ISSN No:-2456-2165

Teacher Trainees' Alternative Conceptions about Intermolecular Forces

Kwarteng, T. A[1], Hanson, R.[2], Nartey, E[3]. Sam, A[4], Quayson, C[5]
[1-5] Department of Chemistry Education,
University of Education, Winneba, Ghana

Abstract:- The study assessed the alternative conceptions that first-year teacher trainees have about intermolecular forces. Descriptive research design was adopted to examine the current situation as it exist. The sample involved 82 first-year chemistry major teacher trainees in the University of Education, Winneba. Purposively sampling technique was used to select students for the study. This is because most of them performed poorly in a pre-assessment test organised for them. Test was the main instrument for data collection. Simple percentages was used to analyse the data. The results indicated that 26% and 37% of the teacher trainees had alternative conceptions on Ion –dipole interaction and London dispersion forces, respectively. Also, more than 50% of the teacher trainees demonstrated alternative conceptions on hydrogen bonding. Some alternative conceptions identified in this study included: interactions between oppositely charged species give ionic bonds, London dispersion force occurs within a single molecule rather than between molecules, Covalent –ionic interaction is the major intermolecular force that exists in different I_2 molecules, and the perception that any molecule which contains 'O' and 'H' forms hydrogen bonding irrespective of their position in the molecule (especially with organic structures used in the study). Another was that Hydrogen bonding only exists between 'O' and 'H' but not between N-H and F-H. It is recommended that science educators should develop appropriate interventions to improve students learning in intermolecular forces.

Keywords:- *Intermolecular Forces, Alternative Conceptions, Hydrogen Bonding, London Dispersion Forces.*

I. INTRODUCTION

Intermolecular forces (IMFs) play an important role in bridging the connection between molecular structure and their properties. Physical properties, such as boiling or melting points, often depend on the type and strength of IMFs present in the compound. IMFs are influenced by electronegativity of elements making up the structure. Previous study indicates that students possess various alternative ideas and conceptions about IMFs, especially relating to their location and effect on compound's properties [1]. It is not surprising that students who struggle to understand IMFs experience difficulties in explaining and predicting chemical and physical properties. When students develop good concepts in intermolecular forces, it facilitates their ability to predict a number of physical properties of compounds, such as melting and boiling points. It therefore seems relevant for students to study and understand the concept of intermolecular forces. The degree to which students understand chemical concepts depends on their ability to integrate microscopic, macroscopic and symbolic levels in chemistry, and these symbols need to be mastered by students to improve their understanding in learning chemistry concepts [2].

When students have alternative conceptions in chemistry it inhibits their effort to create sufficient explanations to questions. Alternative conceptions are ideas or constructs that differ from the well negotiated, most viable scientific constructs [3]. Asghar, Huang, Elliott and Skelling [4] defined alternative conceptions as ideas or general abstractions from common experiences which are different from scientific conceptions. Alternative conceptions are sometimes termed as misconceptions or preconceptions. Students can construct concepts either consciously or subconsciously through explanations for the behaviour, properties, or theories they have experienced. Most of these explanations are believed by students to be correct for the reason that they make sense regarding their understanding of the behaviour of the world around them in their own view. Due to the possession of alternative conceptions by students, it is difficult for them to accept scientific information because it seems wrong for them [5]; [6]. Gilmore, Wilkerson and Hassan [7] asserted that pre-existing conceptions and ideas held by students are perhaps correct but most of them are significantly dissimilar from the view point of what is accepted scientifically and tend to be modernized arbitrarily by only considering what their senses receive. This suggests that students would, or are expected to have alternative conception if their explanation to science phenomena differs from scientific concepts.

In order to improve students' learning of intermolecular forces and other chemical concepts it is important to unravel students' alternative conceptions and correct them. Students with incomplete understanding of scientific concepts resort to rote learning since they lack deep understanding of what they have been taught in the classroom. In Ghana, the specific objectives in the elective chemistry syllabus expect students to be able to "explain how intermolecular forces arise from the structural features of molecules and state how it affects physical properties such as solubility, melting point, and boiling points of substances"[[8], p.9].

