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A cross-age study on the understanding of chemical solutions and their components[1]

Muammer Çalık
KTÜ Giresun Faculty of Education, Department of Elementary Science Education, Giresun, Turkey *muammer38@hotmail.com*

Alipaşa Ayas
KTÜ, Fatih Faculty of Education, Department of Secondary Science and Mathematics Education, Söğütlü – Trabzon, Turkey

The aims of this study were considered under three headings. The first was to elicit misconceptions that students had about the terms 'solute', 'solvent' and 'solution.' The second was to understand how students' prior learning affected their misconceptions. The third was to determine if students were able to make a connection between their own knowledge and chemistry in everyday life. To achieve these aims, a paper and-pencil test composed of 18 open-ended questions was designed, but only four questions related to chemical solutions and their components. The test was administered to 441 students from different grades that ranged from Grade 7 with students aged 13-14 years to Grade 10 with students aged 16-17 years. As a result of the analyses undertaken, it was found that students' misunderstanding about the concepts of dissolution and conservation of mass influenced their knowledge about the these terms. Moreover, it was found that students had difficulties making connections between their knowledge and life experiences. Furthermore, it was elicited that the examples given by most of students under investigation were limited to particular solid-liquid and liquid-liquid solutions; however, some students in the upper grades referred to solid-solid and gas-gas solutions such as air, nitrogen and oxygen (N_2-O_2), and alloy composition. Therefore, it was concluded that although students' conceptions and misconceptions were acquired and stored, they occurred without ostensible links between everyday life and school experiences. Furthermore, depending on the instruction students received and over time, it was deduced that their conceptual understanding showed a steady increase from Grade 7 to Grade 10, except in the case of Item 1. In light of results of this study, some suggestions for future instruction were made.

Chemistry education, solute, solvent, solution, misconceptions

INTRODUCTION

Solution chemistry, because of its importance, has attracted attention of many researchers who have focused on different perspectives in solution chemistry and attempted to elicit students' understanding of the concepts involved. These perspectives are presented as follows: (a) the dissolution concept (Abraham, Gryzybowski, Renner, and Marek, 1992; Abraham, Williamson and Westbrook, 1994; Cosgrove and Osborne, 1981; Çalık and Ayas, 2005a; Ebenezer and

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Erickson, 1996; Longden, Black and Solomon, 1991; Smith and Metz, 1996) (b) the nature of solutions (Fensham and Fensham, 1987; Prieto, Blanco and Rodriguez, 1989); (c) solubility (Ebenezer and Erickson, 1996; Gennaro, 1981); (d), the role of energy in the solution process (Ebenezer and Fraser, 2001; Liu, Ebenezer and Fraser, 2002); (e) the effects of temperature and stirring on the dissolution of solids; (Blanco and Prieto, 1997); (f) the conservation of mass during the dissolution process (Drıver and Russell, 1982; Holding, 1987; Piaget and Inhelder, 1974); (g) structural characteristics (Liu and Ebenezer, 2002); (h) types of solutions (Çalık and Ayas, 2005b; Pınarbaşı and Canpolat, 2003), (i) the concept of vapour pressure lowering, and the relationship between vapour pressure and boiling point (Çalık and Ayas, 2005b; Pınarbaşı and Canpolat, 2003), (j) electrolytes and electrical conductivity (Çalık and Ayas, 2005b), (k) relationship between surface area and rate of solution (Çalık and Ayas, 2005b) and (l) strategies to overcome misconceptions (Ebenezer, 2001; Ebenezer and Gaskell, 1995; Griffiths, 1994; Johnson and Scott, 1991; Kaartinen and Kumpulainen, 2002; Kabapınar, Leach, and Scott, 2004; Taylor and Coll, 1997). The cited studies have tried to answer several questions: (a) what kinds of misconceptions do students have; (b) how common are the misconceptions; (c) how these misconceptions may be replaced with correct ideas; and (d) suggestions as to what teachers can do to improve teaching-learning environment that would reduce students' misconceptions. These studies have used a number of terms such as preconceptions, misconceptions, and alternative conceptions that students have and these terms also reflect some researchers' view of knowledge. That is, alternative conceptions fit ideas associated with constructivism, and misconceptions that are associated with a positivist tendency (Taber, 2000). However, when these terms are used, they often convey a similar meaning (Coştu and Ayas, 2005; Taber, 2000), but the use of the various terms helps to describe students' confusion with the language and ideas of chemistry (Nicoll, 2001). In this article, the term 'misconception' is used to describe any conceptual difficulties, which are different from or inconsistent with those accepted by the scientific community.

