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UNIVERSITY STUDENTS' UNDERSTANDING OF DENSITY AND CONCENTRATION: A CROSS-LEVEL INVESTIGATION

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ABSTRACT: In this study, it was aimed to explore all level university chemistry students, from freshmen to the students who graduated from the university chemistry departments, how students define the concepts of density, concentration, and solvation which are the fundamental and basic concepts of chemistry. Qualitative data were gathered in a test composed of 3 open-ended questions distributed to 135 university students comprising two different academic institutions: Education faculty and science and art faculty. Students were asked to provide a written description of three concepts. The data were analyzed by using both content analysis method and a concept-evaluation scheme. It was found that students had different understanding levels concerning three concepts and problems to the description of them. To add, students had the problem concerning the concept of mass which is a pre-requisite concept for density. The reason for the students' difficulties with density and concentration can be related to nature of these concepts that involve proportional reasoning.

Keywords: University students, understanding, density, concentration, solvation

INTRODUCTION

The chemistry education literature contains a large number of studies about students' conceptions about chemical phenomena and concepts. The students' understanding of the density has been thoroughly investigated at all level (Kohn and Landau 1987; Yeend, Loverude, and Gonzales 2001; Hashweh, 2016). Although density is seen a simple concept, Hashweh (2016) has indicated that it is a difficult concept to understand by middle school children and efforts to foster students' understanding are not very successful. He has investigated the reasons for the difficulties and the specific difficulties that students encounter when learning about density at the middle school level. In his study, firstly he has presented a historical account of the development of the density concept in order to show the difficulties in its development within the scientific community. Hashweh (2016) has concluded three points from this brief historical summary of the development of the scientific concept of density. One of them was that the concept itself was part of the conceptual system included many interconnected concepts. These interconnected concepts were the concepts of mass, weight, volume, and the relations between mass and motion. Yeend, Loverude and Gonzalez (2001) also found that middle school, high school, and college students harboured numerous alternate conceptions, particularly a tendency to associate mass, volume, and density with size.

The concepts of density and concentration are the fundamental concepts that occur at all levels of chemistry education from middle school to university levels. On the other hand, both concepts and difference between them are not easily grasped by the students. Density is a characteristic property of a pure substance and directly related to mass. Concentration is defined as the amount of one component in a matter which contains more than one component. There are several types of concentrations defined. However, density is often confused with concentration. When university students are asked to define the density, it can be seen that they can define the concentration instead of density. In this study, it was aimed to explore all level university chemistry students, from freshmen to the students who graduated from the university chemistry departments, how students define the concepts of density, concentration, and solvation.

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METHODS

Participants

Qualitative data were gathered in a test composed of 3 open-ended questions distributed to 135 university students comprising two different academic institutions: Education faculty and science and art faculty. Students were asked to provide a written description of three concepts that is density, concentration, and solvation.

Analysis of Data

In analyzing the three questions of the test, a concept-evaluation scheme developed in previous research was used (Abraham et al., 1994; Haidar, 1997; Nakiboğlu, 2003). This scheme enables the researcher to look into the data from two points. The students' responses can be separated into different levels of understanding and misconceptions can analyze into different patterns (Haidar, 1997; Nakiboğlu, 2003). The concept-evaluation scheme used in this study is comprised of five categories listed and defined in Table 1. During these analyses misconception statements were identified using a coding system.

Table 1. The Scheme with Five Categories Used in this Study and Description of Each Category

Degree of understanding	Criteria for scoring
Sound understanding (SU)	Responses that include all components of the validated response
Partial understanding (PU)	Responses that include at least one of the components of the validated response, but not all the components
No understanding (NU)	Irrelevant responses
Misconception (MC)	Responses about concept which do not correspond to currently held scientific theory
No answer (NA)	Blank

RESULTS AND FINDINGS

Students' Understanding about Solvation

The first question was about the description of solvation concept. The solvation concept is one of the important pre-requisite concepts for learning both density and concentration. For this reason to find out the patterns of students' understandings and misconceptions of the solvation concept is important. The complete list of students' thoughts for their first question was coded and presented below in Table 2 according to the degree of students' understanding levels about solvation.

Table 2. Degree of Students' Understanding about Solvation

Degree of understanding	1st Grade (N=19) f (%)	2nd Grade (N=19) f (%)	3rd Grade (N=34) f (%)	4th -5th Grade (N=43) f (%)	Graduated (N=20) f (%)	Total (N=135) f (%)
SU	1 (5,3)	1 (5,3)	2 (5,9)	3 (7,0)	4 (20,0)	11 (8,1)
PU	13 (68,4)	11 (57,9)	20 (58,8)	33 (76,7)	12 (60,0)	89 (65,9)
NU	4 (21,0)	1 (5,3)	8 (23,5)	5 (11,6)	2 (10,0)	20 (14,8)
MC	1 (5,3)	0	1 (2,9)	1 (2,3)	1 (5,0)	4 (3,0)
NA	0	6 (31,5)	3 (8,8)	1 (2,3)	1 (5,0)	11 (8,1)

According to Table 2, 8.1 % of all students showed a SU for the solvation concept that the solvation describes as solvation is the process that a substance dissociates to ion or molecules in solvent/liquid by surrounding with solvent molecules. 65.9% of the students suggested that the solvation is changing / disintegration / dissolution / separation/ the separation of particles/ of a substance until disappearing in another substance / in a solvent/ which was considered as PU. About 3% of the students showed misconception and only one misconception statement was identified through analysis of this question. This misconception is "solvation is an amount of matter which solves in a liquid solution" and it can be said that students confuse solvation with concentration.

