Determining the Level of Understanding and Misconceptions of Science Teacher Candidates about the Concepts Related to Material and Its Properties

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Abstract
This study was carried out to determine the level of understanding and misconceptions of science teacher candidates about some concepts related to material and its properties. This research was carried out with 260 science teacher candidates in Science Teaching Education Program of Education Faculty of Necmettin Erbakan University in 2015-2016 academic year. There are 17 scientifically and logically true and false sentences in the questionnaire in order to determine the level of understanding of science teacher candidates about some concepts related to material and its properties. In addition, in order to measure the participation degree of candidate teachers, three options were offered; *"I agree", "I do not agree"* and *"I have no idea"*. The data obtained from this 3-point Likert scale questionnaire were analyzed statistically. When the obtained data were evaluated, it was determined that teacher candidates had misconceptions about some concepts related to material and its properties, and some suggestions were made to eliminate these misconceptions.
Keywords: Chemistry education, Misconception, Material and its properties, Level of understanding

1. Introduction

It is a well-known fact that education process has a great importance in training new generations of a country. Since the lack of information and misconceptions that students have in the process of learning affect the successes of the new subjects negatively (Gopal et al., 2004; Garnett et al., 1995), it is very important for the teachers who have an important position in the process to be equipped in every way and to be free from misconceptions. For this reason, most of the researches on science and chemistry education have been made on determining the misconceptions about the subjects in which the teacher candidates and the students have difficulties while learning, investigating the reasons of these misconceptions and investigating the preventive and remedial methods. These researches reveal that students have some preliminary information about some concepts that can be named as misconceptions and they are incompatible with scientific information, so it is very difficult to change them (Schoon & Boone, 1998; Yağbasan & Gülçiçek, 2003; Özmen, 2004).

The misconception arises from the fact that the students configure the concepts in their minds in a way that is appropriate to their own understanding and learning and if we define the misconception in a simple way; it is the concepts that are scientifically inaccurate but understood by students in their own way (Bahar, 2003; Ebenezer and Fraser, 2001). It is seen that different terms have been used to name these structures in students' minds such as misconceptions, incorrect opinions, preconceptions, alternative structures, momentary reasoning, spontaneous ideas and alternative frames (Azizoğlu & Geban, 2004; Atasoy et al., 2003; Helm, 1980; Hewson & Hewson, 1984; Nakhleh, 1992). In general, while these terms express almost the same things, the use of different terms reflects researchers' own opinions about learning.

Chemistry is an important field of science and it has many complex and abstract concepts. Because it is seen as a difficult subject by students, they are having difficulty in developing understanding at a sufficient level about the concepts. As a result, students develop alternative concepts which are named as misconceptions. For example, the study of Valanides (2000) shows the fact that students believe there is a chemical change during dissolution.

The first step to eliminate the misconceptions which are considered as an obstacle for the emergence of meaningful learning and reaching the desired goals in education is determining the misconceptions (Case & Fraser, 1999). During the entire education process from primary education to university, there are two main sources that students can directly obtain information; book and teacher. In this context, it is very important to determine the misconceptions of teacher candidates and to correct them by using appropriate strategies when it is taken into consideration that the misconceptions of teachers are transferred directly to their students. Numerous researches have been done to determine the misconceptions of students so far. Some of these investigations have been carried out in such fields as; chemical bonding (Ballester Pérez et al., 2017; Özmen, 2004), acid-base (Sheppard, 2006; Widarti et al., 2017), buffer solutions (Harizal, 2012, Orgill & Sutherland, 2008), chemical equilibrium (Bilgin, 2006; Cheung et al., 2009), electrochemistry (Huddle & White, 2000; Lin, et al., 2002) and colligative properties (Luoga et al., 2013; Pinarbasi et al., 2009).

As mentioned above, there are some chemistry issues that students have difficulty in understanding. One of these issues is the substance and its properties which is necessary for the understanding of many areas of the chemistry. For this reason, the objective of this research is selected as determining the level of understanding and misconceptions of science teacher candidates about concepts related to material and its properties.