In studies on solution chemistry, only Prieto et al. (1989) reported that the examples given by some students were limited to particular solids that dissolved in liquids. They emphasised that students claimed that the solute was the most important component in the dissolution process and they described the solute as a passive component. Also, they pointed out that only Grade 8 students mentioned the interaction between a solute and a solvent, however, here the meaning seemed to imply a chemical transformation.

As can be seen from the related literature, even though the cited studies on solution chemistry have concentrated on different perspectives, there appears to be an absence of what students understand about the terms 'solution', 'solute' and 'solvent', whether they are able to apply theoretical knowledge to novel situations, whether the students are able to make connections between school and life experiences, and how the instruction that students receive influences their ideas. Thus, the current study has tried to fill this gap. Therefore, the aims of the study are considered under three headings. The first is to list misconceptions that students retain. The second is to elicit how the instruction that students have received affects their misconceptions. The third is to examine whether students are able to correlate their knowledge with everyday life situations.

METHODS OF ANALYSIS

The study context

In the Turkish educational system, the first chemistry teaching begins with a brief introduction to physical and chemical changes, as a part of the science curriculum at the age of 10-11 years in Grade 4. Then the introductory material on concepts such as atomic structure and chemical reactions is taught to students aged between 13-14 years (Grade 7) (Tebliğler Dergisi, 2000). The formal chemistry lessons begin with secondary education at 14-15 years (Grade 9) (Ayas, Özmen and Genç, 2001).

Instruments and data collection procedure

In order to examine students' level of understanding, taking into account their grade levels and comprehension, cross-age and longitudinal studies are often used (Abraham et al, 1994). However, Abraham et al. (1994) have implied that a cross-age study is more applicable than a longitudinal study if there is limited time, and several researchers have carried out cross-age studies with satisfactory results (Blanco and Prieto, 1997; Krnel, Glažar and Watson, 2003; Westbrook and Marek, 1991). Therefore, in this study, a cross-age study has been undertaken.

In this article, a case study research design was used (Yin, 1994). To use this method, a paper and pencil test composed of 18 open-ended questions was developed but only four questions related to solutions and their components directly. Three of the questions were open-ended, but the other one was a two-tier question that consisted of a multiple-choice portion and an open-ended response. Furthermore, a group of chemistry educators and chemists checked the test for validity and reliability and then confirmed the content validity of the instrument. The test items considered in this study are shown in Table 1.

Table 1. Four test items used in the study

Item 1: Sugar in water

a) sugar is solvent and water is solute
b) sugar is solute and water is a solvent
c) both sugar and water are solutes
d) both sugar and water are solvents

Because……………………………………..

Item 2: What do understand by the terms solution, solvent, and solute? Please explain by filling in the blanks.

Solution……………………………………….
Solvent………………………………………..
Solute…………………………………………..

Item 3: Can you give at least two examples of solutions?
These examples should be different from the examples given in test.

Item 4: Some examples of solutions selected from daily life are presented below. Can you fill in the blanks and write their components (solute and solvent)?

Solution	Solvent	Solute
Lime tea	………	………
Pickled water	………	………
Coca Cola	………	………
Cologne	………	………

Pilot study

Forty students from different grades, who were not included in the study, participated in a pilot study. The administration of the pilot study took about 30 minutes. The pilot study revealed that questions on chemical solutions and their components were quite understandable and clear for all grade levels.

The Sample

The sample under investigation comprised 441 students in different grades that ranged from Grade 7 (age 13-14 years) to Grade 10 (16-17 years). There were 105 students from Grade 7, 102 students from Grade 8, 103 students from Grade 9 and 131 students from Grade 10. The sample was selected at random from two elementary schools and two secondary schools in the city of Trabzon in Turkey. The students in the sample had studied the topics under investigation at a fundamental level in Grade 7. The topics were then taught at a more advanced level in Grades 9 and 10. Moreover, all the topics under investigation were taught in first semester and all of the students in the sample passed the courses at a satisfactory level and had begun the second semester. This study was also undertaken during the second semester. The students were given 30 minutes to answer the test and were encouraged to answer all the questions.

