Assessing Pre-service Teachers' Conceptual Understanding on 'Amount of substance' and the 'Mole' in Ghana

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Abstract: ***The purpose of the study was to assess pre-service science teachers' conceptual understanding on mole concept. Survey design was used for this study. Purposive sampling technique was used to select the sample for the study. The sample for the study was two first year intact science classes at Wesley College of Education. The total sample size was sixty (60) students. Interviews, Mole content knowledge test (MCKT) were designed for the study. The study revealed that pre-service science teachers used in this study have not developed an appropriate conceptual understanding of the mole concept, and therefore possessed a lot of alternative conceptions about the concept.***

Keywords: Stoichiometry, Alternative conception, Knowledge

1. Introduction

Science education has secured a key place in the curriculum of schools of most countries around the world, and Ghana is no exception. Whether learners of science would understand and apply the scientific concepts learnt to effect the needed development or not, depends largely on the preparation given to science teachers. One of the goals of science education is to develop learners' ability to acquire knowledge in specific subject areas and to improve their conceptual understanding.

Chemistry is the science that deals with chemical changes involving the mole, molecule, and particle concepts as well as mathematical computations. As it is well known, the mole is used as a unit to calculate the amount of substances involved in a chemical reaction and the products forming at the end. Thus, an informed understanding of the mole concept is essential to solve stoichiometry questions correctly (Schmidth, 1994). The mole is a central concept in chemistry, and is a fundamental foundation for such complex topics as stoichiometry, the gas laws, solution concentration, solubility product, equilibrium constant, and pH. Staver and Lumpe (1993) claimed that the concept of the mole is essential to "successful understanding of domain-specific knowledge in chemistry", and that understanding and mastery of the mole is very important to chemistry students in their studies. The mole concept is also fundamental to the "mathematics of chemistry", since a majority of the quantitative work in the colleges of education involves the mole, either directly or as a bridge between a variety of quantities (Gower, Daniels & Lloyd,1977; Dorrin, Demmin & Gabel, 1989). Therefore, students' understanding of the mole affects more than just one component of their overall studies in chemistry. Their success in chemistry, particularly in problem solving, will be limited if the proper foundation of the mole and related concepts is lacking.

2. Statement of the Problem

Science educators, parents and other stakeholders in science education in Ghana have expressed concern about the performance of students in chemistry in the Diploma in Basic Education for some time now. Chemistry Chief Examiners' Reports over the years have consistently lamented the poor performance of pre-service science teachers in the elective chemistry paper. Proper understanding of mole concept, which occupies a central position in chemistry and serves as basis for understanding many concepts in chemistry has been cited as a major contributing factor for this reported abysmal performance. In summarizing candidates' weaknesses in the first year, end-of-first semester examination paper for the Colleges of Education, the Chief Examiner for elective chemistry, stated that candidates showed complete lack of knowledge of some topics in the college science syllabus making them perform very badly in the examination (College of Education Chief Examiner for chemistry, 2008, 2009). The mole concept, balancing of chemical equations, among others was cited as examples. He added that questions involving calculations on the mole concept was poorly done. Furio, Azcona, Guisasola and Ratcliffe (2000) asserted that students have difficulties in understanding the mole concept and using it in solving related stoichiometry problems. This has necessitated the need to investigate pre-service science teacher's conceptual understanding on the mole concept and amount of substance.

3. Purpose of the Study

The purpose of the study was to assess pre-service science teachers' conceptual understanding of mole concept.

Research Question

What is the conceptual understanding of pre-service science teachers on mole concept?

4. Methodology

Survey design was used for this study. The focus of the study was on chemistry students at the Colleges of Education in Ghana. The target population was all chemistry students at Wesley College of Education. To be precise, the population was the 2011/2012 first year chemistry students of Wesley College of Education was used.

Purposive sampling technique was used to select the sample for the study. The sample for the study was two first year intact science classes at Wesley College of Education. The total sample size was sixty (60) students. Interviews, Mole content knowledge test (MCKT) were designed for the study. The MCKT was selected from the end of semester examination questions from the University of Cape Coast. The test consisted of twenty (20) multiple choice questions and ten (10) short answer type questions. These questions were critically reviewed by an assessment and evaluation officer, and a subject area expert. Semi-structured interview was used to collect the qualitative data.

5. Results/Discussion

The conceptual understanding of pre-service science teachers on mole concept are presented on Table 1.

Table 1: Descriptive statistics of conceptual understanding of pre-service science teachers on mole concept

Item	N	Mean	Std. Deviation
1. The mole is a number.	60	3.87	1.42
2. The mole is a mass.	60	3.03	1.518
3. The mole is a unit.	60	2.97	1.646
4. The relative atomic mass of an atom is measured in amu.	60	3.22	1.708
5. The mass of 1 mol of Na is equal to the mass of 1 mol of Ca.	60	3.15	1.706
6. The mole is also referred to as Avogadro's number.	60	3.38	1.552
7. The mole represents the number 6.02×10^{23}.	60	3.45	1.588
8. 1 mol of hydrogen gas contains the same number of molecules as there are carbons atoms in 12.0g of carbon-12.	60	2.37	1.518
9. The concept of the mole says that in a defined mass of an element there is precise number of atoms.	60	3.05	1.455
10. The number of molecules in one 1mol of hydrogen gas is the as the number of molecules in 1mol of oxygen gas.	60	2.85	1.516
11. 1mol of hydrogen will occupy twice as much volume as 0.5 mol of carbon dioxide at STP.	60	2.22	1.277

Source: Students' questionnaire N = Number of respondents

From Table 1, it can be noticed that the mean scores of items 3, 8, 10 and 11are below 3. This means that students' conceptual understanding regarding items 3, 8, 10 and 11 were below average. Again, the standard deviation values corresponding to these items (3, 8, 10 and 11) are 1.646, 1.518, 1.516, and 1.277 respectively.

