SCHOOL OF GRADUATE STUDIES

ASSESSING STUDENTS' MISCONCEPTION ON CHEMICAL BONDING USING FOUR-TIER DIAGNOSTIC MECHANISM: A CASE STUDY AT BURKA, SEBETA 10TH GRADE AND BURKA, SEBETA 12TH GRADE SECONDARY SCHOOL AT SEBETA SUBCITY, SHEGER CITY, OROMIA, ETHIOPIA.

MSc. THESIS

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Assessing Students' Misconception on Chemical Bonding Using Four-Tier Diagnostic Mechanism: A Case Study at Burka, Sebeta 10th Grade and Burka, Sebeta 12th Grade Secondary Schools at Sebeta Subcity, Sheger City, Oromia, Ethiopia.

AThesis Submitted to School of Graduate Studies, In Partial Fulfillment of Requirements for the Degree of Master of Science in Chemistry

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We here by certify that we have read and evaluated this Thesis, titled: "Assessing Students' Misconception on Chemical Bonding Using Four-Tier Diagnostic Mechanism" prepared under my guidance by Bacha Bebele Chala. We recommend that it be submitted as fulfilling the Thesis requirement.

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DEDICATION

I dedicate this thesis work to my beloved wife Desi Arega Bedada and my brother Tafa Debele Chala who provided me love and support throughout my studies.

STATEMENTOF THE AUTHOR

By my signature below, I declare and affirm that this Thesis is my own work. I have followed all ethical principles of scholarship in the preparation, data collection, data analysis and completion of this Thesis. All scholarly matter that is included in the Thesis has been given recognition through citation. Affirm that I have cited and referenced all sources used in this document .Every serious effort has been made to avoid any plagiarism in the preparation of this thesis.

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BIOGRAPHICAL SKETCH

The author was born in June 1982 E.C. at Sebeta Awas Woreda, Oromia Regional State, Ethiopia. He attended Elementary Education at Tefki Elementary School from 1992 to 2000 E.C and his high school at Sebeta high School from 2001 to 2004 E.C. He joined Metu University in 2005 and graduated with BSc. Degree in Chemistry in 2007 E.C. He was then employed by Oromoia Region Education Bureau at Birbirsa Secondary School, Sebeta Special Zone, as a chemistry teacher. After working for three years, he joined the School Graduate Studies of Wolkite University in 2011 E.C. to pursue his MSc degree in Chemistry.

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ACRONYMS AND ABBREVIATIONS

FTCBDM	Four-tier Chemical Bonding Diagnostic Mechanism
FTMCT	Four-Tier Multiple Choice Test
FTCBT	Four-Tier Chemical Bonding Test
LK	Lack of Knowledge
2TMCT	Two-Tier Multiple Choice Test
MCS	Misconception Conceptions
A-tier	Answer tier
CCS	Correct Conceptions
MCT	Multiple Choice Test
R-tier	Reason tier
FTDM	Four Tier Diagnostic Mechanisms
FP	False Positive
FN	False Negative

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ASSESSING STUDENTS' MISCONCEPTION ON CHEMICAL BONDING USING FOUR-TIER DIAGNOSTIC MECHANISM: A CASE STUDY AT BURKA, SEBETA 10TH GRADE AND 12TH GRADE SECONDARY SCHOOLS

ABSTRACT

Chemical bonding is a topic that students commonly find abstract and problematic and for which they develop a wide range of misconceptions . Thus, chemical bonding is considered as difficult topic and students had misconception about bond polarity, intermolecular force, intramolecular force, the octet rule, conductivity, Solubility shapes and lattice energy. The purpose of this study was to identify the major misconceptions of grade 12 and 10 students' on the chemical bonding and to identify the sources of these misconceptions. The nature of the study is a descriptive method. Participants of the study were 67 grade 12 students and 75 grade 10 students. The FTMCT was developed after their prior conceptions about the selected topics of the study were collected from students through review of related literature, observation of lessons on chemical bonding, common mistakes of focus class students during different assessment techniques (answering class tests) and individual interview questions with volunteer students. Data was collected by using FTMCT and Interview questions were employed to gather the relevant data. Data was analyzed by using Statistical Package for the Social Science program (SPSS). The results from SPSS (bivariate and reliability analysis) showed that average value of reliability coefficient and correlation between 1st tier and 2nd tiers, 3rd tiers and 4th tiers, 2nd tier and 4th tier were .99, .75, .68, .67 of grade 12 students and .96, .73, .79, .74, of grade10 student respectively. The significances also shown that chemistry daily experiences, text books, language difficulty and chemistry instructional methods were the major source of students' misconception about chemical bonding. The result showed that the majority of the students had high level of misconceptions about chemical bonding. In this study the common misconceptions were identified on chemical boding which was categorized into: bond polarity, solubility, intermolecular force, intramolecular force, the octet rule, shapes, conductivity and lattice energy

Keywords: *chemical bonding, four-tier multiple choice test, Misconception, four tier diagnostic mechanism, False positive, false negative,*

CHAPTER ONE

1. INTRODUCTION

1.1. Background of the Study

Chemical bonds are fundamental to chemistry which indicates the strength of attractions within molecules and chemists understand the properties of matter in terms of the types of bonds that hold atoms together. Chemical bonding is a critical concept in chemistry, because it concerns with a combination of particles and the nature of bonding between particles related to the chemical and the physical properties of the substance [1] [2]. Chemical bonding is an abstract and concept tual topic that can sometimes feel disconnected from the everyday experiences of secondary school students. [3]. Chemical bonding has been classified into a series of three target systems; metallic, ionic, and covalent bonding.