Data Analysis

The open-ended questions listed in Table 1 were analysed under the following categories and headings, which were suggested by Abraham et al. (1994).

- **Sound Understanding**: Responses that included all components of the validated response.
- **Partial Understanding**: Responses that included at least one of the components of validated response, but not all the components.
- **Partial Understanding with Specific Misconception**: Responses that showed understanding of the concept, but also made a statement, which demonstrated a misunderstanding.
- **Specific Misconceptions**: Responses that included illogical or incorrect information.
- **No Understanding**: Repeated the question; contained irrelevant information or an unclear response; left the response blank.

These criteria provided an opportunity to classify students' responses and make comparisons about their level of understanding.

RESULTS

The results obtained from the test are presented below by taking each item into consideration. Percentages of the obtained responses for each Item are shown in Table 2.

Table 2. Percentages of responses given to questions

Items	**1**				**2**				**3**				**4**			
Grades	**7**	**8**	**9**	**10**	**7**	**8**	**9**	**10**	**7**	**8**	**9**	**10**	**7**	**8**	**9**	**10**
SU	4	4	4	4	2	2	4	4	2	9	13	13	0	4	10	7
PU	51	40	70	72	18	20	42	45	19	15	32	23	10	8	12	10
PUMS	24	24	19	17	24	24	42	31	11	11	17	14	53	37	57	63
SM	15	19	4	5	5	0	3	5	0	2	9	7	0	4	3	4
NU	6	13	3	2	51	54	9	15	68	63	29	43	37	47	18	16

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

For Item 1, sound understanding included knowledge that sugar is the solute and water is the solvent because amount of solvent is more than that of solute and the solution phase depends on the presence of a solvent. As can be seen from Table 2, four per cent of Grade 7, 8, 9 and 10 showed sound understanding, the proportion of students' responses categorised under the partial understanding category was 51, 40, 70 and 72 per cent respectively. Moreover, while 24 per cent of Grade 7, 24 per cent of Grade 8, 19 per cent of Grade 9 and 17 per cent of Grade 10 had partial understanding with specific misconceptions, and the proportion of students' responses classified under specific misconception category was 15, 19, four and five per cent respectively. Furthermore, six per cent of Grade 7, 13 per cent of Grade 8, three per cent of Grade 9 and two per cent of Grade 10 students did not respond to the question. Some examples from the given responses for Item 1 are presented in Table 3.

In Item 2, sound understanding is as follows: a solution is a homogenous mixture of two or more substances in a single state, and the solvent is described as the dissolving medium in a solution, amount of which is more than that of solute, finally, the solute is named as the substance dissolved in a solution and occurs as an amount that is less than that of solvent. As can be seen from Table 2, while two per cent of Grades 7 and 8, and four per cent of Grades 9 and 10 show sound understanding, the percentages of students' responses categorised under partial understanding are 18, 20, 42 and 45 per cent respectively. Moreover, the percentages of partial understanding with specific misconception category are 24, 24, 42 and 31 per cent respectively, whereas those in the specific misconception category are five, zero, three and five per cent respectively. Furthermore, 51 per cent of Grade 7, 54 per cent of Grade 8, nine per cent of Grade 9 and 15 per cent of Grade 10 have not provided answers to this item. Some examples of the responses given for Item 2 have been shown in Table 4.

Table 3. Some examples from the responses given for Item 1 (X shows the kinds of responses are identified at each grade)

