7th-12th Grade Students, Pre-service Teachers and Science Teachers' Views on the Dissolution of Salt in a Liquid

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Abstract: In this study, a survey was conducted of students in grades 7 through 12, student teachers enrolled in their senior year at teachers' colleges, and science teachers. Subjects were surveyed on their conceptions of phenomenon related with dissolution, saturation, and extraction. The models and analogies used by student teachers and science teachers to explain dissolution were sought. The highest percentage of students thought of dissolution as a phenomenon in which particles broke into the spaces between other particles. The models or analogies used by the highest percentage of science teachers were similar. They generally conceived of dissolution phenomenon through what we call the 'space conception'. A conception of dissolution phenomenon as 'hydration through attraction of solvent and solute' was held by more student teachers than science teachers; there were some differences, however, according to their academic background. The percentage of teachers professing this view decreased when they attempted to explain the process of extraction of matter in a solution after other matter had dissolved or after the solution was cooled, indicating that the 'hydration' conception was not firmly established in the student teachers' cognition. Therefore, it can be inferred that the conceptions of dissolution as 'hydration' were transformed into the conceptions of dissolution as 'space' after teaching dissolution phenomenon as practicing teachers. This finding should be considered in teacher-training courses.

Key words: Secondary school students, science teacher, pre-service science teacher, dissolution conception, analogy, teaching model, teacher training course

I. Introduction

Dissolution is an important concept widely represented at various levels from elementary school to college. Despite repeated changes made to science textbooks to keep in line with shifts in the official curriculum of elementary, middle, and high schools, the concept of dissolution has always been presented to students. Nevertheless, it was found that the students at all levels have much difficulty in understanding this phenomenon (Noh & Jeon, 1996; Kang *et al.,* 1996; Park *et al.,* 1996; Kang *et al.,* 2000; Paik, 2000). Lee *et al.* (1996) reported that the students felt it most difficult to understand dissolution occurring in the diffusion of gases, diffusion of liquids, dissolution of chalk powder, and eruption phenomenon. They suggested that students had difficulty in understanding dissolution as the attraction between solvent and solute molecules.

Many researchers (Abraham & Williamson, 1994; Anderson & Berkheimer, 1988; Park *et al.,* 1996) have concluded, in studies on the preconceptions and change in conceptions of students, that students have many misconceptions because they interpret the phenomenon of dissolution based upon what they can see, but without any understanding of the micro conceptions related to solvents and solutes. These misconceptions are due to insufficient explanations, confusing expressions in science textbooks, ambiguity regarding the chemical theory related to dissolution, the difficulty of explaining the phenomenon, and the amount of required terminology (Abraham, 1992; Blanco & Prieto, 1997; Ebenezer & Gaskell, 1995; Kang *et al.,* 1998; Kim *et, al.,* 2000).

Most of the above mentioned studies have focused on students' conceptions or on classification of misconceptions. However, Strike and Posner (1992) pointed out that it is more important to understand the causes of misconceptions than to know the features of the misconceptions themselves. Jones *et*

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al. (2000) also stated that attention should be focused not on the classification of preconceptions or misconceptions but, instead, on curricular revision. To know and alleviate the problems occurring in the classrooms, the study of science teachers and the science textbook contents should be done in conjunction with the study of students' misconceptions.

In particular, there is a need for studies on the conceptions of student teachers according to their majors(physics education, chemistry education, biology education, and earth education, etc.) as these may be passed on to students in the future because they might teach science in middle school regardless of their majors. Moreover, it is necessary to study the problems of analogies and models used by the student teachers and teachers when explaining dissolution because there are many studies related to the effects of teachers on students' understanding(Kang *et al.,* 2004; Paik & Cho, 2005; Paik & Shin, 2005; Park *et al.,* 2006). Even when teachers hold scientifically sound conceptions of dissolution, misconceptions can occur amongst students because of the analogies or models used by the teachers (Duit, 1991; Harrison & Treagust, 1993). These results must be considered in the training of teachers.