Chemical bonding is a fundamental to the next learning of several topics in chemistry [4]. For example, it is essential to know the nature of thermodynamics, molecular structure, chemical equilibrium, chemical reactions and some physical properties such as boiling points. It is crucial to understand almost every topic such as inorganic and organic compounds, chemical energy and chemical reactions [5] [6].

Chemical bonding idea is an abstract topic where students have problems, for example, how students could understand topics such as reactivity, and organic chemistry unless they are introduced and taught theories of chemical bonding [7]. Many students have problematic understanding the ideas in chemical bonding; similarly high-school students around the world have been shown to lack an essential understanding of this concept and there is potential for the formation of alternative conceptions [2]. The younger Grade 10 students in their study also had many similar difficulties understanding intermolecular forces and covalent bonds and molecular lattices [8]. One of problematic topic students understandings in learning chemistry is chemical bonding because it involves variety of abstract natures [9].For example, students cannot distinguish ionic and covalent bonding [10] [11]. Others with misconceptions about the polarity of

molecules and, also, on the geometry of molecules[12]. They presenting misconceptions on melting and boiling points or on solubility and electrical conductivity of substances [13]

[14] Identified that students prior experiences, education environment and world assessment affect their interpretation of observations and concepts. As a result, students may come to class room with some misconceptions toward the instructional subject to be educated. However, students face problems in understanding the subject despite its association with daily life experiences [15]. Misconceptions may arise as a result of the variety of contacts students make with the physical and social world or as a result of personal experience, interaction with teacher, other people or through the media. [16] Observes that textbooks and instructional policies are not an effective way of meaningful learning and instruction.

Diagnostic testing can help to identify misconceptions and lay the foundation for conceptual change [17]. The addition of confidence to diagnostic test demands the students to be more careful in choosing answer [18]. Four-tier diagnostic test is a diagnostic test which is used to distinguish students who do not understand concept to students who experience misconception. The four tier tests were often multiple-choice tests that measure confidence ratings for an answer tier and a reasoning tier [19]. Confidence rating (or confidence judgment) refers to the estimations and decisions by an individual regarding the excellence of his or her own performance [20].

1.2. Statement of the Problem

Chemical bonding is one of the most important topics in high school and under graduate chemistry and the topic involves the use of a variety of simple and abstract models varying from simple analogical models to gauche quantum abstract models possessing considerable mathematical complexity [21] [22]. The idea of chemical bonding holds bonds between atoms and / or molecules that were invisible to the eye and distant from everyday life. This could cause students difficulties in understanding chemical bonding [23]. It is also a topic that students commonly find a difficult and develops a wide range of misconceptions [9]. A number of researchers informed those students' misconceptions on the topic of chemical bonding. Such as: shape of molecules, polarity of molecules and nonpolar molecules [24]. Students views that the shape of molecules is determined by the repulsion between molecules; Polarity of molecules is determined by the

number of valence electrons and that the non-polar molecules have atoms of similar electro negativities [25].

Researchers has found that students hold misconceptions on: the application of electro negativity and intermolecular forces [26]. Ionic compounds to occur as discrete molecules as do covalent compounds [27]. [28] Shown that students have a partial understanding of the bond polarity of molecular structures, polarity of molecules, intermolecular forces, molecular shape, the octet rule, lattices and they have some misconceptions about this concept in their studies.

[22] State that students challenged confusion between ionic and covalent compounds with learners believing that ionic compounds are molecular in nature. Numerous students have difficulty understanding the concepts in chemical bonding; similarly high school students around the world have been shown to lack an essential understanding of this concept and there is potential for the formation of misconceptions [2]. In the previous work identified by these authors, the way to assess students' misconception related to chemical bonding using different mechanisms. In this study the four-tier test was the potential to assessing students' misconceptions on the concept of chemical bonding. It is important to know what prior information students bring to learning environment in order to help them to construct new information [29] [30].

In the past and still at present in our country, students previous knowledge was not considered seriously [31]. The gaps between the current study and some of previous work were variety of methods (four-tier test, interview) to identify students misconceptions are being proposed and examined for their effectiveness in the current study.

From his teaching experience of high schools grade 10 and 12 chemistry and current situation observed in Burka, Sebeta secondary schools grade 10 and secondary schools grade 12 , the researcher noted that many students seems worked hard to learn the concept of chemical bonding in high school chemistry. Despite their hard work, it was still observed that most students could not solve the problems related on the concept of chemical bonding in their examinations. They did not show the necessary knowledge and were not able to express their answers clearly and reasonably in chemical bonding. Students' misconceptions about chemical bonding are still observed in these schools. Consequently, the purpose of this study was to distinguish students'

misconception about chemical bonding, to identify the goal concepts, propositional knowledge statements and sources of students' misconception.