UL	Examples	Grade			
		7	8	9	10
SU	• Sugar is a solute and water is a solvent because amount of solvent is more than that of solute and the state of the solution depends on that of the solvent.	X	X	X	X
	• Sugar is the solute and water is the solvent because amount of liquid is more and that of solute is less. As a matter of fact, sugar dissolves into water. That is, the formed solution depends on a large amount of solvent. Furthermore, the amount of solute is less than that of the solvent.		X	X	
	• Sugar is the solute and water is the solvent because the formed solution phase depends on the solvent that is larger in a solution and that is why it is called a solvent. The other substance occurs as a small amount, thus it is named the solute.			X	
PU	• Sugar is the solute and water is the solvent because sugar dissolves into water.	X	X	X	X
	• Sugar is the solute and water is the solvent because water is one of the best solvents.	X	X	X	X
	• Sugar is the solute and water is the solvent. Because the amount of water is large, it is named the solvent. Hence, water dissolves the sugar.	X	X	X	X
	• Sugar is the solute and water is the solvent. Because the water dissolves the sugar, water is the solvent. Nevertheless, the fact that the sugar dissolves in water, it is named the solute.			X	X
PUSM	• Sugar is the solute and water is the solvent because the liquid matter dissolves the solid.	X	X	X	X
	• Sugar is the solute and water is the solvent because sugar becomes solute by dissolving in water.	X	X	X	X
	• Sugar is the solute and water is the solvent because solid matter is always the solute and the liquid is a solvent that has a property that dissolves a solid.	X	X		
	• Sugar is the solute and water is the solvent because when a sugar cube is put into a beaker which contains water, a chemical reaction takes place.			X	X
	• Sugar is the solute and water is the solvent because sugar dissolves in water. Nevertheless, water is a solvent.	X	X		
SM	• Water is the solute and sugar is the solvent because water ruins the structure of sugar, therefore, sugar decomposes into its own ions.	X	X	X	X
	• Water is the solute because sugar disappears into the water.	X	X	X	X
	• Sugar and water are both solute and solvent. Nevertheless, at the beginning of this process, both of them are solvents and then become solutes.	X	X		

UL=Understanding Level SU= Sound Understanding PU= Partial Understanding
PUSM= Partial Understanding with Specific Misconception SM= Specific Misconceptions

Sound understanding in Item 3 incorporates in some examples such as acids, bases, alloys and mixtures. As can be seen from Table 2, while percentages of students' responses classified under sound understanding are two, nine, 13 and 13 per cent respectively, 19 per cent of Grade 7, 15 per cent of Grade 8, 32 per cent of Grade 9 and 23 per cent of Grade 10 students indicated partial understanding in accordance with the same sequence. Moreover, the percentages of students' responses categorised under partial understanding with specific misconception are 11, 11, 17 and 14 per cent, those in the specific misconception category are zero, two, nine and seven per cent respectively. Furthermore, 68 per cent of Grade 7, 63 per cent of Grade 8, 29 per cent of Grade 9 and 43 per cent of Grade 10 students did not provide examples in the test or left the questions unanswered. Meanwhile, examples from the responses given for Item 3 are shown in Table 5.

Table 4. Some examples from the given responses for Item 2 (X shows that these kinds of responses are identified at this grade)

UL	Examples	Grade			
		7	8	9	10
SU	• Solution is a homogenous mixture of two or more substances in a single phase. Solvent is called the dissolving medium in a solution, the amount of which is more than that of solute. Solute is named as the substance dissolved in a solution, as the amount of it is less than that of solvent.	X	X	X	X
	• Solution is a homogenous mixture, which consists of a solute and a solvent. Solvent is a component phase of the solution that depends on its state and occurs in a large amount in a solution. The amount of solute is less than that of solvent., As well, the substance dissolved in a solution is called the solute.			X	X
PU	• Solution is a mixture of two different substances. Solvent has the property that can dissolve a substance in its medium. Solute disperses within another substance.	X	X	X	X
	• Solution is a homogenous mixture composed of a solute and a solvent. Solvent occurs as a large amount in solution and dissolves substances, which have similar properties. Solute is a substance that the solvent dissolves.	X	X	X	X
	• Solution is a homogenous mixture composed of a solute and a solvent. Solvent: The best well-known solvent is water and dissolves a substance by decomposing its own ions or molecules.	X	X		
	• Solution is a homogenous mixture composed of a solute and a solvent. Solvent is the largest amount in a solution. Solute has a small amount in a solution.	X	X	X	X
PUSM	• Solution is a compound composed of a solute and a solvent. Solvent dissolves the substance which is added. When a solute is put into solvent, it decomposes.	X	X	X	X
	• Solution is a compound composed of a solute and a solvent. Solvents are liquids, which decompose to their own ions. Solute is a substance whose ions or molecules separate from each other.	X	X		
	• Solution is a mixture composed of a solute and a solvent. Solvent is a substance that is used to disperse a solute in 100 ml water. Solute is a substance that dissolves in 100 ml water.			X	X
	• Solution is a homogenous mixture composed of a solute and a solvent. Solvent is a substance that melts the solid one and decreases the mass of a solid. Solute is a substance whose mass decreases.	X	X	X	X
	• Reaction between solute and solvent yields a solution. Solvent is a substance that dissolves the other one. Solute is a substance dispersed by solvent.	X	X	X	X
SM	• Solution is a term used for homogenous and heterogeneous mixtures. Solvent is a substance that enables a solute to decompose its own ions. Solute is a substance which the solvent decomposes into its own elements.	X			X
	• Solution: Combining of two substances constitutes a new one. Solvent helps the substances decompose into their own molecules, thus, a new one emerges. Solute is decomposed to its own molecules and then melts.	X		X	X
	• Solution: After combining of two the substances, a new different substance forms. Solvent is a substance that enables a solute to lose its own properties. Solute disappears and loses its own properties into the solvent.	X		X	X