II. Instrument and Sample

1. Instrument

Data were collected by pen and pencil questionnaire sheets designed for this study. The questionnaire consists of six items: two items related to dissolution phenomena, two items related to saturated solutions, and two items related to solubility. The items are either multiple choice questions or a request to give an explanation of the phenomenon through drawing of a diagram or writing.

The items related to dissolution phenomena consisted of an item that attempted to determine how students conceived of dissolution phenomenon and an item used to determine the models or analogies of the dissolution concept used by respondents. The items related to saturated solution consisted of an item to determine how students conceived of the types of saturated solution and an item related to the reason of volume reduction after two materials mixed. The items related to solubility consisted of an item to determine how students conceived of interaction between solutes and an item related to the calculation of solubility change according to temperature change when two kinds of solutes dissolved in a solution.

The questionnaire sheets developed were pre-tested on some students and revised based on the results. The validity of the questionnaire sheets was examined by one professional science educator and four science teachers. The following are examples of the items.

2. Explain the process of dissolving salt in water with analogies or models.
(Open ended question)

5. What happens when dissolve solute B in saturated solution of 50℃ with solute A?
(Multiple choice questions)

① Solute B doesn't dissolve in the solution.
② Solute B dissolves in the solution as same amount of in pure water of 50℃.
③ Solute B dissolves in the solution as amount of solute A extracted.
④ Solute B may dissolve more or less than solubility.
⑤ The others(Please write here________________ ____)

The time for solving this sheet was 40 minutes. Marking of the sheets and the classification of response types were immediately carried out by the researchers. When it was hard to decide the subjects' conceptions by written outcomes, interviews were conducted by the researchers.

To reduce the possible influence of researcher's bias on analysis of the responses of the questionnaire sheets, cross-checking was conduced by researchers and two other science teachers who had master's degrees in science education. The data analysis was based on a previous study (Kang *et al.,* 2004). If the results of the analysis were inconsistent, the criteria of analysis were discussed again for a more objective judgment.

2. Participants

The students studied were enrolled in grades 7 through 12, with the exception of grade 8. The omission of grade 8 is the limit of this research, but should not present a problem in finding tendencies of the students by grade based on the data.

The students were selected from each one class of two middle schools and three academic high schools in Seoul schools located near the place of researchers' work places. Student teachers were selected considering their majors from a teacher's college in Chungju. Student teachers were analyzed according to their majors. Forty-five middle and high school science teachers were selected from a graduate course of chemistry education at a university located in Chungju. Thirty-two of them were teachers of middle school and thirteen were teachers of high school. Tables 1 and 2 display the number of respondents by grade or academic major.

Table 1

Student respondents (Unit: person)

Grade	7^{th}	9^{th}	10^{th}	11^{th}	12^{th}
Number of respondents	72	86	81	86	104

Table 2

Student teachers and science teachers (Unit: person)

Major	Student teachers				Science teachers
	Physics	Chemistry	Biology	Earth Science	
Number of respondents	15	20	13	19	45

Ⅲ. Results and Discussion

1. Conceptions of Dissolution

Three types of thinking about dissolution were analyzed. In the questionnaire, the example of a solute of dissolution was salt. The three response types were: 'salt particles are surrounded by water particles', 'salt particles fit into the holes between the water particles', and 'salt particles become small' etc. The response 'salt particles are surrounded by water particles' was classified as the 'Dissolution as Hydration' concept. As presented in theoretical background, this type of thinking belongs to the scientific conception. The response type of 'salt particles insert into the holes between the water particles' was classified as the 'Dissolution as Hole between particles' concept. This type of thinking is probably due to confusion of dissolution with diffusion

Table 3

The students' conceptions on dissolution Respondent number/Total number (%)