1.3. Objectives of the Study

The study was conducted with the following general and specific objectives.

1.3.1. General Objective

The general objective of this study was to assessing students' misconceptions on the concept of chemical bonding and sources of students' misconceptions related to chemical bonding for grade 10 and 12 Students. In two secondary schools at Sebeta subcity, Sheger city, Oromia Region State.

The specific objectives of this study would be to:

1.3.2. Specific Objectives

- ✓ Identify the major Misconceptions of students on the concept of chemical bonding.
- ✓ Distinguish the sources of students' misconceptions related to chemical bonding.

1.4 Research Questions

The following research questions were addressed in this study

1. What are the common misconceptions of students on the concept of chemical bonding?
2. What are the sources of students' misconceptions related to chemical bonding?

1.5. Significance of the Study

Information about the development of misconceptions was particularly useful for science teaching community in order to develop curriculum materials and design instruction. Therefore, this study was significant in helping teachers and curriculum developers to address and design teaching and learning process. It reduces the gaps in learning that may enhance the prevalence and strength of misconceptions. It also used as a starting point for the development of sequential learning activities based on some common and key misconceptions. Moreover, this study lays a foundation for future studies that aim to investigate the causes of misconceptions and appropriate to bring conceptual

change and develop problem solving skill. For ensuring meaningful learning, investigation of students' misconceptions on certain topics has great significance.

1.6. Delimitations of the Study

The main objective of this study was to assessing students' misconception on the concept of chemical bonding at Secondary Schools. The study was restricted only on the chemical bonding such as bond polarity, intermolecular force, intramolecular force, octet rule, solubility, shapes, conductivity and lattice energy concepts of grade 9 and 11 students chemistry text book in Burqa, Sebeta 10^{th} grade Secondary Schools and Burqa, Sebeta 12^{th} grade Secondary Schools of Sebeta Subcity, Sheger City, Oromia Regional State, Ethiopia.

1.7. Limitations of the Study

This study was focused on the assessing of students' misconceptions on the concept of chemical bonding using a four-tier diagnostic mechanism at Burka, Sebeta 10^{th} grade and Burka, Sebeta 12^{th} grade Secondary Schools at Sebeta Subcity, Sheger City, Oromia, Ethiopia. Consequently, generalizing the finding of this study was limited to only in assessing of students' misconceptions on the concept of chemical bonding. Generalizing the finding of this study into other improvements might lead to causes difficulty. Therefore, application of an assessing approach to another improvement might need additional exploration.

1.8. Operational Definitions of Terms

Misconception: unscientific conceptions that obstacle the real learning of individuals.

Diagnostic test: Diagnostic tests are evaluation tools which are concerned with the retelling earning difficulties that are left unresolved and are the causes of learning complications.

Four-tier misconception test: A four-level multiple-choice test that has been designed with common students' misconceptions.

CHAPTER TWO

2. REVIEW LITERATURE

2. 1. Misconceptions

Misconceptions are unchanging or stable, unscientific conceptions that obstacle the real learning of individuals [32] a listed the properties of misconceptions as: misconceptions are strongly held and stable cognitive structures, vary from expert conception, disturb how students understand scientific explanations, Must be overcome, avoided and eliminated to achieve skillful conception. Scientific misconceptions are commonly held beliefs about science that have no basis in scientific fact. Scientific misconceptions can also refer to preconceived ideas based on environmental or cultural influences. The dissimilarity between students conceptions and scientific conceptions called as misconceptions [33].

A misconception is a basic problem for students and often brings misunderstanding. Modifying students misconceptions from incorrect to correct knowledge can be forceful and problematic [34]. Students transfer their concepts independent from scientifically recognized concepts related to their science lesson [13].

Main reasons for misconception are faulty or insufficient perception of the concepts learnt, concepts of daily language having different meanings in scientific language, not using appropriate teaching approaches while teaching topics and concepts, deficiency in the construction of relationships between the concepts and daily life [35]. Misconception do not occur in segregation from the context in which they appear and students do not just drop their ideas and beliefs just because someone says so or an event disproves what they have come to believe.

Students come into the classroom with prerequisite knowledge or exist in schemas and as they development through their education schemas are sequentially built upon [36]. Learners could have number of preconceptions about a given scientific phenomena. Some of these preconceptions are in conflict with the scientific view. Preconceptions which are in conflict with the scientific view are called misconceptions. Such preconceptions are also called students conceptions [30].

However, it is important to understand that not all preconceptions are misconceptions. It is also necessary to underline that a misconception is not a mistake and it does not stem from lack of knowledge [31]. Somewhat, misconception is the understanding of a concept in a wrong or missing way. If a student has a misconception, his/her conception is not true or missing where as it is true for him / her. Although it is wrong, it works for the student [24].

2.2. Sources of Misconceptions

Probable sources of students' misconceptions are physical experience, direct observation view, school teaching, outside of school teaching, social environment, peer culture, language, text books or other instructional materials, and teachers [32]. Student misconceptions have their origins in a diverse set of personal experiences. Source of misconception are varied and complex, and thus can be difficult to resolve [16].