UL=Understanding Level SU= Sound Understanding PU= Partial Understanding
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Sound understanding in Item 4 is as follows: (for each of the examples, the first named substance is the solvent and the second is the solute) Lime Tea: Water, and Lime and/or essence of lime, Pickled water: Water, and Salt and/or Vinegar, Coca Cola: Water, and CO_2 or gas, Cologne: water and alcohol or ethanol. As can be seen in Table 2, the percentages in the sound understanding category are zero, four, 10 and seven per cent, those in the partial understanding category are 10, eight, 12 and 10 per cent respectively. Moreover, the percentages of students' responses categorised under the heading partial understanding with specific misconception are 53, 37, 57 and 63 per cent respectively, zero per cent of Grade 7, four per cent of Grade 8, three per cent of Grade 9 and four per cent of Grade 10 have demonstrated specific misconceptions. Furthermore, 37 per cent of Grade 7, 47 per cent of Grade 8, 18 per cent of Grade 9 and 16 per cent of Grade 10 did not answer the question. Some examples from the responses given for Item 4 are shown in Table 6.

Table 5. Some examples from the given responses for Item 3 (X shows that these kinds of responses are identified at this grade)

UL	Examples	Grade			
		7	8	9	10
SU	Sugar in tea, and ammonia in water	X	X	X	X
	Soda (drink that includes both water and several mineral salts), and sugar in lemonade	X	X	X	X
	An alloy of Zn and Cu, and solder			X	X
	An alloy of Zn and Cu, and steel			X	X
	Vinegar, and a mixture of $N_{2(g)}$-$O_{2\,(g)}$			X	X
PU	Tea	X	X	X	X
	Lemonade	X	X	X	X
	Soda (a kind of drink that includes both water and several mineral salts)	X	X	X	X
	Air			X	X
	Ammonia in water	X	X	X	X
	Alloy			X	X
	A mixture of acetone and nail polish	X			
	A solution of H_2SO_4			X	X
PUSM	Drink made of water and yoghurt, and sugar in tea	X	X	X	X
	Drink made of water and yoghurt, and soda	X	X	X	X
	Mud, and lemonade	X	X		X
	Piece of chalk in water, and lemonade	X	X		
	Olive oil in water, and tea	X	X	X	X
SM	Drink made of water and yoghurt		X	X	X
	Mud, and olive oil in water		X	X	X
	Piece of chalk in water		X		

UL=Understanding Level SU= Sound Understanding PU= Partial Understanding
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DISCUSSION

The findings show that students have difficulties describing and using the terms solution, solvent and solute. Stavy (1990) maintains that the various types of knowledge exist in the cognitive system of the children and compete with acquired knowledge, which may be available in the cognitive system. Therefore, this process is a struggle in which the strongest knowledge dominates. Thus, this study's findings indicate that even though some students in the sample have an accurate understanding of chemical processes, their knowledge of solubility concepts should be greater. As a matter of fact, the present study reveals that students' misconceptions about solubility concepts may even outweigh their knowledge about the information under investigation. Therefore, this study is in agreement with Stavy's (1990) result. Moreover, some of the students in the lower grades tend to confuse both solute and solvent concepts with information concerning liquids and solids. This may stem from the knowledge their teachers impart because teachers are the prime source of instruction in the educational context.

An interesting finding that has been identified in the responses of students in the lower grades implies that sugar and water are both solute and solvent. Nevertheless, at the beginning of this process, both of them are solvents and then both of them become solutes. This reveals that students in the lower grades are not able to distinguish solutes from solvents. Moreover, as can be seen from Table 2, some of students in the upper grades claim that when a cube sugar is put into the beaker, which contains water, a chemical reaction takes places. This may also be the source of confusion between hydration and hydrolysis. That is, students may try to explain the interaction between a solute and a solvent by means of the hydration process; however, they seem to be confusing hydration with hydrolysis. Prieto et al. (1989) stated that only Grade 8 students refer to interaction between solute and solvent, however, their meanings were similar to a chemical change. Thereby, present study's findings are consistent with Prieto et al.'s (1989) research findings.