Response types	Grade				
	7^{th}	9^{th}	10^{th}	11^{th}	12^{th}
Hydration*	0/72 (0.0)	5/86 (5.8)	14/81 (17.3)	22/86 (25.6)	30/104 (28.8)
Hole	54/72 (75.0)	66/86 (76.7)	54/81 (66.7)	44/86 (51.2)	70/104 (67.3)
Macro scope	8/72 (11.1)	11/86 (12.8)	6/81 (7.5)	3/86 (3.5)	4/104 (3.8)
Others	10/72 (13.9)	4/86 (4.7)	7/81 (8.5)	17/86 (19.7)	0/104 (0.0)
Total	72/72 (100.0)	86/86 (100.0)	81/81 (100.0)	86/86 (100.0)	104/104 (100.0)

* Scientific conception

Table 4

Conceptions of student teachers and science teachers on dissolution Respondent number/Total number (%)

Response types	Major of student teachers				Science teachers
	Physics	Chemistry	Biology	Earth science	
Hydration*	13/15 (86.7)	15/20 (75.0)	10/13 (76.9)	5/19 (26.3)	21/45 (46.7)
Hole	0/15 (0.0)	2/20 (10.0)	3/13 (23.1)	12/19 (63.2)	20/45 (44.4)
Macro scope	0/15 (0.0)	0/20 (0.0)	0/13 (0.0)	0/19 (0.0)	1/45 (2.2)
Others	2/15 (13.3)	3/20 (15.0)	0/13 (0.0)	2/19 (10.6)	3/45 (6.7)
Total	15/15 (100.0)	20/20 (100.0)	13/13 (100.0)	19/19 (100.0)	45/45 (100.0)

*Scientific conception

as pointed out in the theoretical background. The response 'salt particles become small' does not include the microscopic particle view of dissolution phenomena. This type was classified into 'Dissolution as macroscopic observation'.

The classification of the students' conceptions is shown in Table 3, while those of the student teachers' and science teachers' are shown in Table 4.

The higher the grade of the students, the higher the percentage was of students holding the scientific conception of 'Dissolution as Hydration' and the percentage of conceptions of 'Dissolution as macroscopic observation' reduced gradually according to grade. It could infer that science education can influence their students' conceptions. However, the percentage of students holding the 'Dissolution as Hole' conception does not reduce according to the grade and the highest percentage among three types of thinking. This means that students' conceptions were not corrected by science education, and that research is needed on effective teaching methods for changing students' conceptions.

The conceptions of student teachers differ according to their majors. Most student teachers with physics, chemistry, or biology majors have the 'Dissolution as Hydration' concept. However, most student teachers with earth science as their major have the 'Dissolution as Hole' conception, which explains the dissolution phenomenon as solute particles fitting into holes between solvent particles.

The science teachers hold both types of thinking, 'Dissolution as Hydration' conception and 'Dissolution as Hole' conception, evenly. This means that science teachers have a less scientific conception than student teachers. The cause of this requires further research. We can infer that science teachers' unscientific thinking can influence their students when they teach the dissolution phenomena.

2. Thinking on saturated solution

The three conceptions of saturated solution held by students, student teachers, and science teachers are related to their conceptions of dissolution. The question is 'Why can't salt dissolve any more in a saturated salt solution?' The response types were: 'because there is no water particle to surround the salt particles', 'because the holes between water particles are already filled with other salt particles', 'because the size of the salt cannot become any

Table 5

Conceptions of the students on the saturated solution Respondent number/Total number (%)

Response types	Grade				
	7th	9th	10th	11th	12th
Hydration*	2/72 (2.8)	8/86 (9.3)	10/81 (12.3)	20/86 (23.3)	22/104 (21.2)
Hole	48/72 (66.7)	70/86 (81.4)	63/81 (77.8)	46/86 (53.5)	66/104 (63.5)
Macro scope	8/72 (11.1)	7/86 (8.2)	3/81 (3.7)	6/86 (7.0)	13/104 (12.5)
Others	14/72 (19.4)	1/86 (1.1)	5/81 (6.2)	14/86 (16.2)	3/104 (2.8)
Total	72/72 (100.0)	86/86 (100.0)	81/81 (100.0)	86/86 (100.0)	104/104 (100.0)