2. Method

2.1 Research model

In this research in order to determine "*the level of understanding and misconceptions of science teacher candidates about concepts related to material and its properties*", descriptive method was used within the frame of the scanning model. While applying this method, survey technique was used as a data collection tool.

2.2 Population and sample

The population of the research constitutes all the science teacher candidates who are studying at the universities of Turkey. The sample of the research constitutes a total of 260 teacher candidates studying in the 1st, 2nd, 3rd and 4th grades of Science Teaching Education Program of Education Faculty of Necmettin Erbakan University in the academic year of 2015-2016.

2.3 Data collection tool

In the study, a part of 3-point Likert system questionnaire of Dönmez (2011) which was prepared for the study of his master's thesis (Cronbach's Alpha value 69.4%) was used. The related study was prepared with the objective of "determining the understanding levels of pre-service primary school teacher candidates about chemistry concepts and of their misconception" and the part related to material and its properties was used in this study.

2.4 Data analysis

Data obtained from the study were evaluated by using frequency analysis, descriptive statistics, t-test and one-way analysis of variance (ANOVA). For this purpose, the program of SPSS 15.00 for Windows was used to determine the relationship between the variables. Participants in the questionnaire were asked to answer as; "I agree", "I do not agree" or "I have no idea". The answers given by the participants to the questions were re-grouped by being coded as "true", "false" and "no idea". By taking the answers given by the participants into account, the "true", "false" and "no idea" answers were coded respectively as 2.00, 0.00, and 1.00.

3. Findings and Discussion

3.1 Frequency and percent analysis

The frequency and percentages of the answers given by science teacher candidates for 17 questions about "material and its properties" are given in Table 1. When Table 1 is examined, it is assumed that participants have conceptual misconceptions about the questions of Q1, Q3, Q4, Q5, Q7, Q9, Q11, Q13, Q14 and Q16 since the false-answer rate is over 15% for these concepts. However, it can be seen that the rate of wrong answers in Q1, Q3, Q4 and Q9 is very high (above 60%). The questions that contain misconceptions are evaluated respectively below; the reasons leading to misconceptions are interpreted and associated with related literature.

"As we go up to the heights, the atmosphere pressure increases."

This question is a scientifically wrong statement and it was asked in order to determine the misconception of "atmospheric pressure changes with altitude" because the atmosphere pressure falls as we go up to the heights. It was determined that 67.7% of teacher candidates answered incorrectly. This result is in harmony with the findings of Akbaş & Gençtürk (2011). Here it is revealed that the participants generate false information and cannot structure the subject at academic level. This can be attributed to the fact that the concept is abstract and where the atmospheric pressure is originated from has not been understood because of rote-learning based education system.

"*Sugar melts in water. So the sugar turns into water. Finally, sugar becomes water.* "

This question is a scientifically false statement and it was posed to determine the misconception of the dissolution phenomenon. 24.2% of the candidates' thinking this expression as true, may be due to the fact that they consider the dissolution as a chemical reaction and because of the colourlessness of the solution, they may think that sugar turns into water. Prieto et al. (1989) determined that students have conceptual misconceptions about their ideas related to the subject of dissolution as "solvated things melt, dissolve and get lost, a new substance formed, and water and sugar molecules unite". This result shows that students do not reveal the conceptual differences between chemical and physical changes in their cognitive structure.

"Chemistry creates a relationship between the structure and properties of material and discusses the benefits of doing research within these relations."

This question was posed to determine the misconception of the definition of Chemistry. This statement is scientifically false but it is thought as true by 88% of the teacher candidates. Chemistry does not discuss the benefits of doing research, even though it is a material science. Teacher candidates' falling into this misconception may be due to the fact that they respond by taking a part of the question into account rather than the whole of the question.

"Water is a homogeneous mixture of oxygen and hydrogen elements."

67.3% of the teacher candidates were mistaken in thinking the answer given to this question as correct. 67.3% of the teacher candidates' giving wrong answer to this question, which was posed to determine the misconceptions about chemical compounds, shows that they have a quite big misconception. The study by Griffiths & Preston (1992) reveals that students think as; "Water is a homogeneous mixture of oxygen and hydrogen elements". Although many learners know that water is composed of H_2 and O_2, it appears that there are contradictions in their minds whether water is a mixture or a pure substance consisting of molecules. This situation can be interpreted as the fact that the information, students had already learned before, is in conflict with the information they have learned in the university and the meaningful learning does not take place, so this situation causes misconception.