Table 6. Some examples from the given responses for Item 4 (X shows that these kinds of responses are identified at this grade; for each of the examples, the former is solvent and the latter is solute)

UL	Examples	Grade			
		7	8	9	10
SU	• Lime Tea: Water, and Lime, Pickled water: Water, and Salt, Coca Cola: Water, and Gas, Cologne: Water, and Alcohol		X	X	X
	• Lime Tea: Water, and Essence of lime, Pickled water: Water, and Vinegar, Coca Cola: Water, and CO_2, Cologne: Water, and Ethanol		X	X	X
PU	• Lime Tea: Water, and Lime, Pickled water: Water, and Salt	X	X	X	X
	• Lime Tea: Water, and Essence of lime, Pickled water: Water, and Vinegar, Cologne: Water, and Ethanol	X	X	X	X
	• Lime Tea: Water, and Lime, Coca Cola: Water, and Gas, Cologne: Water, and Alcohol	X	X	X	X
	• Pickled water: Water, and Salt, Coca Cola: Water, and CO_2, Cologne: Water, and Alcohol	X	X	X	X
PUSM	• Lime Tea: Lime, and Water, Pickled water: Salt, and Water, Coca Cola: Water, and Gas, Cologne: Water, and Alcohol	X	X	X	X
	• Lime Tea: Water, and Lime, Pickled water: Pickled and Water, Coca Cola: Gas, and Water, Cologne: Water, and Alcohol	X	X	X	X
	• Lime Tea: Water, and Lime, Pickled water: Water, and Pickled, Cola: Water, and Gas, Cologne: Acid, and Lemon	X	X		
	• Lime Tea: Water, and Lime, Pickled water: Water, and Vinegar, Cola: Gas, and Lemon, Cologne: Nitrogen, and Sugar	X	X		
	• Lime Tea: Water, and Lime, Pickled water: Water, and Pickled, Cola: Water, and Gas, Cologne: Alcohol, and Gas	X	X	X	X
SM	• Lime Tea: Lime, and Water, Pickled water: Salt, and Water, Cola: CO_2, and Water, Cologne: Alcohol, and Water		X	X	X
	• Pickled water: Pickled, and Water, Cola: CO_2, and Water, Cologne: Alcohol, and Lemon in Water		X	X	X
	• Cola: CO_2, and Water, Cologne: Alcohol, and Lemon		X	X	X

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As noted in Table 4, some students attempted to use the '100 ml water' criterion to describe both solute and solvent, at upper grades. This showed that some students retained ideas about the solubility topic; hence, they tended to use their algorithmic abilities to explain what they had learned. Moreover, some of the sample referred to the increase or decrease in the mass of the solute. Haidar (1997), Holding (1987), and Stavy (1990), reported that students had difficulties understanding conservation of mass or matter. Thus, the present study demonstrated that the misconception about the conservation of mass constituted a barrier to further learning. This finding furthered Schmidt's (1997) hypothesis, that there was a logical connection between students' misconceptions and their current state of knowledge. Moreover, Prieto et al. (1989) reported that students saw the solute as the most crucial component of dissolution process, and even though some of them used the word solvent, they tended to regard it as a passive component. In this study, some of each sample, except for Grade 7, believed that the solvent had an active role and the solute has a passive role during dissolution process as noted in Table 4. On that point, the current study did not agree with Prieto et al.'s (1989) findings.

Students had difficulties making connections between their knowledge and everyday life experiences (see Tables 5 and 6). Moreover, the examples given by most of students in the investigation were limited to particular solid-liquid and liquid-liquid solutions. However, some of the students in the upper grades referred to solid-solid and gas-gas mixtures and solutions such as air, N_2-O_2, alloys and solder. This might have resulted from their chemistry experience or the instruction they received in which chemistry was taught at a more advanced level. Furthermore, some students, apart from Grade 7, had misunderstandings about heterogeneous mixtures and suspensions. These mistakes revealed that these students were not able to distinguish between homogenous and heterogeneous mixtures.