[29] Student's misconceptions can originate from a variety of different sources, but in chemistry there are good grounds to think that many originate from aspects of the way the subject is educated, acting as pedagogic learning obstacle. Teachers also propagate misconceptions because of their inability to communicate effectively with students .They are thought to be the key to improve student performance. There is considerable evidence that teachers are one of the main sources of student misconceptions [37].

The term misconception also appears inappropriate for those situations where an individual obtains technically incorrect ideas from another-for example where teachers themselves have faulty subject knowledge and present incorrect ideas in class [38]. The identification of possible sources of misconceptions is important because the instructional strategies which ultimately might prove effective in combating misconceptions might differ according to the source of misconception.

2.3. Misconceptions in Chemical Bonding

Chemical bonding is a topic that students generally find abstract and problematic and for which they develop a wide range of alternative conceptions [3] [9]. Because most chemical bonding concepts are abstract, a student cannot easily understand an atom or interactions between atoms or

other elementary particles. Misconceptions in one basic topic, such as the atomic structure, can potentially lead to misconceptions in other related topics, such as chemical bonds. In the science education literature, there have been numerous studies to determine students' understanding misconceptions about metallic, ionic, and covalent bonding. [39] [40] Stated that the subject of chemical bonding is difficult and problematic to students and, as a result, students have a large number of misconceptions.

The fact that chemical bonding is an abstract idea and that it is not related with learners real life experiences makes it difficult to learn. [15] Identified that students have problems in understanding topics such as reactivity, spectroscopy and organic chemistry unless they are taught the theories of chemical bonding. Chemical bonding has been cited as one of the most problematic chemistry concepts for several secondary school and college students to comprehend [16].

Several studies indicate that students have many misconceptions about chemical bonding and studies absorbed used on these viewpoints: investigation of, and changing, student alternative conceptions on chemical bonding at various educational stages [9]. [4] Discovered on students conceptions and their general knowledge and misconceptions on chemical bonds. In the science education literature, they have been numerous studies to determine students understanding and misconceptions about metallic, ionic, and covalent bonding.

[8] Studied on chemical bonding idea and they related the effects of constructivist approach and traditional instruction on the students understanding of the topics. [41] Stated that students have misconceptions about covalent and ionic bonds. [42] The students misconceptions related with sub-topics in chemical bonding. They testified many misconceptions including: - Students views that the polarity of molecules is determined by the number of valence electrons and that the non-polar molecules have atoms of similar electro-negativities.

[24] Considers, as an example, the term covalent bond and proposes that most students entering secondary school do not know what it means. [14] Pointed out that was a common misconception that any species with an octet or a full outer shell of electrons is stable. [43] Studied on students alternative conceptions related to chemical bonding.

[44] Found that students trust that ionic bonds only occur between the atoms involved in the electron transfer. For instance, sodium ion forms only one ionic bond with a chloride ion that gains electron. Student's explanations of ionic bond were that the transfer of electrons, rather than the attractive force between oppositely charged ions resulted from the electron transfer. Covalent bonds are broken when a substance changes state [43]. A recent study in Croatia using Taber's truth about bonding instrument provides extra evidence for origins of this misconception [11] [24].

2.4. Methodologies for Exploring Students' Misconceptions on Chemical Bonding

2.4.1. Interview

The interview shows an important role since providing detailed investigation and opportunity to find comprehensive reports of a student's cognitive structures [45]. The interviews with the other impact can give more comprehensive information about student's alternative conceptions and ideas of a particular concept. For example, testing data can be little bit problematic students can think in different ways and it is time consuming when the interview is used for a large number of students to simplify their alternative conceptions [46].

Interviews may be conducted with individuals or with groups [47]. The purpose of interviewing was stated as finding out what is on people's mind, what they think or how they feel about something [48]. Although interview strategies have the advantages such as gaining in-depth information and flexibility, a large amount of time is required to interview a large number of people in order to obtain greater generalizability. Also training in interviewing is required for the researcher. In addition, interviewer bias may to hurt / damage the findings.

2.4.2. Four-tier Multiple Choice Test

However three-tier tests were thought to be measuring misconceptions free from mistakes and lack of knowledge in a valid way, they still have some limitations due to the hidden rating of the confidence for the first and second tiers in those tests [49]. This situation may results in two problems: one is the underestimation of the lack of knowledge proportions, and the other one is the over estimation of the student's misconception scores and the correct scores. For example, if

a student is “sure” about his answer in the main question tier and “not sure” about his answer in the reasoning tier in a FTMCT; the researcher can decide “LK” for that item.

The fourth-tier requires the self-confidence of the response in the third tier [50]. As a result, depending on the rating of confidence, the researcher may have a decision of “LK” if he is “not sure” or “no lack of knowledge” if he is “sure” [51]. For instance, in a FTMCT, if a student gives a correct answer to the main question in the first tier and is sure about his answer for this tier, then gives a correct answer to the reasoning question in the third tier but is not sure about his answer for this tier, then the researcher’s decision about the student’s answer for this item is “LK” because there is doubt about at least one tier of the student’s answer [52].

