

CHEMISTRY TEACHERS' INTERPRETATION OF SOME STUDENTS' ALTERNATIVE CONCEPTIONS – A PILOT STUDY

Ruby Hanson
Department of Chemistry Education
University of Education, Winneba
Email: maameruby@yahoo.com

ABSTRACT

Chemistry education researchers have shown growing interest in the strategies that teachers employ to diagnose students' prior knowledge and attempt remediation, where necessary, as most concepts in chemistry look abstract. The ways in which Ghanaian teachers identify and address their students' alternative conceptions, especially in the study of chemical equilibrium, was explored on a pilot basis through the use of face-to-face, telephone and email procedures. The outcome was compared with what other researchers in other countries had identified through various means. Trainees whose responses were not clear in their e-mail responses were interviewed through telephone and personal interactions. Eleven Ghanaian chemistry instructors from various parts of the country, who were on an eight-week summer sandwich education programme, participated in the study. Data gathered revealed that majority of the participating teachers were aware of their students' prior conceptions and often had no difficulty diagnosing them but were unaware of all the possible sources of misconceptions nor how to address the root causes of persistent misconceptions. Their non-interactive treatment strategies for the identified misconceptions in their schools were varied, unauthentic and not deep-seated. As many as four common remediation processes were identified for use. On the basis of these findings, it is recommended that the study of students' misconceptions and some of the appropriate and authentic resolution strategies be incorporated into teacher training curricular. [*African Journal of Chemical Education—AJCE 10(1), January 2020*]

INTRODUCTION

Chemistry education entails learning about matter and its interactions, in which knowledge, skills and habits are transferred from one generation to the other through teaching, training and research. It is a systematic process of acquiring fundamental knowledge about the universe. Chemistry education addresses the social object of substance development through laboratory practice, field work and engaging hands-on activities. However, students are seldom exposed to such engaging activities that enable them to experience transformations and interaction of matter. Thus, learners of chemistry tend to build wrong or alternative conceptions about abstract chemical principles by rote, from missing links during concept formation. Alternative conceptions, also known as naïve ideas or misconceptions, are ideas or non-scientific ideas that learners hold. These naïve conceptions are important sources of influence in students' educational backgrounds [1]. These conceptions are often resistant to instructional change because they result from personal ingrained experiences and cannot be changed or corrected easily [2]. They are strongly held onto and defended by learners; yet obstacles to further learning. Simply pointing out students' conceptual weaknesses and asking them to change and accept what an instructor deems unauthentic is not sufficient.

According to research [3], the first step to arrest alternative conceptions held by teachers and students, is to confront them with their weaknesses, help them to acknowledge them, and then excite them to find more logical, and useful alternatives that will expose the flaws in their original beliefs without doubt, in an appropriate learning environment. Some alternative conceptions about chemical equilibrium which have been identified and catalogued by some researchers in chemistry education, among many others, are:

- Misconceptions about the nature of matter [4]
- Confusion about amount of substance and concentration [5]
- Wrong expression for equilibrium constant equations, such as representing solids when they appear in equations [6]
- Chemical stoichiometry [7]
- Wrong application of Le Chatelier's principle when stress is applied to a system [8]
- Confusion over the appearance and disappearance of materials, [9] and a few more.

The topic on chemical equilibrium has been found to be a difficult conceptual framework for students [10]. Locaylocay [6], found in her studies among Philippine students that they held many alternate conceptions about chemical equilibrium which could have stemmed from their inadequate understanding about rates of reactions. Alternative conceptions in chemical equilibrium pose instructional problems to teachers, and comprehension problems to students, as this topic is a pre-requisite for understanding topics such as electrochemistry, complexometric reactions, redox reactions, precipitation reactions, the Hasselbach equation, and ionic product of water. According to Yildirim, Kurt and Ayas (2011), inability of students to make useful interconnections among representational levels of nature and the wrong use of language to explain chemical phenomena, especially with chemical equilibrium, lead to the formation of persistent alternative conceptions. Thus, it is important to tackle these problems and ensure that teacher trainees thoroughly understand the basic concepts on equilibrium, so that they can teach them from first principle, rather than from an algorithmic approach.

A student's misconception could hinder comprehension of subsequent related concepts and obstruct further learning. This supposes the urgency for improving the comprehension of teachers' knowledge of students' conceptions and difficulties in the learning process. Research

results have shown that several of the more common misconceptions are retained, even at higher educational levels among university students, and sometimes beyond that [11]. Voska and Heikkinen [10], in their paper, made suggestions on how to assess students' perceptions about chemical equilibrium in particular, as it is a very difficult topic for students. Thus, secondary students' problems with chemical equilibrium and other challenging concepts could be studied, and remediation strategies suggested. This, however, would be done indirectly through teachers who teach these students. Conversely, it is also possible to study teachers' problems through their students' performance, though this could be implied. This study would contribute towards achieving a near zero tolerance level on teacher- or school-made misconceptions about chemical equilibrium in particular.