"The atoms expand when the material is heated." and *"When the material freezes, the atoms also freeze."*

The teacher candidates who answered these questions that are about the relationship between atom and energy gave 71.9% and 26.4% wrong answers respectively. Both questions are about students' most controversial issues and they involve abstract events related to the microscopic structure of the material. The high rate of false answers for the first expression can be interpreted as this misunderstanding comes from the idea that the atoms will expand when heated, as indicated by Pereira & Pestana (1991). As a result, that may be concluded that students are trying to relate the events at microscopic size to the events that occur at macro size.

Table 1. Frequency analysis related to material and its properties

Questions	**True (2)**		**False (0)**		**No idea (1)**	
	f	**%**	***f***	**%**	***f***	**%**
Q1- As we go up to the heights, the atmosphere pressure increases.	79	30.4	176	67.7	5	1.9
Q2- The ionic compounds are crystalline and their melting and boiling point is very high.	194	74.6	18	6.9	48	18.5
Q3- The atoms expand when the material is heated.	47	18.1	187	71.9	26	10.0
Q4- When the material freezes, the atoms also freeze.	126	48.5	68	26.2	66	25.4
Q5- Sugar melts in water. So the sugar turns into water. Finally, sugar becomes water.	184	70.8	63	24.2	13	5.0
Q6- Materials such as iron, nickel and cobalt are attracted by the magnet.	247	95.0	8	3.1	5	1.9
Q7- Chemistry creates a relationship between the structure and properties of material and discusses the benefits of doing research within these relations.	7	2.7	231	88.8	22	8.5
Q8- Elements and compounds are pure substances.	223	85.8	37	14.2	-	-
Q9- Water is a homogeneous mixture of oxygen and hydrogen elements.	68	26.2	175	67.3	17	6.5
Q10- The chemical properties of isotope atoms are the same but their physical properties are different.	184	70.8	37	14.2	39	15
Q11- As the rate of sugar dissolved in water increases, the boiling point of the water increases and the freezing point decreases.	175	67.3	44	16.9	41	15.8
Q12- Boiling point of water is 100°C and the freezing point is 0°C at sea level.	247	95.0	10	3.8	3	1.2
Q13- The materials forming the mixture lose their properties.	137	52.7	115	44.2	8	3.1
Q14- The materials are only the visible ones.	198	76.2	46	17.7	16	6.2
Q15- The element is composed of single atoms, the compound is composed of different kinds of atoms.	234	90.0	17	6.5	9	3.5
Q16- The diluted solution and the unsaturated solution are the same as the concentrated solution and the saturated solution's being same.	91	35.0	142	54.6	27	10.4
Q17- The reaction of a material with oxygen is called burning.	251	96.5	5	1.9	4	1.5

"As the rate of sugar dissolved in water increases, the boiling point of the water increases and the freezing point decreases."

In this question posed to determine the misconception about the change of melting and freezing points of solutions with concentration, it was determined that 16.9% of teacher candidates answered wrongly. Although this rate is close to the limit value, it can be said that the participants have misconceptions about the boiling and freezing points of solutions. It has also been identified in previous studies that teacher candidates have misconceptions about boiling and freezing points of solutions (Blanco & Prieto, 1997; Pinarbasi et al., 2009).

"The materials forming the mixture lose their properties."

The question was posed to determine the misconceptions about mixtures and it is a scientifically false statement because the ingredients in the mixture do not lose their properties. 44.2% of teacher candidates' responding incorrectly can be interpreted as candidates have not fully understood the concept of mixture and cannot construct it in their minds.

"The materials are only the visible ones."

It is an incorrect statement posed to determine the misconception of the granular structure of the material. Because 17.7% of teacher candidates answered incorrectly -very close to the limit value- it can be said that teacher candidates have misconceptions about this issue.

"The diluted solution and the unsaturated solution are the same as the concentrated solution and the saturated solution's being same."

