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Pedagogics of chemical bonding in Chemistry; perspectives and potential for progress: The case of Zimbabwe secondary education

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Abstract: In this study, the pedagogics of chemical bonding in Chemistry at Secondary school level, perspectives and potential for progress was investigated. The study was premised on the qualitative design methodology grounded and informed by the interpretive paradigm. It was guided by the constructivist theoretical framework acting as a lens through which we viewed our study. Eight (8) Bachelors degree holders, having taught chemistry at Advanced Level for at least 2 years, were purposively selected to comprise a sample of participants. Narrative interviews, followed by focus group discussions to validate the procedure, were carried out. Thematic approach data analysis from audio-taped -transcriptions- resulted in main themes and sub-themes being drawn out. It was found out that teachers teach for examination purposes, hence this followed a simplistic pedagogical approach resulting in misconceptions of chemical bonding being formed by learners. Rigid and dichotomous approach to ionic and covalent bonding, as outlined in textbooks and by teachers, forgetting its continuum scale, resulted in misconceptions in the understanding of chemical bonding. Teachers were found to be contributing factors by virtue of incompetence. Therefore use of learner centred pedagogical bottom-up approach was highlighted. Application of computer-assisted instruction on conceptual understanding of chemical bonding by competent teachers was inexorable.

Keywords: Pedagogics, Chemical Bonding, Misconceptions

1. Introduction

Based on several studies which show that Secondary school children hold misconceptions of chemical bonding in Chemistry [1-7] very few researchers have gone further to study the pedagogics [8] of chemical bonding. Pedagogy is the science or profession of teaching where pedagogic is an adjective. The teacher is responsible for facilitating the understanding of the concept of chemical bonding to the learner. Bonding is a central concept in the teaching and learning of Chemistry. Many Chemistry concepts are central on chemical bonding. Acquisition of correct concepts are therefore essential and critical for understanding almost every other topic in Chemistry such as Carbon compounds, proteins, polymers, chemical energy and thermodynamics [9-11].

What is new with this study is that it is highlighting the pedagogical approaches of teaching Chemistry to assist in stamping out misconceptions. For Zimbabwe in particular, no study along these precepts has ever been carried out. A study is therefore required to consider the pedagogics of chemical bonding in Chemistry at Secondary school level. We have to invest on the best way possible to teach the concepts.

2. Context

Learners' misconceptions regarding chemical bonding have been noted worldwide [12-16]. The misconceptions are largely a result of how students have been taught. [17] argue that, most misconceptions in Chemistry are not derived from the learners informed experiences of the world but from prior science teaching. If so, we need to ask ourselves how often can teaching strategies and pedagogy mislead students? Several factors impact negatively on the acquisition of the concept of chemical bonding, and some are put in context.

2.1. Use of Models

Chemistry as a discipline is dominated by the use of models. The range of sophistication of the scientific models used by chemists to understand chemical bonding is one factor that contributes to students finding this topic difficult [18]. Students are poorer at modeling than teachers expect, and young secondary school students usually do not look further than a model's surface similarities. They think that models are toys or small incomplete copies of actual objects, and therefore they do not like to seek purposes in the model's form [13]. From the results of their studies, [19] strongly recommend that students should learn about the nature of models and their use as thinking tools and learn about the scope and limitations of specific chemical models. Teachers should encourage the use of multiple models for a given phenomenon. Interestingly, teachers themselves may have misconceptions regarding scientific concepts and models. Some teachers conceive scientific models in mechanical terms and believe that models are true pictures of non-observable phenomena and ideas [18].

Chemistry teachers seem to focus their practice on the content of specific models, rather than on the nature of models and modeling, [20]. In order to teach Chemistry in the way that students will understand, teachers need to have a clear and comprehensive view of the nature of a model in general, how their students construct their own mental models and how the expressed models can be constructively used in class. It is very important that students realize that no model is entirely correct and that they understand that science is more about thinking than just describing objects, [13].

According to [19], teachers do not emphasize neither the need for considering the scope and limitations of models during the process of modeling, nor the importance of discussing with the students such matters when presenting a model. [13] claim that models are more than communicative tools: they are important links in the methods and products of science. Moreover, they suggest that students, who participated in negotiating the shared and unshared attributes of common analogical models for atoms, molecules, and chemical bonds, actually used these models more consistently.