Even so FTMCT look to remove many problems aforementioned instruments, they still hold several limitations such as: requiring a longer testing time, not advisable for using in achievement purposes [53]. The possibility of students’ choice of response in the first tier can influence their choice of response in the reasoning tier [54]. As in 2TMCT its A-tier and R-tier measure students content knowledge and explanatory knowledge, respectively. The two additional tiers measure the level of confidence of the students in the correctness of their chosen options for the answer and reason tiers, respectively [55].

CHAPTER THREE

3. RESEARCH METHODOLOGY

3.1. Description of Study Area

The research was conducted in Oromia Regional State, in Sheger city at Sebeta subcity, the case of Burka, Sebeta grade 10 and Burka, Sebeta grade 12 secondary schools. Sebeta is 24Km from Addis Ababa to west.

SHEGER CITY MAP

Figure 1.Map of the study area

3.2. Research Design

For the purpose of this study descriptive research was used to identify students' misconceptions on chemical bonding using four-tier diagnostic mechanism. Descriptive research, occasionally known as non-experimental or co-relational research, involves describing and interpreting events, conditions or situations of the present. It describes and interprets what is. In other words, it is primarily concerned with the present, although it often consider past events and influences as they relate to current conditions. Additional, descriptive research is concerned with conditions or relationships that exist, opinions that are held, processes that are going on, effects that are obvious, that are developing. Descriptive research can use qualitative or quantitative methods to describe or interpret event, condition or situation present.

3.3. Sampling Procedure

The samples of this study were selected from grade 10 and 12 students in Sebeta subcity, Burka, and Sebeta Secondary schools respectively. The study was conducted in the first semester of 2023/2024 academic year. In these two secondary schools a total of 300 grades 10 and 200 grade 12 students were enrolled for the academic year. Out of those, 75 students from grade 10 and 67 students from grade 12 were selected for the purpose of study using the following sampling formula based on their chemistry results of grade 9 and 11 (high- medium-low).

Slovin's formula allows a researcher to sample the population with a desired degree of accuracy[56].

$\mathbf{n = \frac{N}{1+N(e)^2}}$ Where, n=size of sample for the research use, N= total number of students, 1= designates the probability of the event occurring e= accepting margin of error

$$n = \frac{200}{1 + 200(0.1)^2} = 67\ from\ grade 12$$

$$n = \frac{300}{1 + 300(0.1)^2} = 75\ from\ grade 10$$

Table 1. General population of students and number of samples from each school

No.	**Schools' name**	**Total number of Grade 10 students**	**Sample taken**	**Total number of Grade 12 students**	**Sample taken**
1	Burka	145(48%)	34(45%)	96(48%)	31(45%)
2	Sebeta	155(52%)	41(55%)	104(52%)	37(55%)
Total		300(100%)	75(100%)	200(100%)	67(100%)

Table2. Students' sample size

Data collection Sets	Grades and sample size								
	Grade10			Grade 12			Total (T)		
Gender	M	F	T	M	F	T	M	F	T
FTMCT	36 (48%)	39 (52%)	75 (100%)	36 (54%)	31 (46%)	67 (100%)	72 (51%)	70 (49%)	142 (100%)
Interview	2 (67%)	1 (33%)	3 (100%)	2 (67%)	1 (33%)	3 (100%)	4 (67%)	2 (33%)	6 (100%)

F=female M=male T=Total

3.4. Data Gathering Mechanisms

Four-tier chemical bonding diagnostic mechanism was developed based on the following steps.

3.4.1. Outlining content boundaries of the study

To outlining content boundaries of the study, propositional statements were drafted referring the chemistry textbook and syllabus of grade 9and 11. It concerned with outlining the concept boundaries and involves the identification of propositional content knowledge statements. The propositional knowledge statements are related directly to the concept map to ensure that the content being examined is internally consistent. To ensure that the concept area is properly documented is essential that there is a representative covering of concepts and propositional statements for each topic under investigation. An essential feature of this development is the contents and concepts to be investigated are specifically accurate as far as the particular level of study being pursued. The tests were mainly oriented toward the covalent bonding, Ionic bonding and metallic bonding diagnostic mechanism. Specifically examines the conceptual areas of bond polarity, intermolecular force, intramolecular force, the octet rule, solubility, shapes, conductivity and lattice energy

3.4.2. Gaining information about students misconceptions

Before commencing new efforts to identify misconceptions are essential to examine the related literature dealing with research on misconceptions. The source misconception concerning chemical

bonding was carefully identified using sources. Such as: observation of lessons on chemical bonding of focus classes, common mistakes of focus class students in responding worksheets, class tests and individual interview questions with volunteer students.

3.4.3. Elaborating a diagnostic test

The third technique for the test building involves the elaborating of four-tier test items. A four level multiple-choice test that has been designed with common students' misconceptions were delivered.

First tier: Students content knowledge was requested.

Second tier: The confidence rating about the given response in the first tier was requested.