RESEARCH QUESTIONS

This study sought to find out the level of awareness that some Ghanaian teachers had about some of their students' alternative conceptions, especially those about chemical equilibrium. It also sought to find out some of the alternative conceptions reportedly held by their students, as well as the methods that they employ as teachers to remediate them. The study was guided by the following research questions:

- 1. What level of awareness do senior high school teachers have about students' learning difficulties?*
- 2. To what extent are senior high school chemistry teachers able to identify their students' alternative conceptions about chemical equilibrium in particular?*
- 3. What strategies do senior high school teachers use to address students' alternative conceptions about chemical equilibrium?*

THEORETICAL FRAMEWORK

Learners construct knowledge by ‘modeling’ new information onto already existing schema [12, 13]. This implies that whatever students already know, whether wrong or right, affects the gain of new knowledge. There is therefore the need to be cautious when new schema has to be constructed. In Ghana, personal observations made by the researcher during supervision of prospective teachers (teacher trainees or pre-service teachers) on the field for over ten years, have indicated that there is a gap between what these prospective teachers know in theory, and what they have to translate in practice when they have to act as facilitators to help their students to restructure entire schemata. They fail to translate technological, content and pedagogical theories learned in school into realistic practical skills to help their own students to construct knowledge in a professional manner. They often fail to identify both obvious and overt alternative conceptions upon which students build knowledge. If they ever identify these alternative conceptions (or herein also referred to as misconceptions), they disregard them or fail to find appropriate strategies for remediation.

Similar observations about teachers’ inability to translate abstract concepts into concrete concepts for students to create mental models of them have been observed by some researchers in Ghana and other parts of Africa. In Ghana, Anamuah-Mensah [14], Davis (2010), and Ennin [15] found in different instances that Ghanaian High School learners had challenges with understanding operating principles that governed the nomenclature of organic compounds because the compounds and their structures looked abstract and alien. Agogo and Onda [16], similarly found that, Nigerian students perceived topics on hydrocarbons, alkanols, alkanolic acids and alkanoates to be difficult because they carried many misconceptions to class, upon which new knowledge was built. A similar observation was made by Kihwele [17] in Tanzania.

Gengden, Gongden and Lohdip [18] had earlier on found out that besides Nigerian students' challenges with organic chemistry they also had difficulties with concepts of chemical equilibrium, acid-base concepts and volumetric analysis. These confirm Taber's assertion that chemistry curricula commonly incorporate many abstract concepts that are central to further learning in both chemistry and other sciences. Taber (2002) and Svegi, Nurdane, Yezdan and Oktay [19] suggest the conscious use of innovative and conceptual change approaches in teaching chemistry so as to optimise students' understanding.

The conceptual change approach has been advocated as one enterprising way of helping learners to confront their alternative conceptions and build new concepts [19]. Piquette [20], identified four concept change instructional strategies that incorporate the various steps required for conceptual change. These strategies were cooperative groups, refutational texts, analogies, and learning cycles. Some other concept change approaches which have often proved useful by other researchers are mind maps, concept-based laboratory activities, analogies [19], inquiry-based lessons [7] and concept-mapping [21]. This study sought to find out if Ghanaian chemistry teachers employed some of these engaging and constructive approaches to remediate misconceptions, especially about chemical equilibrium, if they were found among Ghanaian high school chemistry students.

METHODOLOGY

The population for the study was a cosmopolitan group that comprised all chemistry teacher trainees in Southern Ghana; namely the Greater Accra, Western, Central, Eastern and Volta regions. There were no trainees from the Northern sector of the country (Ashanti, Brong-Ahafo, and Northern regions) because this was a small graduate class with no enrolled

representative trainees from the said regions in the year that this study was conducted. The sample (who represent the earlier named area of study) comprised of 11 post-graduate teacher trainees in the University of Education 2015 academic year pedagogy programme. This was a purposive sample as the post-graduate teacher trainees (herein called trainees) formed part of a pedagogy and concept formation class that required the development of pedagogical skills for assessing students' prior conceptions. This pilot study was therefore intended to heighten trainees' awareness of the conceptions that secondary school students could come to class with and expose them (the trainees) to possible pedagogical and remediation processes that would enable them to help their students to construct knowledge.