In Chemistry, almost all models are metaphorical models. [21] asked themselves: what happens when Chemistry students fail to recognize the metaphorical status of certain models and interpret them literally? In what way might it detract from the goal we set ourselves as teachers, of facilitating the incremental expansion of our students' conceptual framework? They claim that metaphors may binder insight into a problem, by blocking productive resolution of the problem. In their paper, they analyzed three cases and detailed some cases in which metaphors can mislead rather than enlighten. The metaphor is perhaps the most important part of the model for students. Thus, their recognition of a metaphorical status is crucial for avoiding misconceptions.

2.2. The Language

The language of science is not a part of students' native language in the school and it rather sounds foreign and uncomfortable to most students until they have got accustomed to using it for a long time, [7]. [13] showed that students had difficulties understanding the concept of neutralization. Many students believe that any neutralization reactions would always result in a neutral solution. He attributed part of this difficulty to the ambiguous use of the chemical context.

Students also exhibit misconceptions in chemical equilibrium since firstly the concepts seemed abstract and secondly the words from everyday language are used but with different meanings [23]. Statement of equilibrium concepts contain everyday terms such as shift, equal, stress and balanced, such vocabulary can lead to very different visual images. The misconceptions in chemical equilibrium stems from the label 'equilibrium' being used in physics as well as some everyday life balancing situation such as bicycle riding or weighing balance. Attributes of equality in general, equality of two sides, stability and a static nature become associated with the concept of equilibrium [9]. This may result in misconception that in reversible reaction, the concentration of reactants and products are equal at equilibrium.

2.3. Concept Presentation

Chemical bonding is a topic in which understanding is developed through diverse models, which in turn are built upon a range of physical principles; students are expected to interpret a disparate range of symbolic representations standing for chemical bonds, [10]. According to [14], matter can be represented on three levels, physical phenomena, microscopic (particles), and the symbolic levels (chemical language and mathematical models). [12] claimed that often teachers unwittingly move from one level to another in their teaching. In that way, they do not help students integrate the levels, and each level can be interpreted in more than one way. Thus students become confused rather easily.

More recently, [16] has suggested that students must first thoroughly understand how to convert a symbol into the meaningful information it represents. Only then will they be able to cope with the quantitative computation. According to [1], it is very important to distinguish between internal representation, which is the information stored in the brain, and external representation', which is the physical manifestation of this information. Individuals with very different internal representations might write similar external representations. The instructor writes symbols, which represent a physical reality. Very often, students write letters, numbers, and lines, which have no physical meaning to them. In order to understand the structure of matter, the students need to be familiar with the multiplicity of terms, with the meaning of scientific models, as well as the difference between the macroscopic and the sub-microscopic worlds.

2.4. Textbooks

There are several external factors that can generate students' misconceptions. If so we have to ask ourselves how often are such misconceptions generated by the contents of textbooks and by teachers? How can teaching strategies and the way these concepts are presented in textbooks mislead students? A review of the research relating to students' misconceptions of science concepts revealed that these misconceptions have common features. Students are often strongly resistant to traditional teaching and form coherent, though mistaken, conceptual structures, [24]. The literature indicates several external factors that might cause learning impediments regarding the concepts of chemical bonds. [25] and [26] for example, claim that the analysis of current textbooks is of a pivotal importance because they constitute the most widely and frequently used teaching aids at all educational levels. Some analyses of science textbooks have shown that they tend to present science as a collection of true or complete facts and as generalizations and mathematical formulations, as if the material had been 'read directly from nature'.

In many chemistry textbooks, elements are conveniently classified as metals or non-metals (with a few semi-metals perhaps mentioned). In many cases this dichotomy among elements leads to a dichotomous classification of bonding in compounds: covalent being between non-metallic elements and ionic being between a metal and a non-metal. [27] presents a scientist's view, claiming that the way textbooks and teachers present the classification of the chemical bonds, as if everything is very simple and clear (hydrogen bond, covalent bond, etc.) is deluding and misleading. According to the scientist's view, one of the most important skills is the ability to classify intelligently. Thus, teaching students to classify originally by themselves in order to expand their understanding and to give them the opportunity to perceive the concepts from different points of view. In this way, the students can sharpen their thinking abilities and understand the relations between contents, skills and the scientific process.