Third tier: The reasoning about the answer in the first tier was given.

Fourth tier: The level of confidence about the given reasoning in the third tier was requested.

FTMCT was become fundamental in order to assess and identify students' misconceptions on chemical bonding. Four tier multiple choice tests were improve clarification of the 2TMCT in which its answer and reason tiers measures students content knowledge and explanatory knowledge, respectively.

The tests contained 10 multiple choice questions were built from grade 9 chemistry text books and administered for 75 grade 10 students and from these 5 questions for grade 12 to prove the content and explanatory knowledge of students. Additionally 5 multiple choice questions built from grade 11 chemistry text book for grade 12. The questions built after the chemical bond lessons had been educated at grade 9 and 11. Totally 10 questions were prepared for 67 grade 12 students with one correct choice and all item with four tiers. All items were built up as: Answer tier, Confidence rating for answer tier, Reason tier and Confidence rating for reason tier. The confidence rating lengths range from Just Guessing (a) to absolutely Confident (f). When the students were selected confident, very confident, absolutely confident and just guessing, very unconfident, unconfident it will be accepted as correct answer (1) and wrong answer (0) respectively.

A specification net was intended to ensure that the diagnostic test honestly covers the propositional knowledge statements and the concepts on the concept map underlying the topic. The tests were administered for 75 from grade 10 and 67 from grade 12 students who had been educated chemical

bonding in chemistry lesson. The time allotted for the test was 50 min. Finally the necessary information from four-tier diagnostic mechanism was collected.

3.5. Interview Questions

Among various methods of diagnosing misconceptions, interviews have the crucial role because of their in-depth inquiry and possibility of elaboration to obtain detailed descriptions of a student's cognitive structures. The interview shows an important role subsequently providing detailed investigation and opportunity to find comprehensive reports of a student's cognitive structures [45]. The interviews with the other impact can give more comprehensive information about student's misconceptions and ideas of a particular concept. For example, testing data can be little bit problematic students can think in different ways and it is time consuming when the interview is used for a large number of students to simplify their misconceptions [46].

In addition to four tiers diagnostic mechanism, interview used to identify the sources of students' misconceptions. It gives time to think to the participants, to elaborate on their answers and reasoning gives a chance to the researcher to gain in-depth information. Interview used to draw out students' mental models for chemical bonding and also used to identify the sources of students' misconceptions related to chemical bonding. It used to determine the most imaginative contexts for eliciting the students' misconceptions about chemical bonding.

Interview used to identify the students' misconceptions about chemical bonding, daily using language, outside of school teaching, social environment, teachers, peer culture, school teaching, and textbooks as the probable sources to misconceptions. Interview participants were identified based on their results of four-tier tests .For the purpose of interview 3 questions were built from grade 9 chemistry text books with its procedure and 3 students were interviewed from grade 10 and from the built questions 1 of them have given for grade 12 . Additionally 2 questions were built for grade 12 students from grade 11 chemistry text books for grade 12 students, 3 students selected for interview questions which had totally 3 questions have given. The investigator was recorded interviews with mobile phone and interview lasted nearly 50 min and it held one week

3.6. Data Analysis

The data were collected from FTMCT and Interview questions were analyzed. Student's response by choosing *A, B, C,* or *D* for the answer and reason tiers, and chance *a, b, c, d, e* or *f* for each degree of confidence ratings. For each item of four-tier chemical bonding diagnostic mechanism, the answer and reason were first scored separately: '1' and '0' for each correct and incorrect response, respectively. Quantitative variables use a different type of analysis and measurement, requiring different type of measurement scales: nominal, ordinal, interval, and ratio [48]

Table 3. Names of variables and their coding

Variables		**Coding**
correct scores	correct only 1st	Correct answers for only 1st tiers of each item were coded as '1' and '0' else.
	correct only 3rd	Correct answers for only 3rd tiers of each item were coded as '1' and '0' else.
	Correct all four	Correct answers for both 1st and 3rd tiers of each item and 'absolutely sure' or 'sure' for 2nd and 4th tiers were coded as '1' and '0' else.
Misconception Scores	Misconception only 1st	Alternative choices representing each misconception for only 1st tiers were coded as '1' and '0' else
	Misconception only 3rd	Alternative choices representing each misconception for only 3rd tiers were coded as '1' and '0' else.
	Misconception all four	Alternative choices representing each misconception for both 1st and 3rd tiers and 'absolutely sure' or 'sure' for 2nd and 4th tiers were coded as '1' and '0' else.
Confidence Scores	2nd confidence	Choices of 'absolutely sure' or 'sure' for the 2nd tiers of each item were coded as '1' and '0' else.
	4th confidence	choices of 'absolutely sure' or 'sure' for the 4th tiers of each item were coded as '1' and '0' else
	Both confidences	Both confidences choices of 'absolutely sure' or sure 'for both 2nd and 4th tiers of each item were coded as '1' and 0' else

3.7. Validity and Reliability of Mechanisms

In the present study, to ensure the validity of the four-tier chemical bonding test scores, three different correlations were calculated for obtaining construct validity evidence.