In a pre-assessment test, first year chemistry teacher trainees in the University of Education, Winneba (UEW) performed poorly when their conceptual understanding on intermolecular forces was assessed. These teacher trainees had all completed high school education. Aboagye, Amponsah and Graham [9] assert that most high school students who read science hold alternative conceptions on changes of state of

ISSN No:-2456-2165

matter. In their study, a two-tier test to explore students' conceptions of change of state of matter was developed. Their study revealed that 32.9 % and 67.1 % of the students held correct conception and alternative conceptions respectively on phase change of ice cube when melting. They attributed this to secondary school science students' lack of clear understanding of the behaviour of molecules of substances during phase transition. Similarly, in Chemistry, substances undergo a lot of physical changes and intermolecular forces influence them. In order to develop students' ability to properly explain the various physical changes substances undergo in Chemistry, it is important to unravel students' alternative conceptions in intermolecular forces.

A. Objectives of the study

The study objective was to assess teacher trainees' conceptual understanding of intermolecular forces so that it could inform the adoption of best teaching practices for teacher trainees.

B. Research questions

What alternative conceptions do teacher trainees have about intermolecular forces in explaining physical properties of substances?

II. METHODOLOGY

A. Research design

This study is a descriptive research design. Descriptive research describes a phenomenon and its characteristics by examining the situation as it exist [10]. It includes identification of attributes of phenomenon based on observational basis, or exploration of correlation between two or more phenomena. According to [11] descriptive research designs do not manipulate variables; instead, the researcher describes and draws conclusions from frequency counts and other types of analysis [12]. The population for the study was all first-year students reading chemistry in University of Education, Winneba (UEW). However, only 82 students reading chemistry as a major course in first year were purposively sampled to participate in a pre-assessment test. According to Bernard [13], purposive sampling also termed as judgment sampling, is the deliberate choice of selecting participant owing to the qualities they possess. It is a nonrandom technique which need no underlying theories. Simply put, the researcher finds people who are willing to give information relating to their knowledge or experience. Test was the main instrument used for collecting data and it was validated by a senior lecturer in the Department of Chemistry Education, University of Education, Winneba, Ghana. The diagnostic test consisted of two tier questions. In the first-tier, the teacher trainees (students) were to choose a correct option in a multiple-choice question and in the second tier provide explanation for the option they had selected. The students' answer sheets were marked and categorised based on their level of understanding as 'understand', 'misconception' and 'not understand'. A similar approach was used by [14] to assess students' alternative conceptions in chemical equilibrium and by Hanson ([15], [16]) in undergraduate chemistry teacher trainees' illuminative assessment and pre-service teachers' alternative conceptions about word equations.

B. Data analysis

In this study, students' alternative conceptions on intermolecular forces were unearthed by analysing the options that they selected in the first tier of a diagnostic test and the pattern of their explanation in the second tier. Afterwards, the criteria in Table 1 was used to evaluate the percentage of teacher trainees who understood the concepts and were scored as 3, those who had alternative conceptions (misconceptions) were scored either as 1 or 2, and those who did not understand the concepts at all were scored zero. In analysing the results, the sum of teacher trainees who scored 1 and 2 were categorised to be those having alternative conceptions. Again, deductions and conclusions were drawn based on responses that students provided to the diagnostic questions.

Table 1: Criteria for scoring students level of understanding

Students Answers		Scores	Level of understanding
First tier	Second tier		
True	True	3	Understand
True	False	2	Alternative conception
False	True	1	Alternative conception
False/No answer	False/ No answer	0	Not understand

III. RESULTS AND DISCUSSION

Teacher trainees' responses and explanations for choosing the correct answers were analysed and categorised into the levels of understanding outlined in Table 1. The levels of understanding were then summarised into percentages. Table 2 provides a summary of students levels of understanding based on their responses to questions 1 to 3 of the diagnostic test.

Table 2: the percentage of the students'level of understanding and their alternative conceptions

S/N	Question	Levels of understanding category			
		0	1	2	3
1.	When NaCl dissolves in water, aqueous Na^+ and Cl^- ions result. The force of attraction that exists between Na^+ and H_2O is called a (n) __________ interaction. A) dipole-dipole B) ion-ion C) hydrogen bonding **D) ion-dipole** E) London dispersion force Reason:	50 (61%)	8 (10%)	13 (16%)	11 (13%)
2.	Of the following substances, only __________ has London dispersion forces as its only intermolecular force. A) CH_3OH B) NH_3 C) H_2S **D) CH_4** E) HCl Reason:	32 (39%)	14 (17%)	16 (20%)	20 (24%)
3.	Elemental iodine (I_2) is a solid at room temperature. What is the major attractive force that exists among different I_2 molecules in the solid? **A) London dispersion forces** B) dipole-dipole rejections C) ionic-dipole interactions D) covalent-ionic interactions E) dipole-dipole attractions Reason:	21 (26%)	24 (29%)	4 (5%)	33 (40%)