Reference [18] suggests that many of the ideas used to understand chemical bonds are not accessible at an introductory level. Instead, curricula models need to be used in order to simplify the topic. Ideally, students will develop their own 'tool kit' of bonding concepts as part of their progression in learning about the subject [7]. Reference [11] considers, as an example, the term covalent bond and suggests that most students entering secondary school do not know what it means. As they progress through school, encountering introductory and more advance college chemistry, they construct a meaning as they learn the term in a range of contexts. According to [11];

"A young student who has just learnt the term of a covalent bond in a very limited context does not share the same set of meanings for the term as teachers. This is not a case of the teacher being right and the student wrong, but of them having a different concept of covalent bond. The teacher and the student use the same word, but…the teacher's meaning is not only extended, it is more sophisticated, more subtle, and more deeply integrated into a framework of chemical ideas' (p. 56).

Finally, students do not possess the rich meaning of the term, as teachers do. It is suggested that there is a gap between students and their teachers concerning students' understanding of these concepts. For the teacher the task is a routine exercise, but for the students it is a novel problem.

2.5. Lack of Effective Communication

According to [24], a lack of effective communication between students and teachers can lead to a mismatch between what is taught and what is learned, in the context of science lessons, symmetry between the nature of teachers' understanding of a particular science topic and students' ideas regarding this topic is critical, because such a match illustrates what scientific knowledge is being taught and learned in the classroom. One way that teachers and textbooks simplify the physical and chemical concept is by using anthropomorphic explanations. For example, [7] showed that 10^{th} grade students commonly adopt as an explanatory principle the notion that atoms want to have "octets' or 'full outer shells', and that chemical processes often occur to allow atoms to achieve this. Even some school textbooks incorrectly refer to eight electrons in the third or higher shells as a full shell.

The term 'sharing', used to describe the covalent bond, often keeps its 'social' connotations when used by students. For example, the shared electrons may be seen to still 'belong' to specific atoms, and so bond fission is often assumed to be haemolytic, since each atom would want to get its own electron back. It could be argued that the uncritical and unthinking use of terms like 'sharing electrons' by teachers and its use in textbooks are not helpful to students.

Reference [10] suggested not learning by the 'octet framework', which may lead to learning impediments. The existence of bonding, which does not lead to atoms having full electron shells, is consequently something of a mystery to many students. Moreover, students may have difficulty accepting anything that is not clearly explicable in 'octet' terms as being a chemical bond. Hence, hydrogen bonding and van-der-Waals forces cannot be readily fitted into such a scheme, and the difference between inter-molecular and intra-molecular bonding is not clear to students. Therefore it is against this background that this study looked at the pedagogics of chemical bonding in Chemistry. The research questions which guided this study are:

1. What are the sources of student misconceptions in chemical bonding?
2. How can these misconceptions be dealt with?

The theoretical framework that is used in this study is Bruner's Constructivist's theory [28] which states that learning is an active process in which learners construct new ideas or concepts based upon their current / past knowledge. The learner selects and transforms information, constructs hypotheses, and makes decisions, relying on a cognitive structure to do so.

3. Methodology

3.1. Research Method and Design

Our study is located in the qualitative design paradigm. “Qualitative research is no longer just simply ‘not quantitative research’--- it is intended to explain social phenomena ‘from inside’ in a number of different ways,” [29] p. xi. Some of the common ways argued by [29] are:

- analyzing experiences of individuals or groups. The experiences can be related to professional practices.
- analyzing interactions and communications. This can be done by recording practices of interacting and communications. Common to such approaches is that they seek to unpack how people construct the world around them. In this study, qualitative design shall be employed.

This study was grounded and informed by both the interpretive and participatory paradigms and worldviews. In the interpretive worldview, my participants who were teachers in Secondary schools were interviewed. We relied as much as possible on the participants’ view of the situation,” [30], p. 20. Their interpretation of the pedagogics of chemical bonding was obtained [31].

3.2. Participants

Research participants were eight (8) teachers purposefully selected from five (5) Secondary schools within Gweru urban district. They were selected on the basis that they had graduated from a University with a Bachelor’s degree with Chemistry as one of the majors. They had taught Chemistry at Advanced Level (A ‘Level) for more than 2 years. All were males except one lady who was a Bio-Chemist. Age range was (25- 42 years).