The trainees were experienced teachers who kept busy schedules and so three-part questionnaires were sent to them via emails to respond to at their convenience, but were required to mail back their responses at an appointed time. Only 11, out of a targeted 19 trainees, participated in the study (by sending their feedback within the stipulated period). The first part of the questionnaire sought to find out if the trainees were aware that students had alternative conceptions in general, and about chemical equilibrium in particular. The second part probed the extent to which teachers were able to identify students' alternative conceptions (learning difficulties) in chemical equilibrium. The third part of the questionnaire examined the strategies that were used by the teachers to help their students to conceptualise important principles in the topic, chemical equilibrium. A sample of the questionnaire is presented as Appendix A. An interview schedule was used to augment responses on the questionnaire. This is presented as Appendix B. Only three, out of the 11 trainees, had ambiguous free responses which required clarification through interviews. These three trainees, were interviewed between 8-12 minutes

over the telephone. A similar protocol was used by Piquette and Heikkinen [22] in their quest for strategies that teachers used to address alternative conceptions.

All the trainees in this study possessed Bachelor of Science Degrees, that qualified them to teach in upper secondary (Senior High) schools as non-professional teachers, because they did not have the requisite professional pedagogical skills. These non-professional teachers, had enrolled in a pedagogy class that could enable them to acquire the necessary pedagogical skills to become professional teachers. All trainees in this study had taught for at least two or more years as non-professional teachers in various categories of secondary schools - endowed and deprived schools. A concise background of the trainees is presented in Table 1. These trainees are designated as T1 to T11 and the schools where they teach are designated as S1 to S8.

Table 1: Profile of Trainees

Teacher	Gender	Teaching experience	Identity of School	Resourcefulness of School
T1	M	4	S1 (GA)	Endowed
T2	M	3	S1 (GA)	Endowed
T3	F	5	S2 (WR)	Endowed
T4	M	2	S3 (ER)	Deprived
T5	M	5	S4 (CR)	Deprived
T6	M	4	S4 (CR)	Deprived
T7	F	6	S5 (CR)	Average
T8	M	3	S6 (VR)	Average
T9	M	2	S6 (VR)	Average
T10	M	3	S7 (GA)	Deprived
T11	M	4	S8 (WR)	Deprived

T = Teacher. S = School; GA= Greater Accra Region; WR = Western Region; ER = Eastern Region; CR = Central Region; VR = Volta Region

The data obtained from the questionnaire and interview sessions were coded into categories. One of these was the trainees understanding of the term *alternative conceptions* and awareness of their existence among learners. Through this, some of the basic alternative conceptions that students brought to class and the strategies that teachers used in unearthing them

when teaching chemical equilibrium, in particular, were also uncovered. Some of the instructional strategies that teachers used in addressing supposed problems were also identified as another category of findings. This cross-case interpretive research would be built around a collective case study, as the researcher would interpret and describe themes that arise across the case study for the 11 teacher trainees.

RESULTS AND DISCUSSION

Data gathered showed that about a quarter (that is three) of these trainees, who were also practising teachers, could not clearly explain what alternative conceptions (herein also referred to as misconceptions) were. They had varied ideas about the concept of ‘misconception’. Trainee T7 implied in her answer to ‘what alternative conceptions were’ that, if students did not understand a topic then it implied that they had misconceptions. That was quite vague. T1 said that when students are confused, then that could be explained as evidence of misconceptions. One participant who was interviewed on telephone attributed part of students’ misconceptions to non-performance (incompetence) in class by some of his fellow teacher-colleagues. He further attributed some of these observed challenges to inappropriate instructional strategies that some teachers used. Nonetheless, he failed to categorically explain what misconceptions were, just as had vaguely been explained on his answered questionnaire.

Data gathered from the trainees clearly indicated that their students in Grade 11 (Secondary school form 2) had challenges in understanding many basic chemistry concepts such as phase equilibria, solution equilibria, periodicity, hybridisation, stoichiometry, and especially chemical equilibrium. Most of the identified student misconceptions that the trainees brought to light were mostly pre-conceived notions, vernacular, non-scientific and conceptual

misconceptions. Some of these were the use of wrong descriptions for terms associated with the nature of matter which students might have gathered from their environment (everyday language) and cultural beliefs.

Trainees indicated that they had all made observations about students' challenges with various chemistry topics and attempted to use various teaching strategies to solve them. Two years of teaching was enough for any critical and reflective teacher to make a good assessment of their teaching environment. The first research question was answered by data gathered from Part A of the questionnaire. It sought to find out trainees' awareness and interpretation of misconceptions, examples of misconceptions, if their students generally exhibited alternative conceptions in their chemistry studies, what some of these alternative conceptions were, and whether their students, particularly, had alternative conceptions in their study of chemical equilibrium. Almost all the trainees were aware that students came to class with alternative conceptions, or misconceptions as some of them called them, and that they showed more alternative conceptions with the topic, principles of chemical equilibrium and analytical chemistry. The understanding of some of these topics are requisites for understanding the concept of chemical equilibrium. Seven (7) out of the eleven (11) trainees indicated that they were aware of such student-prior conceptions from oral answers that students sometimes presented in class, especially during the introductory part of a lesson. They enumerated some of the common identified misconceptions and difficulties with certain topics that their students brought to class as acids and bases, the nature of solutions, periodicity, electrochemistry and analytical chemistry. It was identified that different types of misconceptions existed among Ghanaian students. A few of the statements (gathered from participants) as made by Ghanaian students to substantiate the fact that students have unscientific beliefs are presented as topical issues below. It must be noted that they are primary data, as they