*__Correct Answers in bold__

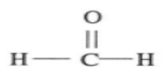
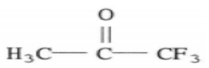
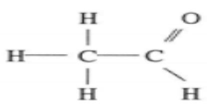
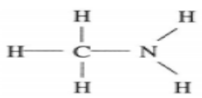
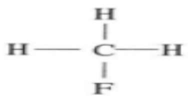
From Table 2, it can be seen that 50 (61%) of the teacher trainees did not understand the interaction that occurs between ionic crystals and polar solvent as in question 1, 21(26%) had misconceptions on this question while only 11(13%) were able to choose option "D" as the correct answer with correct explanation. Some of the teacher trainees who chose the correct answer but gave wrong explanation indicated that the sodium ion will form ionic bond with the negative charge in water molecules and stay together. These students alluded that any interaction between opposite charged species is ionic bond, hence their reference to interactions between sodium ion and polar water molecule as ionic bond. Some of the students' explanations did not include some key information. For instance, their explanation did not include the fact that it is the partial negative charge on the oxygen atom in a polar water molecule that will interact with the positive charge on the surface of the sodium ion to form the ion–dipole. This is a clear indication that the students were confused and could not decipher between the interaction that occurs in molecules and the bond formation between atoms. Others asserted that the sodium ion induces a negative charge in water and bonds with it. Similarly, [17] reported that many students in their study had difficulty in differentiating ionic bonds and covalent bonds as well as other intermolecular forces. In another study, some students were uncertain about chemical bonding definition and they further limited the definition of a chemical bond to an ionic bond by stating a chemical bond as electrostatic force that binds atoms or ions [18]. Additionally, [19] conducted a study in Slovakia to identify students' misconceptions on chemical bonding. It was found out that 17.6% of students thought NaCl was a molecule, while 21.1% of the students argued that the atoms of Na and Cl attract each other and form NaCl. The basis of these misconceptions and students' difficulties could be due to poor teaching methodologies, techniques and representations used in teaching chemical bonding.

In responding to question 2, 32(39%) of the teacher trainees demonstrated that they did not understand how London dispersion forces (LDFs) occur and were not able to choose the correct answer and so gave wrong explanations to the question. It was noted that 30(37%) of them had misconceptions. Some respondents selected CH_4 as the correct answer but reasoned that "the hydrogen in CH_4 has a positive charge and this sometimes attracts the electrons in the carbon atom to bring about the London dispersion forces in CH_4." From this explanation, the implication is that a charge should be present to bring about the temporary instantaneous dipole. This means that the students perceived LDFs to occur within a single molecule rather than between molecules. This study is in agreement with the findings of [1]. In their study, majority of their participants' drawings showed that IMFs are located within a single molecule rather than between separate molecules. Also, the idea that CH_4 is a nonpolar molecule and the fact that London dispersion force occur due to asymmetrical distribution of electrons was also not stated in their explanation. This suggests that students' understanding of London dispersion forces was shallow. In this current study, 20 (24%) of participants were able to give the correct explanations to the correct answers that they chose.

In the case of question 3, about 21 (26%) of the teacher trainees did not understand the question and so chose a wrong answer and gave a false explanation. About 28(33%) of the teacher trainees demonstrated that they had misconceptions, with 33(40 %) showing that they actually understood the concepts and so provided the correct explanation and chose the correct answer in support. Most of the students who had misconceptions on question 3 chose option 'D' as their correct answer. This wrong answer intimated that covalent–ionic interaction was the major attractive force that existed in different I_2 molecules. This suggests that the respondents were uncertain about covalent bond in I_2 molecules and the interaction that different I_2 molecules being nonpolar substances undergo. Teacher trainees lacked good understanding of how London dispersion force occurred in molecules. They were confused about intermolecular forces and intramolecular forces. Similarly, [20] reported that students lacked good understanding of concepts related to intermolecular forces.