*Scientific conception

Table 6

Conceptions of student teachers and science teachers on the saturated solution Respondent number/Total number (%)

Response types	Major of student teachers				Science teachers
	Physics	Chemistry	Biology	Earth science	
Hydration*	10/15 (66.7)	9/20 (45.0)	10/13 (76.9)	3/19 (15.8)	14/45 (31.1)
Hole	2/15 (13.3)	2/20 (10.0)	3/13 (23.1)	14/19 (73.7)	23/45 (51.1)
Macro scope	0/15 (0.0)	0/20 (0.0)	0/13 (0.0)	1/19 (5.3)	0/45 (0.0)
Others	3/15 (20.0)	9/20 (45.0)	0/13 (0.0)	1/19 (5.3)	8/45 (17.8)
Total	15/15 (100.0)	20/20 (100.0)	13/13 (100.0)	19/19 (100.0)	45/45 (100.0)

*Scientific conception

smaller' etc. The first response type was classified into the conception of 'Hydration'. The second type is classified into the conception of 'Hole'. The third type is classified into Macroscopic observation ('Macro scope'). The classification results of the students' conceptions are presented in Table 5. The classification results of the student teachers' and science teachers' conceptions are presented in Table 6.

The higher the grade of the students is, the higher the percentage of scientific conception tends to be. However, the percentage of students classified as holding the 'Hole' conception is the highest. This percentage does not reduce according to grade. This means that students' conceptions were not corrected by science education, and that research is needed on effective teaching methods for changing students' conceptions.

As with the results for dissolution, the conceptions of student teachers differ according to their majors. Most of the student teachers with physics, chemistry, or biology majors are classified as having held the 'Hydration' conception of saturated solution. However, the student teachers with earth science majors mainly are classified as having held the 'Hole' conception. The similarity of the two results (Table 4 and Table 6) adds weight to the suggestion that conceptions vary according to the major of the student teachers.

The student teachers of the four kinds of major will teach dissolution phenomena to middle school students in the future; it can be inferred that the student teachers' thoughts of dissolution might influence their students.

3. Conceptions on the phenomenon of dissolving a solute in a solution saturated with another solute

When we asked 'what would be happen when we dissolve sugar in the solution saturated with salt?', the responses of this question were classified into four types. The first type of response was that sugar would not dissolve. The second type of response was that the amount of sugar that would be dissolved is the same as the amount of salt that was extracted. The third type of response was that sugar would dissolve in a saturated solution as much as in pure water regardless of the salt in the solution. This type of response is related to the basic hypothesis of the solubility calculation represented in **'Explanation of saturated solution in science textbooks'** in the theoretical background. This type of thinking does not consider the interactions of mixed particles in the solutions.

The fourth type of thinking was that sugar might dissolve more or less than the solubility in pure water. This type of thinking can be classified as a scientific conception because this answer is right when we consider the interaction between solutes and solvent particles. The percentage of students' conceptions according to grade is presented in Table 7.

The conception held by the highest percentage of subjects is the first type, which sugar does not

Table 7

The conceptions of the students on dissolving a solute in the saturated solution with another solute

Respondent number/Total number (%)

Response types	Grade				
	7th	9th	10th	11th	12th
The other solute doesn't dissolve.	20/72 (27.8)	33/86 (38.4)	40/81 (49.4)	11/86 (12.8)	36/104 (34.7)
The other solute dissolves as much as the solute of saturated solution is extracted.	20/72 (27.8)	13/86 (15.1)	11/81 (13.6)	16/86 (18.6)	30/104 (28.8)
The other solute dissolves as much as the solubility.	14/72 (19.4)	25/86 (29.1)	5/81 (6.2)	12/86 (14.0)	20/104 (19.2)
The other solute dissolves more or less.*	2/72 (2.8)	12/86 (14.0)	20/81 (24.6)	21/86 (24.4)	12/104 (11.5)
Others	16/72 (22.2)	3/86 (3.4)	5/81 (6.2)	26/86 (30.2)	6/104 (5.8)
Total	72/72 (100.0)	86/86 (100.0)	81/81 (100.0)	86/86 (100.0)	104/104 (100.0)

*Scientific conception

dissolve in a saturated solution. This conception is unscientific because there is no consideration of particle interaction. The conception that 'the other solute dissolves in a quantity equal to that amount of the solute of the saturated solution that is extracted' is also unscientific for the same reason.