were obtained from trainees, though not directly from secondary school students. Some naïve comments that were gathered about acids, bases and salts suggest that Ghanaian students have alternative conceptions which require further investigation. These are presented.

Acids, bases and salts

The acid-base concept is an important chemistry topic. Reactions within our bodies and many other systems occur in acidic or basic media. Equilibrium must be maintained in such circumstances for any system to work effectively. According to participants in this study majority of upper secondary school learners cannot distinguish among, and apply the theories and basic concepts of acids and bases. The trainees intimated that students mostly had distorted conceptions about the Lewis theory. Their concept about acids and bases was the loss of protons. The concept of loss or gain of electrons and the availability or otherwise of vacant orbitals of the right energy at play in the Lewis concept of acids and bases was less easily understood by students, the trainees said. Their idea about a base was that there should be the presence of a hydroxyl ion. They could not perceive that substances could be acids or bases based on other parameters such as the possession or otherwise of vacant orbitals of the right energy or a specie's ability to release or accept electrons. They further added that students assumed that "acids can 'burn up' or 'chew up' substances" (T4, T5, T6, T11). A few other unscientific statements purported to be provided by students in class, in support of the participants' assertions, were:

- *Neutral salts give neutral solutions when dissolved in water (T2, T3, T4, T5, T10);*
- *An acid with more than one replaceable hydrogen is a stronger acid than that with only one (T1 to T11);*
- *Weak acids are dilute acids while concentrated acids are strong acids (T1, T4, T9, T11);*

- *Strong acids have greater reaction potential than weaker acids (T4 to T6 and T10 to T11);*
- *Inorganic acids are stronger than organic acids (T1 to T11); and*
- *Buffer solutions are mostly acidic (T3, T5, T6).*

Some trainees further explained that this latter misconception about buffers came about because the ethanoic acid/ethanoate buffer was often cited in textbooks to explain the concept of buffer solutions. Based on evidential statements provided by participants in this study, it is obvious that they were to an extent, aware that their students possessed alternative conceptions about the nature of acids, bases and salts.

The trainees were aware that the subject of acids and bases has an important place in primary and secondary chemistry education. Concepts concerning acids and bases are interrelated. Although frequently thought of by students as too complex to learn, they should not be so. These concepts need to be taught, using appropriate interactive and engaging teaching methods in order to prevent the formation of misconceptions, especially, teacher-made misconceptions. When students have difficulty understanding any one of these concepts, they tend to experience difficulties with related concepts (Kauffman, 1988). The next section provides summative evidence from the participating teacher trainees about some of the alternative conceptions that high school students come to class with, about the particulate nature of matter.

Particulate nature of matter (PNM)

The trainees further intimated that some of their students generally had poor conceptions about the particularity of matter, its measurement, and associated units because they failed to connect among the different levels of particulate matter. They added that lower secondary school

students, on learning about atoms from their teachers, presume that different sizes and colors of atoms result in the different substances that they see and carry this on to upper secondary school. They implied that such inadequate understanding of the nature of matter could be hindrances to further understanding of chemical equilibrium, especially when discussing the Le Chatelier's principle [8].

Some other misconceptions that they identified were in how students failed to use the 'particle' idea in their descriptions about the concept of solids. One obvious vernacular misconception, they all spoke about, was that students thought that when a chemical bond breaks, then the particles melt or become disarrayed. The use of wrong terms by students, as observed by trainees in this study, could be attributed to weaknesses in students' reasoning patterns and cognitive structures. Some trainees went on to say that often their students wrongly thought that all organic substances possessed molecular bonds, while all inorganic compounds contained ionic bonds. There was no room for molecular species. The trainees intimated that such answers put them on red alert, and they knew that they had to devise new strategies to help their students to unlearn (deconstruct) their wrong ideas. Students also held the belief that inorganic compounds were 'harder' than organic compounds, because of their strong ionic bonds. They thus intimated that inorganic compounds had higher melting points than organic compounds. None of the teachers made any reference to states of matter and the influence that they bore on symbolic chemical equilibrium representations. An interpretive analysis of the summative evidence provided by the participants confirm their submission that students have alternative conceptions about matter, as the next section further outlines.