On the other hand the other seven (7) items have mean values greater than three (3) but less than four (4). This indicates positive conceptions with slight uncertainty. Again the standard deviation values for these items are large; an indication of great variation among the responses. This means that a good number of the respondents have negative conceptions regarding these concepts.

Again, in answering research question one (1), students' responses to the interview schedule in were analysed. During the interview session, the subjects were asked to think aloud while answering the questions and were interrupted when necessary. Calculating the number of chloride ions in 0.4mol of calcium chloride ($CaCl_2$) in the interview schedule required subjects to write a balanced dissociation reaction for calcium chloride ($CaCl_2$) (i.e. $CaCl_2 \rightarrow Ca^{2+} + 2Cl^-$) and note that 1mol of calcium chloride ($CaCl_2$) produces 2mol of chloride ions ($2Cl^-$). Hence, 0.4mol of calcium chloride ($CaCl_2$) produces 0.8mol of chloride ions (Cl^-). Again, the subjects were to proceed to indicate that 1mol of chloride ions contains the Avogadro number (i.e. $L = 6.02 \times 10^{23}\ mol^{-1}$) of ions and therefore, 0.8mol will contain $0.8 \times 6.02 \times 10^{23}$ to obtain 4.816×10^{23} chloride ions. This operation was perfectly achieved by 2 students (20%). A total of 3 students representing 30% showed partial understanding by failing to balance the dissociation reaction and as such could not deduce that 0.4mol of calcium chloride ($CaCl_2$) produces 0.8mol of chloride ions (Cl^-). They instead multiplied 0.4mol by 6.02×10^{23} to obtain 2.408×10^{23} chloride ions. They failed to realise that calcium chloride ($CaCl_2$) contains two chlorine atoms and such will produce two chloride ions on dissociation.

In addition, 1 student representing 10% showed partial understanding with specific misconception by changing formula of calcium chloride ($CaCl_2$) to correspond to that of the products. They changed the subscript ($_2$) of chlorine in the calcium chloride to one ($_1$) in the reactant. For example, $CaCl \rightarrow Ca^{2+} + Cl^-$. These students stated that 0.4mol of calcium chloride ($CaCl_2$) produce 0.4mol of chloride ions. They therefore multiplied the 0.4mol to 6.02×10^{23} to obtain 2.408×10^{23} chloride ions.

Two (2) students representing 20% of the ten students interviewed showed specific misconception. They stated that 0.4mol of calcium chloride ($CaCl_2$) contains 1.605×10^{23} chloride ions. They explained that the fraction of chlorine in calcium chloride is 2/3 and so 0.4mol calcium chloride contains 2/3 of 0.4mol chloride ions which is 0.267mol. Hence the number of chloride ions was calculated to be 1.605×10^{23}. These students lack the conception that on dissociation, 1mol of calcium chloride ($CaCl_2$) produces 2mol of chloride ions (Cl^-) (i.e. $CaCl_2 \rightarrow Ca^{2+} + 2Cl^-$) and as such the amount of chloride ions is 2×0.4 (i.e. 0.8) instead. Finally, 2(20%) subjects showed no understanding of the concept at all by failing to write anything in the spaces provided. They told the researcher they had no idea.

Table 2: The distribution of students' understanding of the mole concept on the interview schedule

Conception	Number of subjects	Percentage (%)
Sound understanding	2	20
Partial understanding	3	30
Partial understanding with specific misconception	1	10
Specific alternative conception	2	20
No understanding	2	20

From Table 2, it can be concluded that only 20% of the pre-service science teachers had conceptual understanding of mole concept. This means majority of the students do not understand mole concept. The finding from the study confirms García, Pizarro, Pereira, Martín and Bacas (1990) in a survey using a large student sample from secondary education to first-year university course. They reported an increased proportion of wrong answers concerning the mole concept, that is, answers that differ from the I.U.P.A.C. definition. They concluded that there is a superficial learning of the concept. This results lend credence to the findings of Dierks (1981), Novick and Menis (1976) and Cervellati *et al.* (1982) that the mole concept is one of the chemistry topics students perceive to be difficult and therefore posses a lot of misconceptions about it.

6. Conclusion

The study sought to find out the conceptual understanding of pre-service teachers on mole concept. It can be concluded from the findings that the pre-service science teachers used in this study have not developed an appropriate conceptual understanding of the mole concept, and therefore possessed a lot of alternative conceptions about the concept.

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