The conception that 'the other solute dissolves as much as the solubility' regardless of the salt already dissolved is the basic hypothesis of the problem of 'the separation of mixture by solubility'. Only 18% of the students held this conception. The conception that 'the other solute dissolves more or less' is a scientific conception related to hydration. Only 15% of the students studied held this type of conception. The percentage of 10^{th} and 11^{th} grade students holding this conception is higher than the percentage that of 7^{th} and 9^{th} grade students; therefore, educational efforts need to correct students' alternative conceptions to scientific conceptions.

The percentages of student teachers' conceptions on the dissolving of a solute in the saturated solution are presented according to major in Table 8.

The highest percentage of student teachers holding the scientific conception that the other solute dissolved more or less in the saturated solution was found amongst the student teachers majoring in chemistry. The majority of student teachers with physics, biology, and earth science majors held unscientific conceptions.

Of the student teachers majoring in physics, 33.3% thought that the amount of the other solute that dissolved would the same as the amount of the solute that was extracted from the solution. 33.3% of that group thought that the other solute would dissolve as much as the solute solubility regardless of salt in saturated solution. 38.5% of student teachers who major in biology and most of the science teachers also held that conception; this conception is the basic hypothesis embedded in the solubility problems in science textbooks, and indicates that student teachers and science teachers are seriously affected on their thoughts by science textbooks.

31.5% of the student teachers majoring in earth sciences thought that the other solute would not dissolve. Therefore, the student teachers' conceptions differ according to their major. However, the reason for these differences was not found in this research. Further research is needed to find the difference of teachers' thoughts by their majors.

4. Models or analogies of dissolution used by student teachers and science teachers

To teach students dissolution phenomena, it is necessary to use models or analogies because the students need to understand the movement of unseen particles. Although teachers know the concept of dissolution scientifically, they may pass misconceptions on to students through the models or analogies they use. Therefore, it is necessary to investigate the models of dissolution used by student teachers and science teachers if we want to understand the cause

Table 8

The conceptions of the student teachers and science teachers on the dissolving of a solute in the saturated solution with other solute

Respondent number/Total number (%)

Response types	Major of student teachers				Science teachers
	Physics	Chemistry	Biology	Earth science	
The other solute doesn't dissolve.	2/15 (13.3)	1/20 (5.0)	0/13 (0.0)	6/19 (31.5)	2/45 (4.4)
The other solute dissolves as much as the solute of saturated solution is extracted.	5/15 (33.3)	2/20 (10.0)	3/13 (23.1)	4/19 (21.1)	2/45 (4.4)
The other solute dissolves as much as the solubility.	5/15 (33.3)	2/20 (10.0)	5/13 (38.5)	1/19 (5.2)	30/45 (66.7)
The other solute dissolves more or less.*	1/15 (6.8)	14/20 (70.0)	4/13 (30.7)	4/19 (21.1)	8/45 (17.8)
Others	2/15 (13.3)	1/20 (5.0)	1/13 (7.7)	4/19 (21.1)	3/45 (6.7)
Total	15/15 (100.0)	20/20 (100.0)	13/13 (100.0)	19/19 (100.0)	45/45 (100.0)

*Scientific conception

of students' diverse conceptions of dissolution phenomena.

The models used by student teachers and science teachers to explain dissolution phenomena were divided into two: one is related to the conception of 'hydration' considering the interaction of particles in a solution (Fig. 2 & Fig. 3); the other is related to the conception of 'hole' considering the size difference between particles in a solution (Fig. 4 & Fig. 5).