Changes in matter

When trainees were asked to explain how they identified students' challenges or otherwise with changes in matter, only T3 responded during a telephone interview. She said that she looked out for students' understanding about physical and chemical changes. Often her students with conceptual difficulties reasoned that a physical change meant retention of state, while chemical change meant the emergence of different states of matter. She added that such students, changes that occurred in the state of water from the solid through the liquid to the gaseous phases meant a chemical change, as the states of matter had changed. Again, 'a physical change occurred when reactants and products were the same on both sides of a chemical equation'. When asked to link how this would affect students' understanding of chemical equilibrium, she answered that they might not appreciate 'chemical' changes that go on if phase changes or colour changes do not occur. These statements confirm findings from other researches [5, 4] that have delved into students' alternative conceptions about matter. Such challenges make it difficult for students to appreciate the concept of hybridisation and the geometry of molecular compounds.

Hybridization

Almost all the trainees, except, T2 and T3, admitted that their students mostly had misconceptions about hybridization and chemical stoichiometry. T1 was in the same school as T2 but had a different view about students' conceptions of hybridization, from him. This observed difference could mean that teachers assess students' conceptions through different lenses. In the case of hybridization, trainees surmised that their students conceptualized hybridization as a reaction that occurred between electrons and not orbitals. Their students also believed that native orbitals had to contain electrons before they could 'mix' up, and this resulted

in a lot of confusion for the students, so that hybridization in the Be^{2+} ion, in a compound such as $[\text{Be}(\text{OH})_4]^{2+}$ or $[\text{Be}(\text{H}_2\text{O})_4]^{2+}$, was not possible. The supposed ‘impossible’ situation fitted in with their misconception about hybridization. Again, there was a question on how students’ understanding could affect their understanding of chemical equilibrium. The trainees could see no linkage, but were of the view that it was also a difficult topic for students.

The mole concept and chemical stoichiometry

Some of the alternative concepts identified by the prospective professional teachers among their students were on the mole and chemical stoichiometry. These topics and their underlying concepts were perceived as difficult because students exhibited many alternative conceptions in their study of the said. Some student statements provided in support of the teachers’ claims were:

Mole ratios were said to be dependent on concentration, so that increasing concentrations of reactants affected the stoichiometric mole ratios. In some cases, the mole was defined as a molecule (T2, T4 and T11). Students presume that the ‘mole’ is an abbreviation for the word ‘molecule’. High school students, according to the prospective professional teachers or trainees, had challenges with writing and balancing of chemical equations.

Trainees reported on other misconceptions that were evident among learners.

Chemical equilibrium

- Equilibrium occurs when species on the left and right sides of an equation are the same and the reaction stops (T1 to T11).
- Students find it difficult to determine the direction in which a reaction will move if a particular stress is imposed on it as was found by Novak [8].

- When a reactant is used up in a chemical reaction, then the reaction will stop (T6, T10 and T11).

On the question about how the trainees identified difficulties that students had with chemical equilibrium and what some of these misconceptions were, many answers were obtained from the trainees. All the trainees admitted that it was a challenging topic for students as well as for some of them. Even T1 to T3, who had shown indications of their students being conceptually sound, admitted that their students also had conceptual difficulties with the chemical equilibrium concept.

Some of the assertions made by the trainees as coming from their students were:

- *Forward reaction decreases as soon as equilibrium is attained;*
- *Chemical reaction stops when equilibrium is attained;*
- *Forward reaction ceases momentarily to allow the backward reaction to proceed;*
- *Increasing reactants increase the forward reaction;*
- *When a system at equilibrium is disturbed by increasing the concentration of reactants, the reverse reaction rate decreases instantly; and*
- *When equilibrium is established again after concentration of reactants is increased, the rates of the forward and reverse reactions would be greater than at the initial equilibrium.*

Data gathered from the participants in this study indicate that Ghanaian students have challenges in understanding many basic chemistry concepts, especially chemical equilibrium, which could be found to belong to different types of misconceptions. Since majority (8/11) of the participants indicated their awareness of students' challenges with the concept of the mole

concept and chemical equilibrium, the purported challenges and the strategies applied to alleviate them were probed further.

Trainees' responses to students' challenges with the topic of *chemical equilibrium* were numerous. Novak [8] attributed such observed difficulties to inappropriate teaching methods, teachers' incompetence, teacher-misinterpretations, and illogical sequencing and presentation of facts by students themselves. The trainees in this current study agreed with some of these earlier findings about misconceptions on chemical equilibrium. Some students' major difficulties identified with chemical equilibrium were categorized as shown in Table 2.