3.3. Data Gathering Tools

The data generating instruments used included semi-structured interviews which were audio taped and field notes were used. We used field notes [32] after returning from each interview which provided this study with personal log that helped us to keep track of the development of this study to visualize how the research plan had been influenced by the data. The semi structured interview can be referred to as narrative interviews. An interview is a face-to-face verbal interchange, in which the interviewer attempts to elicit information from another person or persons [33], but a narrative interview on the other hand can be referred to as an in depth type of interview since in one-to-one situations, participants are asked to tell their chemistry teaching stories in a variety of ways, [34]. The narrative interviews began with the researchers interviewing or having conversations with participants who told stories of their experiences with regards to teaching chemical bonds. Their objectives, methods, challenges, in general were sought. Misconceptions held by students were to be elaborated by participants. Their possible sources were to be identified. How to teach to stamp out or avoid such misconceptions were highlighted.

First interview which lasted about 30 minutes was introduction of the persons and research objectives and questions to be answered. All individual face to face narrative interviews took place in the school premises where the teacher was teaching. Private offices were used and in some cases sports fields which seemed to be quiet places were used for interviews. Second session was interview on the first research question which wanted teachers to identify sources of students’ misconceptions. This lasted for about one hour per participant. Third session which lasted for about an hour again per participant was on second research question which dealt with how the misconceptions could be dealt with. The fourth and last session took place in Gweru gardens where a focus group discussion took place on a Saturday afternoon for about 2 hours. Focus group discussion centered on the same research questions. They were meant to enrich information obtained through individual narrative interviews.

In order to avoid dominance by few individuals during the interview session, we provided a platform for all individuals to participate without feeling intimidated or inferior by giving each participant the room to make contributions, pertaining to his / her teaching experience. During the discussion session, the participants took the lead while we listened and gave necessary guidance.

Responses from audio taped semi-structured narrative interviews were transcribed, coded in order to organize the data and analyzed for common themes and sub-themes. This narrative data and field notes were analyzed using themes and descriptions of context. Qualitative analysis and presentation of research data was done in form of descriptions of observed phenomenon and direct quotes of participants.

This triangulation is a validity procedure where we searched for convergence among multiple and different sources of information to form themes or categories in a study [35]. As a validity procedure, triangulation is a systematic process of sorting through the data to find common themes or categories by eliminating overlapping areas. Further validity of the study hinged on the assurance that the teachers had the same understanding of chemical bonding as the researchers had.

3.4. Ethical Considerations

Participants in the study gave their consent in writing before commencement of the study after the purpose of the study and what would be expected of them had been explained. Since their selection was purposive, they were assured that they were free to withdraw at any stage without any negative consequences. Pseudonyms were assigned to participants to maintain and guarantee anonymity and confidentiality.

4. Results and Discussion

The main themes which emerged from the findings are represented in Table 1

***Table 1.** Sources of misconceptions.*

Main Theme	Subtheme
Teaching for examinations-	Prizes / simplistic teaching approach
Terms and explanations used by teacher Presentation of concepts in textbooks	Octet rule: Ionic / covalent bond
Ineffective communication between teachers and students	
Syllabus structure	Topics not linked – pedagogical approach
Lack of competent chemistry teachers	Teachers having misconceptions too of chemical bonding

Participant 7 argued saying *we teach for examinations to enable our students to pass. Inini ndinova driller.* The translation from Shona vernacular used by this participant is that the participant as a teacher, teaches children through memorization or rote for the sake of passing examinations. Education Provincial leaders, who are the local governing authorities in the Ministry of Education, ranks and promotes teachers according to the performance of their pupils whom they teach. Final year examinations per level are used as a measuring stick. In such cases teachers may use all simpler techniques, including memorization in order to make children pass examinations. Chemical bonding concepts may be misconstrued, or oversimplified for the sake of passing examinations.

