivity of solution, boiling point elevation and characteristics of dissolution process compared to other concepts. On the other hand, they have poor understanding on concept of temperature factor affecting solubility rate, classification of solutions, properties of solutions and difference between melting and dissolution. Furthermore, the results showed that many prospective science teachers could not learn the concepts related to solution chemistry well enough.*

Key words: *conception, solution chemistry, misconception, prospective science teacher.*

Mustafa Özden
Adiyaman University, Turkey

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 Treagust (1989); Ebenezer and Gaskell (1995); Quiles-Pardo and Solaz-Portol ´es (1995); Ayas and Demirbaş (1997); Ayas and Coştu (2002); Akınoğlu 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; Çalık, 2005), the nature of solutions (Fensham and Fensham, 1987; Prieto, Blanco and Rodri-

ISSN 1648–3898

guez, 1989; Ebenezer and Gaskell, 1995; Longden, Black and Solomon, 1991; Slone and Bokhurst, 1992; Fellows, 1994), solubility (Ebenezer and Erickson, 1996; Gennaro, 1981), energy in solution processes (Ebenezer and Fraser, 2001; Liu, Ebenezer and Fraser , 2002), the factors affecting solubility and solubility rate (Blanco and Prieto, 1997; Uzuntiryaki and Geban, 1998), classification of solutions, vapor pressure lowering, solubility of a gas in water and the relationship between vapor pressure and boiling point (Pınarbaşı and Canpolat, 2003; Liu and Ebenezer, 2002; Çalık, and Ayas, 2005).

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, 2001; Liu, 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 teachers do 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 Adıyaman 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.

Table 1. The subject matters related to open-ended questions.

Question No.	The subject matters related to questions
1	Factors affecting Solubility Rate
2	Classification of Solutions
3	Properties of Solutions
4	Dissolution
5	Boiling Point Elevation
6	Electrical Conductivity of Solution
7	Difference between Melting & Dissolution

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.

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

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

ISSN 1648–3898

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 3. Understanding Categories and Contents.

Understanding Levels	Scoring Criteria
Sound Understanding (SU)	Responses that included all components of the validated response
Partial Understanding (PU)	Responses that included at least one of the components of validated response, but not all the components
Partial Understanding with Specific Misconception (PUSM)	Responses that showed understanding of the concept, but also made a statement, which demonstrated a misunderstanding
Specific Misconceptions (SM)	Responses that included illogical or incorrect information
No Understanding (NU)	Repeated the question; contained irrelevant information or an unclear response; left the response blank

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 4. Percentages of responses given to open-ended questions.

Item No.	SU	PU	PUSM	SM	NU
1	7	10	17	59	7
2	10	24	35	28	3
3	21	10	28	41	0
4	76	7	7	10	0
5	38	17	24	17	4
6	48	14	31	7	0
7	0	28	41	31	0

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 is 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 confusion (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 prospective science teachers think that boiling point of a solution is inversely proportional with atmospheric pressure by memorization and some of them can not realize that boiling point is proportional with the time period of boiling process of solution at the same temperature by using identical heater. The following 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,

ISSN 1648–3898

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 solvent with molecules or ions of a solute; 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: When the sugar is put in water, what happens to sugar in water?*
> *S: 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); Akınoğlu 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, Unal, 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-

ISSN 1648–3898

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

Abraham, M. R., Gryzybowski, E. B., Renner, J. W. and Marek, A. E (1992). Understanding and misunderstanding of eighth graders of five chemistry concepts found in textbooks. *Journal of Research in Science Teaching*, 29, 105-120.

Abraham, M .R., Williamson, V. M. and Westbrook, S. L (1994). A cross-age study of the understanding of five concepts. *Journal of Research in Science Teaching*, 31 (2), 147-165.

Akınoğlu, O., Yaşar, Z., (2007). The effects of note taking in science education through the mind mapping technique on students' attitudes, academic achievement and concept learning. *Journal of Baltic Science Education*, 6(3), 34-43.

Akpınar, E., (2007). The effect of dual situated learning model on students' understanding of photosynthesis and respiration concepts. *Journal of Baltic Science Education*, 6(3), 16-26.

Ayas, A., and Coştu, B. (2002). Levels of understanding of the evaporation concept at secondary stage. *The First International Education Conference, Changing Times Changing Needs*, Eastern Mediterranean University, Gazimagusa- Northern Cyprus.

Ayas, A., Özmen, H. & Genç, H. (2001). Chemistry teaching in Turkey. *Energy, Education, Science and Technology,* 7(2), 59-65.