Table 2: Common students' challenges with chemical equilibrium

Misconceptions on equilibrium	No. of trainees who observed misconceptions
1. Expressing equilibrium as a dynamic process	08 (All except T2, T3 and T7)
2. Effect of external stress on equilibrium	10 (T2 to T11)
3. Inappropriate mathematical skills	06 (T4 to T6; T8, T10, T11)
4. Inability to interpret sentence questions mathematically	09 All except T1, T2; T7
5. Misunderstanding of expressions (language difficulties)	10 All except T3 from S2
6. Level of abstraction (of concepts)	11 (T1 to T11)
7. Inability to interpret terms like 'limiting reactant'	11 (T1 to T11)
8. Difficulty in understanding that equilibrium shifts were to keep K_c constant	06 (T4, T5, T6, T8, T10 and T11)

N = 11

Apart from the common major misconceptions enumerated in Table 2, four trainees (T4, T5, T6, T10) intimated that some of the preconceived notions and non-scientific beliefs were difficult to correct as students always went back to their naïve pre-conceptions. For example, students could not comprehend that a system in equilibrium was not 'at rest' and so often referred to 'completion' of 'visible' or observable macroscopic reactions as attainment of equilibrium. Three of the trainees (T3, T8, T11) reported that students do not understand that the

position of equilibrium could shift without causing a change in the value of the constant, 'K'. Heikkinen and Piquette [22] made a similar observation in their study and suggested strategies for remediation. The extent of students' difficulties in understanding the effect of stress on systems is in consonance with observations made by van Driel and Graber [23], Locaylocay [6] in the Phillipines, and Mavhunga and Rollnick [24] in South Africa. Respondents were consistent in their free-response answers on students' challenges with the concepts in chemical equilibrium.

From the discussions above, it is clear that the trainees in this study had a high level of awareness of misconceptions that students had about chemical equilibrium and many other chemistry topics. The trainees, however, could not see the connectivity between the many challenges in various topics that they enumerated and the topic, 'chemical equilibrium'.

The second research question sought to find out the trainees' alertness in identifying challenging cues that suggested alternative conceptions from their students. It was obvious that until students demonstrated conceptual or algorithmic difficulties through oral and written responses, teachers hardly noticed them, nor deliberately sought for them. The trainees, nevertheless, possessed knowledge of the fact that students could possess alternative conceptions. In other words, a teacher would not be able to identify any alternative conceptions from his students' attitudes and body language of students if they sat passively in class. Therefore, teachers have to initiate activities that can enable such challenges to be exhibited overtly. Trainees in this study were of the view that appropriate interactive, engaging environments had to be deliberately created to elicit students' prior conceptions, yet they hardly practised what they intimated. Analysis of questionnaires submitted in this study indicated that the trainees had no standard diagnostic processes or cues for identifying students' conceptual

challenges about chemical equilibrium as Part B of the questionnaire sought to find out. Nevertheless, if they were able to identify them, then they worked on remediation through various instructional practices.

Research question three probed the kind of instructional strategies reportedly used by teachers to address identified alternative conceptions about chemical equilibrium (Part C of the questionnaire). Some of the trainees' instructional remediation techniques were the use of analogies (T1, T4, T7, T9), animations (T1 and T3), video simulations (T1, T9), prior knowledge (T4, T6, and T10), a walk-through a correct solution (T6, T10 and T11), and blackboard pictorial demonstrations and sketches (T5, T8 and T3). Upon further probe, the trainees suggested the use of other logical instructional strategies for future use, such as conceptual explanations (T5 and T6), and solving mathematical problems from first principle (T1 to T3 and T10), but only T3 mentioned some topics for which she would apply some diagnostic and engaging strategies. They all intimated that the deliberate use of activities with colourful solutions could be helpful to enable students build mental models about chemical equilibrium. Activities that involve colour change in chemical equilibrium has been found to enable students to understand the concept of 'equilibrium', as the colour changes enable them to form mental models of the various changes in equilibrium position [8]. In other visual studies students were able to literally see and appreciate the equilibrium shifts with respect to colour changes on a macroscale so that they were able to relate equilibrium position to changes in concentrations of reactants and products. Data from the interview sessions corroborated most of the data gathered from the questionnaires. In all, analogies, as said to be effective in concept construction, was the main conceptual or remediation tool used in the trainees' classrooms to enable their students to construct concepts on chemical equilibrium. The use of cooperation group, learning cycles, refutational texts, concept-

based text and other interactive or diagnostic tools were not employed. The use of analogies have been emphasised by Svegi et al. [19] as useful tools for construction of knowledge as they enable learners to build new concepts on existing schema [12, 13].