It can be said that the participants have the misconceptions because 54.6% of the teacher candidates responded wrongly to this question posed to determine the misconceptions related to solution concentration. The dilute solution is unsaturated but that does not mean that the concentrated solution is a saturated solution. This situation is due to the fact that they respond by taking a part of the question into consideration rather than the whole of the question.

3.2 Descriptive analysis

The descriptive analysis results of science teacher candidates about "material and its properties" are given in Table 2. The "true", "false" and "no idea" answers given to the questions by teacher candidates were coded as 2.00, 0.00, and 1.00, respectively. It is evaluated according to the score obtained from the analysis that when this score is in the range of 0.00-0.66, the teacher candidates generally have the wrong information, when in the range of 0.67-1.33, the teacher candidates do not have an idea, and when in the range of 1.34-2.00, the teacher candidates have correctly constructed their information.

When table 2 is examined, it can be said that teacher candidates generally have misinformation about concepts in such questions with scores between 0.00-0.66 as; *"As we go up to the heights, the atmosphere pressure increases. ($\bar{X}_{S1}$=0.63)", "The atoms expand when the material is heated. ($\bar{X}_{S3}$=0.46)", "Chemistry creates a relationship between the structure and properties of material and discusses the benefits of doing research within these relations. ($\bar{X}_{S7}$=0.14)", "Water is a homogeneous mixture of oxygen and hydrogen elements. ($\bar{X}_{S9}$=0.59)".*

And it can be said that no meaning has emerged in teacher candidates' minds about concepts in such questions with scores between 0.67-1.33 as; "*When the material freezes, the atoms also freeze. ($\bar{X}_{S4}$=1.22)", "The materials forming the mixture lose their properties. ($\bar{X}_{S13}$=1.08)" and "The diluted solution and the unsaturated solution are the same as the concentrated solution and the saturated solution's being same. ($\bar{X}_{S16}$=0.80)".* This situation, while not being directly regarded as a misconception, can be regarded as a situation that can create a basis for the misconception in students' minds.

Table 2. Descriptive analysis related to material and its properties

Questions	***N***	$\bar{X}$	***Sd***
Q1- As we go up to the heights, the atmosphere pressure increases.	260	0.6269	0.91915
Q2- The ionic compounds are crystalline and their melting and boiling point is very high.	260	1.6769	0.59878
Q3- The atoms expand when the material is heated.	260	0.4615	0.78257
Q4- When the material freezes, the atoms also freeze.	260	1.2231	0.83611
Q5- Sugar melts in water. So the sugar turns into water. Finally, sugar becomes water.	260	1.4654	0.85805
Q6- Materials such as iron, nickel and cobalt are attracted by the magnet.	260	1.9192	0.36920
Q7- Chemistry creates a relationship between the structure and properties of material and discusses the benefits of doing research within these relations.	260	0.1385	0.41690
Q8- Elements and compounds are pure substances.	260	1.7154	0.70008
Q9- Water is a homogeneous mixture of oxygen and hydrogen elements.	260	0.5885	0.87647
Q10- The chemical properties of isotope atoms are the same but their physical properties are different.	260	1.5654	0.72965
Q11- As the rate of sugar dissolved in water increases, the boiling point of the water increases and the freezing point decreases.	260	1.5038	0.76858
Q12- Boiling point of water is 100 ° C and the freezing point is 0 ° C at sea level.	260	1.9115	0.39770
Q13- The materials forming the mixture lose their properties.	260	1.0846	0.98274
Q14- The materials are only the visible ones.	260	1.5846	0.77394
Q15- The element is composed of single atoms, the compound is composed of different kinds of atoms.	260	1.8346	0.51946
Q16- The diluted solution and the unsaturated solution are the same as the concentrated solution and the saturated solution's being same.	260	0.8038	0.92789
Q17- The reaction of a material with oxygen is called burning.	260	1.9462	0.29959
The general total	260	22.0500	3.80121

Moreover, in Table 2, when looking at the general total ($\bar{X}$ = 22.05), it appears that the average of teacher candidates' opinions about *material and its properties* is close to the "no-idea" expression. The main factor for this outcome's being emerged is the scores belonging to the concepts in the questions of Q1, Q3, Q7 and Q9. In addition, other questions affecting the average value are Q1, Q3, Q7 and Q9, which have scores between 0.67 and 1.33.