Oversimplifying and overgeneralizations of concepts makes students fail to use higher cognitive traits [36]. [5] argues that students who memorize concepts will in turn fail to use "big ideas" in the real world of science. Participant 2 argued that it is very difficult to assess concepts and misconceptions….*the challenge is …we are not able to tell between students who understand and students who recite…..because a correct answer is just a correct answer. I have no indication regarding his understanding. Such contribution shows that questions used for assessment are low order, which just require right / wrong answers. They are not searching questions, as argued by [36].*

Participant 5, during focus group discussion indirectly concurred by saying *one of my popular questions relates to why boiling point of Cl_2O is lower than that of H_2O_2. The acceptable answer is that boiling point of Cl_2O is lower because the hydrogen bonds between the H_2O_2 molecules are stronger than the van der Waals interactions between Cl_2O molecules.* The same teacher participant 5 went on to say *the use of correct terms cannot make us guarantee that the students understand the concepts or rather the answer could have been the result of memorization.* [37]argues that although rote memorization of some facts is critical, in many cases it seems that students memorize patterns but are not able to fully reason through them. Although students are to be taught to pass examinations, [38] would argue that this must be balanced by the need to present material in a way that is scientifically valid and provides a suitable platform for future learning. In other words, the teacher needs to find the "optimal level of simplification" simplifying sufficiently to suit the learners' present purposes, but not oversimplifying to undermine the future needs.

Participant 1, in agreement with all other members of the focus group contributed an issue to do with one weakness hitherto in the pedagogics of chemical bonding. There is a continuum between ionic bond and covalent bonding and no dichotomy, but teachers wrongly present the bonds in terms of "yes and no". Participant 1 said …*teaching chemical bonding is a problem, some of us teachers want a specific answer like either ionic or covalent bond as though there is nothing in between or in the middle.* There was some silence in the group implying that the majority of the members themselves also had a misconception since participant 1 was appearing to be introducing a new controversy. In response participant 6 said *zvakaoma izvi.* The participant was saying these concepts are difficult. Participant 6 went on to say…*one of the problems why bonding concepts are difficult is because of the definitions. they tend to make things rigid and absolute which is a big mistake. …chemical bonding is a complex concept. We don't seriously sit down to think how deep and rich this concept is. We simplify bonding which is not even simple* (others laughed) *hence we lead students' into forming misconceptions like the octet rule, that rule misleads pupils.* [11] points out that the octet rule does not explain why bonding pairs of electrons do not repel each other despite the same charge and how moving electrons can stay between two nuclei of atoms. Consequently, students cannot understand strengths of covalent bonding correctly. This rule satisfies bonding concepts at lower forms but not higher forms like Advanced Level in Zimbabwe. Chemistry should not be taught in such a way that low order; clear-cut answers are the order of the day. Higher order cognitive skills are to be employed if teacher –student interactions are to be meaningful. Such approach will be a sound pedagogical perspective.

During focus group discussion, it was pointed out that some misconceptions are a result of inadequate information obtained from textbooks. Textbooks were identified to be sources of misconceptions on chemical bonding [38,9,19]. In many textbooks, elements are conveniently classified as metals or non-metals, sometimes a few semi-metals. Very often, this dichotomy among elements leads to a dichotomous classification of bonding related to compounds, covalent being between non-metallic elements and ionic being between a metal and a non-metal. The teaching of this concept is often too simplistic. Furthermore, many chemistry textbooks do not relate to hydrogen bonds and to van der Waals interactions as chemical bonds [39] They are often presented as "just forces". [37] suggests that hydrogen bonding is a basic chemical principle that has applications in all areas of Chemistry. Students of chemistry need to be able to analyze situations in which hydrogen bonding can occur in phrases and explain facts by using declarative knowledge, resulting in students lacking fundamental understanding of this concept [15].

Participant 4 had this to say….*for instance, we say the bonding in metals is "metallic"; text books also say so, but are we aware that although the electrons are delocalized, the bonding is basically covalent.* The contribution by participant 4 is correct. It would seem today many students of chemistry have a misconception of metallic bonding as a result of "the sea of electrons or delocalized electrons in metals". [40] pointed out the importance of avoiding confusion between what they called "children's science" and "scientist science". Teachers must teach aiming to produce scientists. Scientists must be able to think and operate like scientists. [28] argue that children must be given the chance to construct knowledge through discovery method. Based on a long term study, [8] argued that the new direction for teaching the chemical bond concept must be a bottom-up framework (p.25). Its general approach relies on basic concepts such as Columbic forces and energy at the atomic level to build a coherent and consistent perspective for dealing with all types of chemical bonds.