When a question was posed on what the trainees (prospective professional teachers) could do in future to identify students' prior conceptions with their new expertise early enough and possibly remediate identified misconceptions, three trainees (T1, T4 and T6) in this current study intimated that they would attempt to link new material to prior knowledge to alleviate or minimise the occurrence of teacher-made and conceptual misconceptions. Two of the trainees (T5 and T9) suggested the use of experimentation, as hands-on activities could be used to enable students to remember whatever they learn – from first-hand experience. This is in consonance with Kimberlin and Yezierski's [7] and Chanyoo et al.'s [25] findings about engaging students in hands-on activities for concept formation, cognition, and retention. Four trainees (T4, T5, T10, and T11), did not subscribe to employing the lecture method to teach the concept of chemical equilibrium. They opined that it had not been useful to their students and so would not subscribe to that, but rather adopt interactive, engaging, learner-centred teaching methods.

Teachers must be knowledgeable about some of the basic or common misconceptions that their students could come to class with. Such fore knowledge could be basis for unveiling and correcting other misconceptions which students could possibly hold. Besides, more innovative, relaxing, engaging and interesting approaches to teaching and assessments (such as jig-saw puzzle and concept cartoons) could provide an opening for overt learner expressions. The constructivist paradigm could be employed to teach concepts about chemical equilibrium effectively as it will enable students to construct knowledge from first-hand experience.

Further interpretive deductions from the trainees' responses suggested that secondary school students were unable to reason analytically, logically and abstractly, such that they could not mentally visualise interactions that occurred at the microscopic level. Thus, they could not switch among macro, micro, and sub-microscopic and symbolic levels of matter. This could be a ground for poor concept formation about matter. Trainees T1, T2 and T3 intimated that their students did not face challenges switching among the three particulate levels. It is worth noting the category of schools that these three trainee-teachers come from- endowed schools S1 and S2.

In order to help students, operate at the three different particulate levels abstractly in their study of chemical equilibrium, interactive visual and engaging activities would have to be adopted. These would facilitate the concepts about the particulate nature of matter, which are requisites for understanding the concept of equilibrium. The use of the constructivist paradigm, as in other studies [8, 19] was found to be and still could be useful for teaching chemical equilibrium. Constructivist-based teaching suggests that since an understanding of learners' prior conceptions provides useful insight into their thinking, it should enable teachers to devise constructivist pedagogies that would suit their learners. When prior knowledge is considered during knowledge construction, students are able to disabuse their initial naïve conceptions.

Findings from this study suggest that an awareness of prior conceptions could be useful in enabling students to form scientific concepts about chemical equilibrium. Constructivist-based teaching supports that since an understanding of learners' prior conceptions provide insight into their thinking patterns, it should enable teachers to devise teaching strategies that could suit their students. It was found in this study that the trainees did not use appropriate diagnostic processes or tools to assess their students' prior conceptions. Most of their questions were recall ones that did not demand judgemental reasons which could oust deep-seated unscientific conceptions.

Though their probing skills were shallow, the trainees said that their knowledge about whatever misconceptions that they identified enabled them, they said, to choose appropriate remediation strategies so that students could more easily scaffold and build scientifically acceptable views about science.

An interesting trend that emerged from alternative conceptions showed that basically all students have several misconceptions about chemical phenomena. Teachers used simple recall questions that were not followed up with reasoning or judgemental questions. If the pre-assessment questions were in written form, they were often multiple-choice questions or one-word answer type questions. Treagust [26] suggests the use of tier questions which can quite often probe further to unearth the root cause of students' misconceptions.

The prospective professional teachers (T1, T2, T3) from endowed schools reported less misconceptions, followed by teachers (T7 to T9) from average schools and lastly, teachers (T4, T5, T6, T10 and T11) from deprived schools. The implication here is that, students in less endowed schools appeared to be more disadvantaged in terms of their conceptual understanding of chemical principles, especially chemical equilibrium, which is a requisite to many other chemistry concepts. The root cause of this observation will require further studies. Nevertheless, trainees from deprived schools showed more eagerness to adopt innovative, interactive and engaging activities to support their students to build scientific conceptions, followed by trainees from average schools. Teacher-trainees from the endowed schools, with appreciably good students who displayed less misconceptions, were less enthused about adopting engaging activities in class.