Ayas, A., Demirbas, A. (1997). Turkish secondary students' conception of introductory chemistry concepts. *Journal of Chemical Education,* 74, 518-521.

Bahar, M., Özel, M., Prokop P. and Uşak, M. (2008). Science student teachers' ideas of heart. *Journal of Baltic Science Education*, 7(2), 78-85.

Blanco, A., and Prieto, T. (1997). Pupils' views on how stirring and temperature affect the dissolution of a solid in a liquid: A cross-age study (12 to 18). *International Journal of Science Education,* 19, 303-315.

Coştu, B., Ayas, A., Niaz, M., Ünal, S. and Çalık, M. (2007). Facilitating Conceptual Change in Students' Understanding of Boiling Concept. *Journal of Science Education and Technology*, 16 (6), 524-536.

Çalık, M. (2008). Facilitating Students' Conceptual Understanding of Boiling Using a Four-Step Constructivist Teaching Method. *Research in Science & Technological Education*, 26(1), 59-74.

Çalık, M. (2005). A cross-age study of different perspectives in solution chemistry from junior to senior high school. *International Journal of Science and Mathematics Education,* 3(4), 671-696.

Çalık, M., Ayas, A. (2005). A cross-age study on the understanding of chemical solutions and their components. *International Education Journal*, 6(1), 30-41.

Ebenezer, J. V., Gaskell, P. J. (1995). Relational conceptual change in solution chemistry. *Science Education,* 79, 1-17.

Ebenezer, J. V. and Erickson, L. G. (1996). Chemistry students' conception of solubility: A phenomenograpy. *Science Education*, 80 (2), 181-201.

Ebenezer, J. (2001). A hypermedia environment to explore and negotiate students' conceptions: Animation of the solution process of table salt. *Journal of Science Education and Technology*, 10, 73-91.

Ebenezer, J. V., and Fraser,M.D. (2001). First year chemical engineering students' conception of energy in solution processes: Phenomenographic categories for common knowledge construction. *Science Education,* 85, 509-535.

Eisen, Y., & Stavy, R. (1988). Students' understanding of photosynthesis. *The American Biology Teacher,* 50 (4), 208-212.

Fellows, N.J. (1994). A Window in to Thinking: Using Student writing to Understand Conceptual Change in Science Learning, *Journal of Research in Science Teaching*, 31(9), 985-1001.

Fensham, P., Fensham, N. (1987). Description and frameworks of solutions and reactions in solutions. *Research in Science Education*, 17, 139-148.

Gennaro, E.D. (1981). Assessing junior high students' understanding of density and solubility. *School Science and Mathematics*, 81, 399-404.

Goodwin, A. (2002). Is salt melting when it dissolves in water? *Journal of Chemical Education* 79, 393-396.

Haidar, A. H., and Abraham, M. R. (1991). A comparison of applied and theoretical knowledge of concept based on the particulate nature of matter. *Journal of Research in Science Teaching,* 28, 919-938.

Johnson, K., Scott, P. (1991). Diagnostic teaching in the science classroom: Teaching/learning strategies to promote development in understanding about conservation of mass on dissolving. *Research in Science and Technological Education,* 9(2), 193-212.

Kaartinen, S., Kumpulainen, K. (2002). Collaborative inquiry and the construction of explanations in the learning of science. *Learning and Instruction,* 12, 189-212.

Kabapınar, F., Leach, J., Scott, P. (2004). The design and evaluation of a teaching-learning sequence addressing the solubility concept with Turkish secondary school students. *International Journal of Science Education,* 26, 635-652.

Köse, S., (2007). The effects of concept mapping instruction on overcoming 9th grade students' misconceptions about diffusion and osmosis. *Journal of Baltic Science Education*, 6(2), 16-25.

Lamanauskas, V., Gedrovics, J., Raipulis, J. (2004). Senior pupils' views and approach to natural science education in Lithuania and Latvia. *Journal of Baltic Science Education*, 1(5), 13-23.

Lee, O., Eichinger, D. C., Anderson, C. W., Berkheimer, G. D., and Blakeslee, T. D. (1993). Changing middle school students' conceptions of matter and molecules. *Journal of Research in Science Teaching,* 30, 249-270.

Liu, X., Ebenezer, J., and Fraser, D. M. (2002). Structural characteristics of university engineering students' conceptions of energy. *Journal of Research in Science Teaching, 39*, 423-441.

Longden, K., Black, P., and Solomon, J. (1991). Children's interpretation of dissolving. *International Journal of Science Education,* 13, 59-68.