As described by [5] p 1680 "It is possible to show how this diversity (of bond types) arises from a small number of fundamental principles instead of presenting it as a large number of disparate concepts". The framework proposed by [15] (see figure 1) introduces the elemental principles of an isolated atom (stage1); it then follows with discussions of general principles of chemical bonding between atoms (stage 2) and the general principles are then used to present the different traditional categories of chemical bonding as extreme cases of various continuum scales (stage 3). Equipped with this knowledge, students can then construct [28] a coherent understanding of different molecular structures (stage 4) and properties (stage 5).

Stage 5	Properties
Stage 4	Structures
Stage 3	Bonds – A continuum approach
Stage 2	The chemical bond- Fundamental principles
Stage 1	A Single atom- Elemental principles

Figure 1. *Schematic illustration of "bottom-up" framework (Levy, et.al 2008).*

The primary purpose of the first stage is to provide a qualitative description that is conceptually consistent with quantum mechanics but gives a very clear, intuitive answer to the question which puzzles many students, "what really causes atoms to interact and form a chemical bond?"

When this model is introduced to the students, one of the objectives is to dispel the notion that chemical bonding is difficult. Energy and force are the concepts to be introduced and their interrelations are dealt with. The understanding that nuclei are held together because of nucleus – electron attraction, which is a simple consequence of Coulomb's law, is the first step towards a rational view of chemistry which is not based on rules of thumb. A crucial concept is that stability in general which is obtained by minimizing energy. The above principles are best explained by considering the energy curve of any two isolated atoms as postulated by [5] (see figure 2).

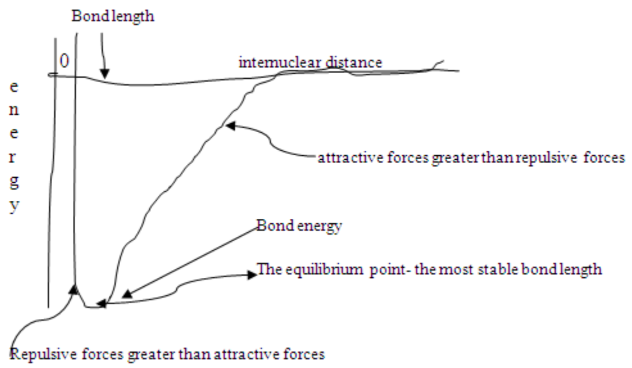

Figure 2. *A schematic energy curve for any two atoms that interact (based on [5]).*

If this model is understood, all other chemical bonds can be explained in terms of energy stabilization (i.e. bond energy and all equilibrium inter-atomic distances (i.e. bond length) reflect positions where there is no net force on the nuclei i.e. attraction balances repulsion [8].

The teacher may facilitate class practical experiments to enable learners to discover and construct such understanding. Learning of chemical bonding will become meaningful and correctly conceptualized. Bottom – up approach (Learner-centered approach) will become the acceptable and advantageous pedagogical approach for chemical bonding (see Table 2).

Table 2. *How to deal with misconceptions.*

Main Theme	Subtheme
Learner centered approach	bottom – up approach
Competent science teachers	workshops- mentoring
Use of E-learning	e.g. Cyber School

Participants argued that Zimbabwe Chemistry syllabi have topics which are not linked. Inexperienced teachers are not able to link them coherently hence some misconceptions in bonding arise. Participants did not request for syllabi to have topics which are linked. This will remove creativity and originality in pedagogical approaches. New and inexperienced teachers from the University must be attached to mentors for a prescribed minimum period of time, for instance 2 years. Mentoring will assist new and inexperienced teachers to be able to link syllabus topics.

The qualified practicing teachers must hold school, district, provincial and national workshops where pedagogical issues on chemical bonding are threshed out. This will assist in producing competent teachers with time. Participants argued that qualified and competent chemistry teachers will have the pedagogical skills to identify, and manage students' misconceptions. Teachers who are competent do understand students' view of science concepts and therefore impact new knowledge. According to the constructivist view of learning, learners existing ideas are important to make source of new experience and new information [41].