Table 4. Correlation between four Tier Diagnostic mechanisms for grade10 and 12

		Grade 10		Grade 12	
	Correlation	1st –tier and 2nd – tier		1st –tier and 2nd-tier	
A-tier	Pearson correlation	1	.73*	1	.75*
	Sig. (2-tailed)		.017		.013
	No. item	10	10	10	10
2nd –tier	Pearson correlation	.730*	1	.75*	1
	Sig. (2-tailed)	.017		.013	
	No. items	10	10	10	10
	Correlation	3rd –tier and 4th –tier		3rd-tier and 4th tier	
R-tier	Pearson correlation	1	.79**	1	.68**
	Sig. (2-tailed)		.006		.031
	No. items	10	10	10	10
4th –tier	Pearson correlation	.79**	1	.68**	1
	Sig. (2-tailed	.006		.031	
	No. item	10	10	10	10
	Correlation	2nd –tier and 4th –tier		2nd -tier and 4th –tier	
2nd –tier	Pearson correlation	1	.74***	1	.67***
	Sig. (2-tailed)		.014		.033
	No. item	10	10	10	10
4th –tier	Pearson correlation	.74***	1	.67***	1
	Sig. (2-tailed	.014		.033	
	No. item	10	10	10	10

The Correlation between first tiers and second tiers; Correlation between third tiers and fourth tiers; Correlation between second tier and fourth confidence tiers were .73, .79, .74 grade 10 and .75, .68, .67 grade 12, respectively. There were positive significant correlations between all tiers.

It means that students with high scores have higher confidence than students with low scores. The interpretation of correlations between all four tiers as below.

-1 = perfectly negatively correlated, 1= perfectly positively correlated, [-1– 0.3] = negatively correlation. [1– 0.3] =positively correlated, [-0.3– 0.3] = no correlation.

Estimating the percentages of false positives (that means correct answers with a wrong reasoning), false negative (that means wrong answers with correct reasoning), and LK (that means not sure in both or any of answer and reasoning). The content outline of the topics chemical bonding was defined through the review of chemistry textbooks, teacher's guide and syllabi and organized the aim concepts and propositional knowledge statements.

Table 5. Summary of main ideas and their propositional knowledge statements that are involved in chemistry textbook and syllabus associated to understand chemical bonding topic noticeably.

Main concepts	**Knowledge statements**
Intramolecular forces	Holds the atoms together within particles. Affects chemical properties.
Intermolecular forces	Forces between the molecules. Affects physical properties.
Conductivity	In the molten state and in water solutions, ions are free to move. Thus molten ionic compounds or their aqueous solutions conduct a current when placed in an electrolytic cell.
Polar bond	Unequal shared electrons and electronegativity difference between atoms
Nonpolar bond	When bonding electron-pairs in a covalent bond are shared equally, the result is a nonpolar bond.
Lattice energy	When a cation and an anion come closer, they get attracted to each other due to the electrostatic (columbic) force of attraction.
Octet rule	Atoms tend to gain or lose electrons until they have achieved an outer shell that contains an octet of electrons (eight electrons).
Bond polarity	Is a measure of equally or unequally shared electrons in a covalent bond
Shapes of molecules	When electrons repel areas of electron density repel equally (single, double, triple bond and lone pair).
Strength of bonds	A bond's strength defines how strongly each atom is linked to another atom.

The particular value of all the basics of descriptive statistics was determined based on variables of CCS and MCS results in all tiers. Reliability, item discrimination index, item difficulty were also calculated and they were helpful result to this study. When $\alpha \geq 0.7$, the test is reliable that means the FTMCT is reliable. The content framework of the topics chemical bonding was described through the review of chemistry textbooks, teacher's guide and syllabi and prepared the target concepts and propositional knowledge statements.

Difficulty Index (DIF p): The difficulty index (DIF p) of an item is defined as proportion or percentage of the examinees who correctly answered a given test item. It is one of the key parameters of item analysis. It ranges from 0 to 1 or (0% to 100%). $\boldsymbol{DIF = \frac{RH+RL}{NH+NL}}$ $\boldsymbol{or}$ $\boldsymbol{\frac{RH+R}{N}}$ Where, RH-The number of right answers in the higher group; RL-The number of right answers in the lower group; NH-The number of examinees in the higher group; N-Total number of examinees and NL-The number of examinees in the lower group. An item that everyone answers correctly would have a p value of 1.0. The value of item difficulty indices found based up on the CCS in all four-tiers have values of .49, .51, .53, .56 grade 10 and .51, .55, .52, .57 grade 12 to the first, second, third and fourth tier tests, respectively[57].

Discrimination Index (DI): Index of discrimination is that ability of an item on the basis of which the discrimination is made between the superior (the group of high achievers) and the inferior (the group of low achievers) or it is the ability of an item to distinguish high and low score students. It ranges from -1 to +1. We can use the Formula $\boldsymbol{DI = \frac{2(RH-R)}{N}}$. The items discrimination index calculated based up on the CCS in all four-tiers have values of .88, .80, .85, .85 grade 10 and .84, .99, .92, .89 grade 12 to the first, second, third and fourth tier tests, respective[57].