Table 3 provides a summary of teacher trainees' levels of understanding based on their responses to questions 4 to 5 of the diagnostic test.

Table 3: Percentage of students' level of understanding and their alternative conceptions

IV. S/N	Question	Levels of understanding category			
		0	1	2	3
4.	Which one of the following substances will have hydrogen bonding as one of its intermolecular forces? A)  B)  C)  **D)**  E)  Reason:	10 (12%)	25 (31%)	18 (22%)	29 (35%)
5.	Of the following, _______ has the highest boiling point. A) N_2 **B) Br_2** C) H_2 D) Cl_2 E) O_2 Reason:	24 (29%)	16 (20%)	14 (17%)	28 (34%)

***Correct Answers in bold**

Table 3 indicates that, in response to question 4, a total of 10(12%) of teacher trainees did not understand the concept on hydrogen bonding formation and so chose a wrong answer and gave a wrong explanation. Another 43(53%) of the teacher trainees had misconceptions on hydrogen bonding formation. Among the teacher respondents who had misconception, most of them chose option 'C' with few choosing option 'A'. They explained that "hydrogen bonding in the given species occurred between hydrogen and oxygen atoms". As a result of this explanation, students chose molecules containing 'O' and 'H' as their answers. They did not conceptualise that hydrogen should be bonded directly to the oxygen atom in the molecule given. Also, teacher trainees did not know that Hydrogen bonding occurs when H bonds to an electronegative species like N and F. Pérez *et al* [21] noted in a study that in choosing molecules that contain hydrogen bonding, students do not mind if H atoms are or not directly bonded to the other highly electronegative atoms (N, O or F) and this denotes students' lack of understanding on how a hydrogen bond is formed. Other authors ([22]; [23], [24]) have found similar results in studies that involved the identification of molecules that contained hydrogen bonds. Concretely, [25] pointed out that high school students said that dimethylether formed H-bonds because it had oxygen atoms, but not the HF or CH_3F

molecules. Another study carried out by [22] with 9th-grade students revealed that they all believed that any molecule containing hydrogen atoms could establish H-bonds. However, in this current study, 29(35%) of the teacher trainees showed good understanding.

Again, in Table 3, 24(29%) of the teacher trainees were not able to choose Br_2 as the molecule with the highest boiling point in answering question 5, and in addition did not write any explanation. Only 30(37%) of the trainees demonstrated that they had misconceptions, with less than half of the teacher trainees (31%) showing good understanding. Some of the teacher trainees who had misconceptions chose Br_2 as the correct answer but explained that all the molecules were nonpolar molecules (i.e., N_2, Br_2, H_2, Cl_2, O_2) and that they all contained London dispersion forces. They reasoned that the Br_2 molecule had the biggest atomic number and hence, more heat was required to boil it. In this explanation, students were expected to link the increase in molecular mass to increase in the number of electrons in Br_2, which subsequently led to increase in London dispersion forces than in N_2, H_2, Cl_2 and O_2. This exposed the teacher trainees' shallow or partial understanding of London dispersion force.

C. Major findings of the study

Some of the teacher trainees alternative conceptions were that:

- Any interaction between oppositely charged species results in ionic bond. They, therefore, asserted that the interaction between sodium ion and polar water molecule would result in an ionic bond.
- In London dispersion force, a charge should be present to bring about the temporary instantaneous dipole.
- London dispersion force occurs within a single molecule rather than between molecules
- Covalent–ionic interaction is the major intermolecular force that exists in different I_2 molecules
- Once a molecule contains 'O' and 'H', then it forms hydrogen bonding irrespective of its position in the molecule (especially with organic structures used in the study).
- Hydrogen bonding only occurs between 'O' and 'H' but not between N-H and F-H.
- Atomic number predicts the strength of London dispersion force.

V. CONCLUSION

The study assessed the entry conceptions of teacher trainees on intermolecular forces. It was revealed that most of the first-year teacher trainees admitted to read Chemistry held a number of alternative conceptions in intermolecular forces. The responses given by the teacher trainees suggested that they did not gain conception of intermolecular forces in their high schools, possibly from poor teaching strategies or students' own inabilities to construct conceptual knowledge. It is recommended that students' misconceptions should be taken care of so as to facilitate their understanding in learning higher chemistry concepts.

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