Martlew, M., & Connolly, K. (1996). Human figure drawings by schooled and unschooled children in Papua New Guinea. *Children Development*, 67, 2743-2762.

Özden, M. (2008). Influence of Content Knowledge on Pedagogical Content Knowledge: The case of teaching Phases of Matters, *Educational Sciences: Theory & Practice,* 2, 611-645.

Özden, M. (2009a). Primary Student Teachers' Ideas of Atoms and Molecules: Using Drawings as a Research Method. *Education*, 129(4), 635-642.

Özden, M. (2009b). Enhancing Prospective Teachers Development through Problem-Based Learning in Chemistry Education: Solutions and Properties. *Asian Journal of Chemistry* 21(5), 3671- 3682.

Peterson, R. F., Treagust, D. F. (1989). Grade-12 students' misconceptions of covalent bonding and structure. *Journal of Chemical Education,* 66, 459-460.

Pınarbaşı, T., Canpolat, N., Bayrakçeken, S. and Geban, Ö., (2006). An Investigation of Effectiveness of Conceptual Change Text-oriented Instruction on Students' Understanding of Solution Concepts. *Research in Science Education*, 36, 313-335.

Pınarbaşı, T., Canpolat, N. (2003). Students' understanding of solution chemistry concepts. *Journal of Chemical Education*, 80(11), 1328-1332.

Pridmore, P., and Bendelow, G. (1995). Images of health: exploring beliefs of children using the 'draw-and-write' technique. *Health Education Journal,* 54, 473-488.

Prieto, T., Blanco, A., Rodriguez, A. (1989). The ideas of 11 to 14-year-old students about the nature of solutions. *International Journal of Science Education*, 11 (4), 451-463.

Prokop, P., Fančovičová, J. (2006). Students' ideas about the human body: Do they really draw what they know? *Journal of Baltic Science Education,* 2 (10), 86-95.

Prokop, P., Prokop, M., Tunnicliffe, S. D., & Diran, C. (2007). Children's ideas of animals' internal structures. *Journal of Biological Education,* 41(2), 62-67.

Quiles-Pardo, J., and Solaz-Portol´es, J. J.(1995). Students and teachers misapplication of Le Chatelier's Principle: Implications for the teaching of chemical equilibrium. *Journal of Research in Science Teaching,* 32, 939-957.

Reiss M. J., Tunnicliffe S. D., Andersen A. M., Bartoszeck A., Carvalho G. S., Chen S. Y., Jarman R., Jónsson S., Manokore V., Marchenko N., Mulemwa J., Novikova T., Otuka J., Teppa S., & Rooy W. V. (2002). An international study of young peoples' drawings of what is inside themselves. *Journal of Biological Education,* 36, 58-64.

Slone, M., Bokhurts, F.D., 1992, Understanding of Sugar Water Solutions. *International Journal of Science Education*, 14(2), 221-235.

Smith, K. J., Metz, P. A. (1996). Evaluating student understanding of solution chemistry through microscopic representations. *Journal of Chemical Education,* 73, 233-235.

Stavy, R. (1988). Children's conception of gas. *International Journal of Science Education,* 20, 553-560.

Taylor, N. & Coll, R. (1997). The use of analogy in the teaching of solubility to pre-service primary teachers. *Australian Science Teachers' Journal,* 43(4), 58-64.

Tunnicliffe, S.D and Reis, M,J (1999a). Students' understandings about animal skeletons. *International Journal of Science Education*, 21, 1187-1200.

Tunnicliffe, S.D and Reis, M,J (1999b). Building a model of the environment: How do children see animals. *Journal of Biological Education,* 33, 142-148.

Uzuntiryaki E. and Geban Ö., (1998), The effect of student's understanding conceptual change approach about solution chemistry. *Education 97-98*, TED Ankara College, 1(1), 51-56.

Valanides, N. (2000). Primary student teachers' understanding of the particulate nature of matter and its transformations during dissolving. *Chemistry Education: Research and Practice in Europe,* 1, 249-262.

Zoldosava, K., Prokop, P. (2007). Primary Pupils' Preconceptions About Child Prenatal Development. *Eurasia Journal of Mathematics, Science & Technology Education,* 3(3), 239-246.

ISSN 1648–3898

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.

Received 18 August 2008;
accepted 29 May 2009.

Mustafa Özden	Assistant Professor, Adiyaman University, Faculty of Education, Department of Science Education, Adiyaman, Turkey. Phone: +90 416 2232210-1103. E-mail: mozden@adiyaman.edu.tr Website: http://english.adiyaman.edu.tr/index.php?lo=anasayfa