Students' Understanding about Density

The second question was about a description of density concept. The main goal of this question is to find out the patterns of students' understandings and misconceptions about density. The complete list of students' thoughts for the second question was coded and presented below in Table 3 according to the degree of students' understanding levels about density.

Table 3. Degree of Students' Understanding about Density

Degree of understanding	1st Grade (N=19) f (%)	2nd Grade (N=19) f (%)	3rd Grade (N=34) f (%)	4th -5th Grade (N=43) f (%)	Graduated (N=20) f (%)	Total (N=135) f (%)
SU	11 (57,9)	3 (15,8)	4 (11,8)	6 (14,0)	0	24 (17,8)
PU	1 (5,3)	4 (21,0)	13 (38,2)	8 (18,6)	7(,0)	33 (24,4)
NU	1 (5,3)	8	5 (14,7)	4 (9,3)	4 (20,0)	22 (16,3)
MS	6 (31,6)	4 (21)	7 (20,6)	25 (58,1)	9 (45,0)	51 (37,8)
NA	0	0	5 (14,7)	0	0	5 (3,7)

According to Table 3, only 17,8 % of all students showed sound understanding for this question that they described density as "density is a mass of a substance per its unit volume". While none of the graduated students described the density correctly, 57,9 % of the first-grade students showed sound understanding. In partial understanding, the students have given mathematical expression instead of definition for density such as mass to volume ratio or the mass divided by volume or d=m/V.

It can be seen from Table3, all levels students had a misconception about density. It was found that those students presented the definition of concentration instead of density. They described density with the expression of concentration such as "density is the amount of substance in per unit volume or the amount of substance in per liter".

Students' Understanding about Concentration

The third question was about the description of concentration concept. The main goal of this question is to find out the patterns of students' understandings and misconceptions about concentration. The complete list of students' thoughts for the second question was coded and presented below in Table 4 according to the degree of students' understanding levels of concentration.

Table 4. Degree of Students' Understanding about Concentration

Degree of understanding	1st Grade (N=19) f (%)	2nd Grade (N=19) f (%)	3rd Grade (N=34) f (%)	4th -5th Grade (N=43) f (%)	Graduated (N=20) f (%)	Total (N=135) f (%)
SU	12 (15,8)	10 **(52,6)**	9 (26,5)	13 (30,2)	3 (15,0)	47 (34,8)
PU	1 (5,3)	3 (15,8)	9 (26,5)	24 (55,8)	12 (60,0)	49 (36,3)
NU	2 (10,5)	3 (15,8)	5 (14,7)	5 (11,6)	2 (10,0)	17 (12,6)
MS	3 (15,8)	1 (5,3)	4 (11,8)	1 (2,3)	0	9 (6,7)
NA	1 (5,3)	2 (10,5)	7 (20,6)	0	3 (15,0)	13 (9,6)

According to Table 3, 34,8 % of all students showed sound understanding for this question. 9% of students had the misconception that one of them was "concentration is the case that the components of a substance are dense".

Comparison of Students' Understanding about Density and Concentration

The results of comparison of the students' understanding level about density and concentration are presented in Table 5.

Table 5. Frequencies of Students' Understanding about Density (D) and Concentration (C)

Degree of understanding	1st Grade D/C	2nd Grade D/C	3rd Grade D/C	4th -5th Grade D/C	Graduated D/C	Total D/C (%)
SU	11/12	3/10	4/9	6/13	0/3	24/47 (17,8/34,8)
PU	1/1	4/3	13/9	8/24	7/12	33/49 (24,4/36,3)
NU	1/2	8/3	5/5	4/5	4/2	22/17 (16,3/12,6)
MS	6 /3	4/1	7/4	25/1	9/0	51/9 (37,8/6,7)
NA	0/1	0/2	5/7	0/0	0/3	5/13 (3,7/9,6)

According to Table 5, both SU and PU levels of concentration concept were higher than density concepts'. Most of the students confused density with concentration.

CONCLUSION

It was concluded that all level of students' understanding about concentration were higher than the degree of understanding about density. When the students asked to define the density it was determined that most of the

students defined the concentration instead of density. Smith, Carey, and Wiser (1985) indicated that the difficulty with density arises mainly from undifferentiated conceptions that become differentiated within a new conceptual system. It was also found that all students had the misconception about density. Most common misconception identified in this study was that "density was the amount of a matter in the unit volume". Besides, most of the students' responses about density indicated NU contains irrelevant answers.

RECOMMENDATIONS

Before teaching density and concentration to students, students' pre-requisite knowledge about these concepts (solvation, mass, volume and mole, mole number) was examined and corrected. Density and concentration concepts which are used together in some calculations should be kept on the agenda and repeated in all level. Differences between concentration and density should be clarified.

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