The major findings from the study were that students come to class with many alternative conceptions about natural phenomena that could impede further learning about the nature of

matter, especially about chemical equilibrium. Teachers would therefore have to create favorable classroom conditions to facilitate the proper study of chemistry concepts required at the secondary school level (Grades 10 to 12). This could be achieved through:

- i. Enhanced interaction with students
- ii. Planning for conceptual teaching
- iii. Use of diagnostic assessments
- iv. Expansion of teaching strategies
- v. Use of extension exercises

CONCLUSION

The research indicated that about 7 (63.6%) of the trainees were largely aware of their students' alternative conceptions, and some appropriate instructional strategies to use for remediation, especially with chemical equilibrium. They intimated that some of the strategies that they employed in solving some identified conceptual difficulties were engaging activities such as analogies, solving problems with students on the board, pictorial demonstrations and blackboard illustrations. However, only analogies were the main instructional tool that the trainees employed. A few of the trainees intimated that they adjusted their instructional strategies when they found out their students' conceptual inefficiencies and worked out remediation procedures, but were unable to describe the exact procedures that they employed. What was more important was their awareness of difficulties which could arise from students' inability to understand some scientific language as well as difficulties in dealing with abstract concepts. It was obvious that information and communication technology tools were hardly used in schools to foster visualisation and subsequent concept formation. The trainees admitted that teachers

could be a source of some of the identified students' misconceptions and so would be more careful of how they introduced concepts so that their students would form authentic scientific frameworks.

A trend that emerged from teachers' awareness about students' misconceptions showed that students in endowed schools exhibited less conceptual challenges than those from deprived schools, as reported by trainees who teach in the said schools. Furthermore, all the 11 trainees showed a high level of awareness of the fact that their students came to classes with several misconceptions, regardless of the type of school they were found in. All students had some kind of naïve conceptions about chemical phenomena, especially chemical equilibrium.

Interestingly, these Ghanaian trainees did not mention that other causes of misconceptions could be external factors such as the home, parents, or textbooks as other researchers had found [3, 18, 27]. It is hoped that these findings would make other chemistry educators aware of the possible alternative conceptions that high school students could have, assess the extent of misconceptions, especially about chemical equilibrium and the probable remediation techniques that could be used. The interpretive role that was assumed by the researcher enabled a deep probe of the challenges that teachers face and the conceptual teaching roles that they have to assume. This is because being a conceptual teacher enables effective facilitation, good planning, and a closer relationship with one's students for cognitive growth and improved academic performance.

IMPLICATIONS FOR STUDY

Findings from this study could provide useful hints for chemistry teachers in many important tasks, as it will help to raise awareness of alternative conceptions in the teaching and

learning of chemical equilibrium. It could also lend ideas for the design of curriculum, study materials, laboratory experiments, and constructivist assessments. Evidence gathered suggests that teachers were aware that the concepts of chemical equilibrium were challenging for most students who held on to their original beliefs. Although data obtained was enough to establish that trainees had ideas about varieties of classroom teaching strategies, these did not necessarily mean that conditions for fostering conceptual change were ensured as the latter were not evident from data received. Diagnostic assessments could be employed, as they determine the level of entry knowledge, skills, and understanding at the beginning of a lesson for curriculum adjustment to meet learners' needs, strengths and weaknesses.

LIMITATIONS

Trainees were not representative of all 10, and now 16 regions in the country because only postgraduate who had enrolled for the said pedagogy course participated in the study and represented their native regions. Since this was a pilot study more than 10% of the representative regions in Ghana is acceptable. It is hoped that a further study will encompass representative samples from all over the country.

The use of email to collect data was found to be less stressful than the 'on the spot' 'pen and paper' data collection procedures. The return rate of the questionnaire was also quite high (73%) from the sample, and 58% from the entire population. However, some respondents did not answer all the questions as there was a possibility to overlook or skip over some of them. It is hoped that next time an internet –based survey would be employed in data collection, where the setting would be such that, questions would have to be compulsorily answered before follow up items drop down from a menu. This would help to minimise missing data so that a fairer

judgement and holistic view of a study situation could be obtained to ensure a better implementation of a response-contingent strategy (Heikkinen & Piquette, 2005).

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Appendix A: Open-ended Questionnaire

1. What are misconceptions?
2. Are you aware that some of your students have alternative conceptions about some topics? Yes/ No
3. If yes, explain in details some types or examples of misconceptions that they have.
.....
4. What peculiar alternative conceptions have you identified with respect to the topic *chemical equilibrium*?
a. None b. a few c. a lot d. not aware of any misconceptions
5. Kindly explain whatever choice that you make in an expanded/clearer form.
.....
6. What strategies do you use to assess students' prior conceptions?
.....
7. State topics for which you used prior or pre-assessments and the types of probes used.
.....
8. What innovative procedures would you suggest for use in future, in order to facilitate students understanding of chemical equilibrium?
.....

Appendix B: Semi-structured interview

1. What are alternative conceptions?
2. What types of alternative conceptions have you identified among students in your teaching career?
3. Could you please give examples of them?
4. How were you able to identify them? How did you figure out that they were naïve/ prior/ alternative conceptions?
5. Have you taught the lessons on chemical equilibrium before?
6. What alternative conceptions did you identify in the topic 'chemical equilibrium'?
7. How would you suggest that chemical equilibrium in particular and other chemistry topics be taught?