CONCLUSIONS

One of the aims of the Turkish secondary science curriculum is to increase students' scientific literacy (Ayas, Çepni, Johnson and Turgut, 1997). Scientific literacy includes the following fundamental dimensions: (a) understanding key concepts and principles of science; (b) having the capacity for scientific ways of thinking; and (c) using scientific knowledge and ways of thinking for individual and social development. Therefore, assuming that scientific literacy shows that some of the sample under investigation appear to lack some of these ideas and are unable to apply their knowledge to novel situations; it may be concluded that although students' misconceptions affect one another directly, students' knowledge appears to be stored in a a somewhat fragmented manner without relevant links between everyday life and knowledge acquired through school experiences.

When we look at students' level of understanding by considering the sum of the percentages in 'sound understanding' and those at 'partial understanding' categories, there are some discrepancies. From Grades 7 to 9, there are similarities between responses to Items 3 and 4 that increase with grades, but the level of understanding of Grade 10 students shows a decline in comprehension. In fact, Grade 10 students perform at a higher level than both Grades 7 and 8, but they score lower than Grade 9 on these items. On Item 2 there is steady improvement with grade, and on Item 1, the level of understanding of the sample shows a 'U shaped' developmental curve. Taking the scores into consideration, it is inferred that in spite of the fact that Grade 8 students have not attended chemistry courses, they perform at a higher level than Grade 7 students, except on Item 1. Therefore, it may be concluded that this variation results from students' everyday knowledge. For example, in the case of Item I, it is possible that in order to explain the terms under investigation, the Grade 7 teacher may use a sugar-water solution; thus, Grade 7 students may have memorised and be familiar with these statements, and therefore, they may score higher than Grade 8 students. However, depending on the instruction the students have received and natural improvement with age, it may be generalised that students' conceptual understanding reveals a steady increase when it is compared with that of Grade 7, except in the case of Item 1.

IMPLICATIONS FOR PRACTICE

Posner, Strike, Hewson and Gertzog (1982) have stated that the use of four conditions of the conceptual change model might be able to replace conceptual misconceptions held by students with a scientific one. The first condition that involves dissatisfaction with existing knowledge is most important because the effectiveness of the others relies on its quality. Thus, if teachers wish to devise their own strategies by means of a conceptual change model, they need to understand their own students' conceptions and common misconceptions. Thus, they may use the present study's findings as the first step to design the other stages and guide learning.

Many researchers agree that learning is the interaction between pre-existing knowledge and new knowledge (Driver and Easly, 1978; Zietsman and Hewson, 1986). Since learning builds on the pre-existing knowledge, the learning and teaching environment should contain an advanced level of organisation and thus, teachers should try to make connections between pre-existing and new knowledge. In this way, they may identify their own student' misconceptions and then organise their courses at a more effective level by taking into consideration of the idea that misconceptions are a barrier to further learning (Herron, Cantu, Ward and Srinivasan, 1977; Novak, 1988). Therefore, teachers should recognise this study's results and use them in their classes.

Curriculum developers, teachers and teacher educators should work together with researchers to design materials that help students to develop scientific ideas and enable them to make connections between life and school experiences. Also, after collaboration, the effectiveness of the improved materials should be investigated, tested, revised, and pursued. Thus, the materials should exist in the Turkish science curriculum that could be implemented at all schools throughout the country. Moreover, some students who do not plan to continue at school should become scientifically literate and conversant with some of the important ways in which science, mathematics and technology depend upon one another. In this way, teachers, curriculum developers and teacher educators are likely to pay more attention to this idea and seek to improve the educational environment.

Some of the phenomena that students encounter are significant in chemistry teaching; one is solutions that students come across in their everyday life. In addition, some students also have significant misunderstandings about chemical processes. This shows students' lack of understanding of their own experiences and observations. Therefore, in the teaching-learning environment, we need to provide students with skills to interpret and express their own knowledge. To do so, it is necessary to devise strategies that provide students with the means to express their views as analogies, laboratory activities, and arguments. Furthermore, some tasks could be designed to help students understand the nature of solutions., This may prevent the acquisition of the bias that solution chemistry is difficult to learn. Moreover, examples related to solution chemistry should not be restricted to solid-liquid and liquid-liquid solutions, as the more examples that are given, the greater the opportunity for students to make connections between everyday life and school experiences.

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