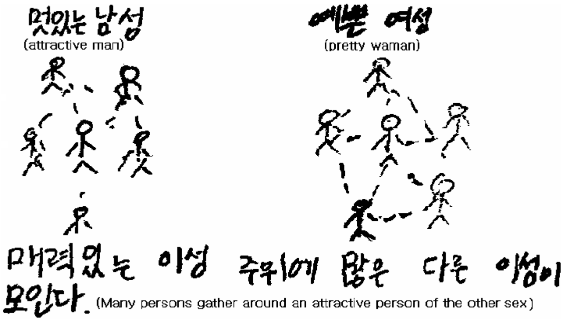

Fig. 2 *An example using the 'hydration' model and the analogy of interaction between the interaction of particles and personal attraction: "Women are attracted by a handsome man, and men are attracted by a pretty woman".*

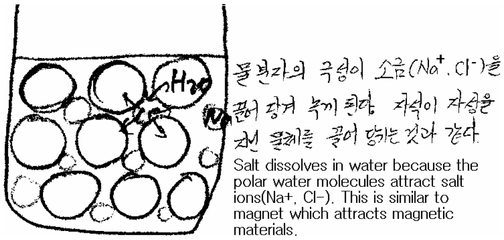

Fig. 3 *An example using both the 'hydration' model and the analogy of interaction between particles: The interaction between particles is expressed in arrows and is compared to the magnet that draws substance of magnetic property.*

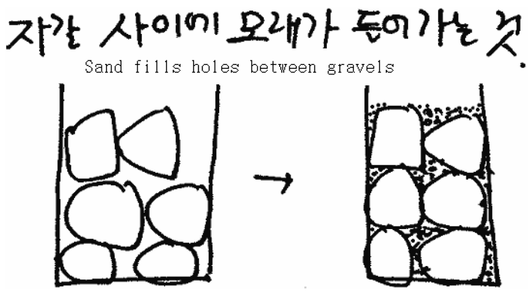

Fig. 4 *An example using 'hole' model and the analogy of the holes made by different sizes of particles: "A solvent dissolves in a solute as sand fills holes between pieces of gravel".*

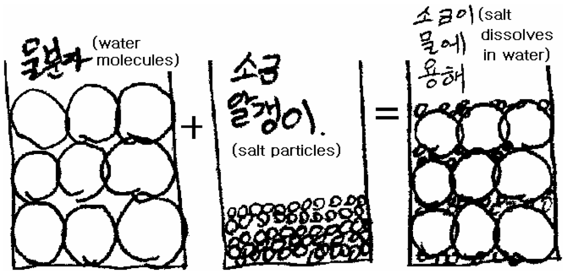

Fig. 5 *An example using 'hole' model: "Salts dissolve in water because salt particles fill holes between water molecules".*

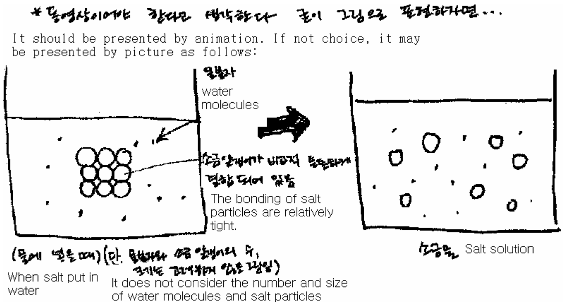

Fig. 6 *This model expresses dissolution phenomena as diffusion phenomena: "Salt particles diffuse into water molecules". This kind of expression was classified as 'other' category in Table 11.*

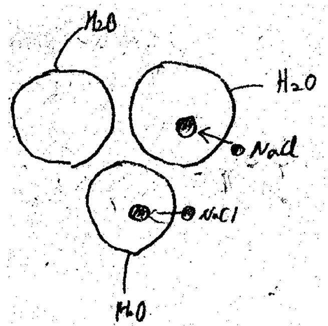

Fig. 7 *This model expresses salt dissolution in water as NaCl particles are included into water molecules.*

Also, some confused dissolution phenomena with diffusion phenomena as in Fig. 6.