The participants revealed that some misconceptions are a result of ineffective communication between teacher and student. Participant 3 had this to say….*you may write Cl_2 on the board, this might conceptually mean a lot of things even if the topic is clear.* Therefore teachers may over assume that they are communicating, when in fact they are not. [27] argued that a lack of effective communication between students and teachers can lead to a mismatch between what is taught and what is learned. According to [14] and [12], matter can be represented on three levels, macroscopic (physical phenomena), microscopic (particles), and symbolic- representational (chemical and mathematical language). The symbolic level can be seen as having the key role of mediating between the phenomenological-descriptive level of what students can directly perceive and the abstract conceptual level of theoretical entities such as quanticles (e.g. 'H_2' can stand for both the substance and the molecule , and so acts as means of linking one to the other). Where possible, let there be more of learner talk and activity rather than teacher talk. The teacher will be able to analyze and stamp out misconceptions well on time. Therefore, an important goal is to allow students to express their own misconceptions during a lesson or, in the attempt to introduce new subject matter in a lesson, to let them be aware of inconsistencies regarding their ideas and the up-to-date scientific explanation. In this way, they can be motivated to overcome these discrepancies. Only when learners feel uncomfortable with their ideas, and realize that they are not making any progress with their own knowledge will they accept the teacher's information and thereby build up new cognitive structures.

For the teaching process, it is therefore important to take students' developmental stages into account according to student's existing discrepancies within their own explanations, inconsistencies between misconceptions and scientific concepts, discrepancies between preliminary and correct explanations of experimental phenomena, and possibilities of removing misconception [41].

Participants suggested that schools should turn to use of e-learning to minimize students' misconceptions in chemical bonding and any other topics. For instance Cyber School makes teaching and learning environment more visual and concept formation is enhanced. There is need to integrate computer technologies into learning and teaching [42-44]. In the chemistry education literature, there have been numerous studies reporting positive effects of the use of computers on students' achievement [45]. Computer – assisted curricula also provide opportunities for inquiry – based approaches to the learning of chemistry and it seems they discouraged rote memorization and algorithmic problem solving while encouraging conceptual understanding and critical thinking [46]. In line with recent research findings, many educators now advocate for the use of computers in teaching chemistry [47] and computer-assisted learning (CAL) environments attempt to make explicit the information embedded in traditional physical representations as well as to provide a visual representation of the physical interactions for students [48-50]. In recent years computer technologies and web-based teaching and learning in particular, have gained momentum in teaching and learning the sciences [51-54]. More specifically, in alignment with the idea of visualization to support students' learning the chemical bonding concept, [52] noted the importance of integrating computer-based visualizations in learning abstract concept and phenomena. [53] suggested that molecular models, simulations, and animations have the potential to contribute to the learning of chemistry in general and to better understanding of the chemical bonding concept in particular. Drawing on a combined quantitative and qualitative research study [54] were able to conclude that the web-based learning activities which integrated visualization tools with active cooperative learning strategies provided students with opportunities to construct their knowledge regarding the abstract aspects concept of chemical bonding.

5. Conclusions and Recommendations

It is concluded that in terms and explanations used by teachers, presentation of concepts in textbooks and ineffective communication between learners and teachers, examination oriented pedagogics, simplistic teaching approach, incompetent teachers; all contributes to students' misconceptions in chemical bonding. The study identified the following strategies as ways of minimizing learners misconceptions; use of e-learning, for example Cyber school which makes teaching and learning environment more visual than conceptual so that student can better relate, learner centered pedagogical bottom-up approach, and use of competent teachers. It is recommended that science teacher education should be improved. Thus graduating teachers should be equipped with the various strategies for teaching skills so as to improve teaching and learning in chemistry. Chemistry teachers should be motivated and supported by school administration, parents and community at large. The current chemistry textbooks should be revised to include the element of conceptual change. [27] presents a scientist's view, claiming that the way textbooks and teachers present the classification of the chemical bonds, as if everything is very simple and clear (hydrogen bond, covalent bond, etc.) is deluding and misleading. Relevant research results about student misconceptions should be communicated to curriculum developers to inform improvement in the practice.

The limitation of this study is that a small urban sample of 8 teachers was used. It is argued and recommended that a larger sample including rural teachers be used to verify findings. The study was carried out within one small district which could have had uniform cultural setting, which may have a bearing on the findings. It is suggested that future research should focus on groups of participants from several schools in different societal and cultural settings.

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