3.3 One-way analysis of variance according to the variance of class (one-way ANOVA)

According to the one-way analysis of variance carried out at 0.05 significance level given in Table 3, it was determined that the misconception levels of science teacher candidates about the material and its properties did not differ significantly according to the variance of class (p>0.05). This conclusion proves that the readiness level of class groups is equal.

Table 3. One-way ANOVA results according to variance of class (p<0.05)

Grade (N)	**Source of variance**	**Sum of Squares**	***Df***	**Mean Square**	***F***	***p***
1st grade (75) 2nd grade (71) 3rd grade (62) 4th grade (52)	Between Groups	25.723	3	8.574	0.591	0.622
	Within Groups	3716.627	256	14.518		
	Total	3742.350	259			

One-way ANOVA was applied at a significance level of 0.05 in order to determine the effect of the variance of class on the understanding levels of science teacher candidates related to some concepts about the material and its properties. The results in Table 3 show that the variance of class does not affect the level of understanding related to some concepts about the material and its properties (p>0.05). This conclusion proves that the readiness level of class groups is equal.

4. Result and Suggestions

Nowadays, many researchers agree that while the curriculum is being developed and teaching materials are being prepared, students' misperceptions must be taken into account. Students' understanding of scientific concepts and issues in a meaningful way has an important role in achieving their goals in science education programs (Kılıç & Sağlam, 2009). It is of great importance to eliminate the misconceptions of science teacher candidates because they are effective in achieving this aim. For this reason, in this study, our aim is to investigate the misconceptions and the level of understanding of science teacher candidates about the concepts related to material and its properties.

Teacher candidates in the sample of the research have incorrect information about some concepts related to material and its properties, which is described as misconception. These concepts are; *"atmosphere pressure", "the relationship between the material and energy", "the definition of chemistry"* and *"chemical compounds"* and also these concepts have been questioned in the questions of *"As we go up to the heights, the atmosphere pressure increases."*, "*The atoms expand when the material is heated.", "Chemistry creates a relationship between the structure and properties of material and discusses the benefits of doing research within these relations."* and *"Water is a homogeneous mixture of oxygen and hydrogen elements."* In addition, it has been determined that no meaning has emerged in teacher candidates' minds about concepts questioned in such questions as; "*When the material freezes, the atoms also freeze.", "The materials forming the mixture lose their properties." and "The diluted solution and the unsaturated solution are the same as the concentrated solution and the saturated solution's being same."* These concepts are usually abstract concepts related to the microscopic structure of materials. This is indicated by Del Poza (2001) as the change in the perceptions of students in the transition from macroscopic size to microscopic size is one of the reasons for the misconceptions.

As a result, it is seen that the science teacher candidates in the sample of the study have misconceptions about some concepts related to material and its properties. When we think that teacher candidates will be teaching these concepts in the future, it becomes clear how important it is to detect and eliminate these misconceptions. It is considered that, if these misconceptions arising from this study are taken into consideration while teaching the material and its properties, it will increase the quality of learning.

The researches have shown that traditional teacher-centered teaching approaches fail to prevent the misconceptions (Bodner 1986; Felder 1996). In terms of these findings and results obtained from this research, the following suggestions can be made to correct and prevent the misconceptions and to make meaningful learning possible.

- Activities should be held to ensure that teacher candidates encounter with misconceptions. In this way, it will be possible for teacher candidates to become aware of their misconceptions and to correct them.
- In researches carried out to determine the misconceptions of teacher candidates, there should be questions or statements that allow students to reason and think logically.
- Attention should be given to explain and exemplify the subjects and concepts related to daily life. Because students' attention will be maintained and learning qualities will be raised in this way, misconceptions can be

avoided.

- Teacher candidates should be given instructional activities appropriate to their level of understanding and comprehension. In this way, concept teaching can be carried out more easily, so candidates will be able to learn the concepts more meaningfully and permanently.
- Teacher candidates should be aware of effective learning methods and apply them to prevent misconceptions. At this point, teacher training institutions should apply programs that enable teacher candidates to gain experience during undergraduate study.

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