A few student teachers thought that the solute particles were included in the solvent particles as in Fig. 7.

The models and analogies used by the student

Table 11

Conceptions of student teachers and science teachers on the models and analogies of dissolution

Respondent number/Total number (%)

Response types	Major of student teachers				Science teachers
	Physics	Chemistry	Biology	Earth science	
Hydration*	10/15 (66.7)	13/20 (65.0)	11/13 (84.6)	3/19 (15.8)	9/45 (20.0)
Hole	2/15 (13.3)	3/20 (15.0)	2/13 (15.4)	1419 (73.7)	22/45 (48.9)
Others	3/15 (20.0)	4/20 (15.0)	0/13 (0.0)	219 (10.5)	14/45 (31.2)
Total	15/15 (100.0)	20/20 (100.0)	13/13 (100.0)	19/19 (100.0)	45/45 (100.0)

*Scientific conception

teachers and science teachers were classified into three types as shown in Table 11.

A high percentage of student teachers whose majors are physics, chemistry, or biology used models or analogies that described dissolution in terms of the interaction between particles including the hydration concept. However, a high percentage of practicing science teachers and of student teachers whose major is earth science used models or analogies of dissolution related to holes filling particles. This tendency is similar to that shown in Table 4, which means that student teachers and science teachers use models or analogies as their conceptions.

IV. Implications for Teaching and Learning

This study investigated the conceptions of dissolution, saturation, and the extraction of solutes from solutions that were held by students from grades 7 through 12 grade, student teachers of science, and science teachers. Also, the analogies or models used by the student teachers and science teachers to explain the dissolution phenomena were investigated.

The result of this study shows that many students thought of solute dissolution as solute particles breaking into the holes between solvent particles. A higher percentage of science teachers used models or analogies related to the 'hole' conception than to any other type. Therefore, it is necessary for the student teachers to recognize this problem through teacher training courses and to develop effective teaching models or analogies to prevent students' misconceptions.

The student teachers mainly held scientific conceptions; however, more science teachers had misconceptions than student teachers. The analogies or models used by the student teachers and science teachers were related to their conceptions of dissolution, saturation, and extraction of solutes. If we connect these results, it can be inferred that student teachers' thoughts of dissolution might be changed after they become practicing science teachers due to the analogies or models they use to explain the dissolution phenomena. If it is possible, teacher-training courses should focus on recognition of the coordinate conceptions soaked into models or analogies used for explanation of scientific phenomena.

The characteristics of student teachers' thoughts according to major might be considered, too. The student teachers whose major is earth science will teach dissolution phenomena as much as the student teachers majoring in physics, chemistry, or biology. If their thoughts about dissolution differ, their students may become confused or misinformed.

From the results of this study, we conclude that student teachers' scientific conceptions related to dissolution are not firm because their thoughts related to saturation or extraction of solute phenomena were not scientific. They could not relate their scientific thinking of dissolution to other situations consistently. These problems were also found in science textbooks that were used in science classes. Both the models or analogies and the calculation problems used in science textbooks might arouse misconceptions related to dissolution phenomena. The problems of science textbooks contributing to the formation of misconceptions of students were pointed out in the previous studies (Abraham, 1992; Blanco & Prieto, 1997; Duit, 1991; Kang *et al.,* 1998; Kim *et al.,* 2000). If we fail to relieve student teachers and science teachers from the misconceptions identified by this research, they will transfer these misconceptions to students through their teaching: the high percentage of students' misconceptions supports this possibility.

There is a saying that 'the quality of the student can not surpass that of the teacher.' This saying may be interpreted as meaning that teachers who aim to reduce the misconceptions of their students, and to help their students to form scientific conceptions, should begin by correcting their own misconceptions; to do this, improvement in teacher training courses considering these research findings is necessary.

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