Table 6. Interpretation of Difficulty Index and Discrimination Index

DIF p	Evaluation items	DI	Evaluation items
< 0.20	Most difficult	Negative	Worst/ defective
0.40-0.59	Moderately difficult	< 0.2	Not discriminating
0.80-0.89	Easy	0.02-0.29	moderately discriminating good
>0.90	Easiest	0.30-0.39	Discriminating item, good
		≥ 0.40	very discriminating items or very good

In the range of the difficulty index of (0.40–0.59), it indicates that all four-tier were moderately difficult. All the four tier items of the discrimination index greater than 0.40, it indicate very discriminating items. Additionally, the Cronbach's alpha coefficient was calculated in order to establish the internal consistency of the test scores for the four-tier chemical bonding test as a measure of reliability of the test scores.

Table 7. The average reliability coefficient of four tier diagnosis mechanism for grade 10 and 12

Four tier Diagnostic Mechanism	Cronbach's Alpha For Grade 10	Cronbach's Alpha For Grade 12	N of Items
A-tier	.99	.99	10
2^{nd} -tier	.85	1.00	10
R-tier	.99	.99	10
4^{th} –tier	.99	.99	10
Average Reliability coefficient	.96	.99	10

The average reliability coefficient of students' scores was calculated based on the students' answer in all four-tiers of the test was .96 grade 10 and .99 grades 12 respectively. When $\alpha \geq 0.7$, the test is reliable that means the FTMCT is reliable. The data was analyzed by using Statistical Package for the Social Science program (SPSS) version 20.

Five classifications are based on the students' response on each tier of four tier chemical bonding diagnostic test. The five classifications consist of, false positive, false negative, lack of knowledge, scientific conceptions and misconception. The division of the four tier test categorization was made the proportion of less knowledge not lessened and the proportion of alternative conceptions not exaggerated. For computing the proportions of false negatives and false positives, only answers without lack of knowledge were considered, that means, they were computed over the students' scores who were "Totally sure" or "Sure" about their answers in the first and third tiers of the test. False positive and false negative in decision making considered as misconception [58].

A student who chose the correct answer for the first tier and the wrong answer for the third tier when he is "Totally sure" or "Sure" about on both of the tiers was coded as "1" indicating false positive. For the false negatives, a student who chooses wrong answer for the first tier and correct

answer for the third tier, when "Totally sure" or "Sure" on both of the tiers was coded as "1". The result of difficulty indices increases from first tiers (ordinary MCTs) to all four tiers since the proportion of correct answers increases from a one tier to four tiers scoring.

Table 8. Determining students' conceptions classifications (decision making in four-tier test)

Answer	**Confidence**	**Reason**	**Confidence**	**Group of Conception**	**Abbreviation**
First-tier	Second-tier	Third-tier	Fourth-tier		
Correct	High	Correct	High	Scientific conceptions	SC
Correct	High	Correct	Low	Lack of knowledge	
Correct	Low	Correct	High	Lack of knowledge	
Correct	Low	Correct	Low	Lack of knowledge	LK
Correct	High	Incorrect	Low	Lack of knowledge	
Incorrect	Low	Correct	High	Lack of knowledge	
Incorrect	High	Correct	Low	Lack of knowledge	
Incorrect	High	Incorrect	High	Misconceptions	M
Correct	High	Incorrect	High	False Positive	FP
Incorrect	High	Correct	High	False negative	FN

True response score '1' (correct) High confidence rating ≥ d

False response score '0' (incorrect) Low confidence rating < d

CHAPTER FOUR

4. RESULT AND DISCUSION

In this chapter, the items and outcomes of four-tier test and Interview questions were analyzed, discussed and interpreted. It proceeds first by analysis of the concepts in the diagnostic tools and description of the outcomes of the study followed by presenting brief discussion and interpretation of the outcomes under all mechanisms. The percentage of answers was calculated for the majority answers given by students for every point of concept. $\mathbf{P} = \frac{\mathbf{S \times 100\,\%}}{\mathbf{N}}$ Notes: P - Percentage of the number of students who scientific conception, lack of knowledge, misconception, false negatives and false positives, S - the number of students who scientific conception, lack of knowledge, misconception, false negatives and false positives, for Grade 12 and grade 10 respectively. N - Number of students who done the test.

Table 9. Percentages of, scientific conception, lack of knowledge, misconception, false positives and false negatives grade 12

Items	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**Ave**
Scientific conception	5.9	6.3	11	11	4.7	4.7	6.3	6.3	6.3	4.7	6.68
Lack of Knowledge	73	69	67	74	75	70	77	72	75	72	72.4
Misconception	7.8	11	6.3	6.3	9.4	9.4	9.4	11	9.4	7.8	8.76
False Positives	9.3	4.7	6.3	4.7	7.8	7.8	9.4	4.7	4.7	9.4	6.89
False Negatives	6.2	9.4	9.4	4.7	3	7.8	3.1	6.3	4.7	6.3	6.1

Table 10. Percentages of, scientific conception, lack of knowledge, misconception, false positives and false negatives grade 10

Items	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**Ave**
Scientific conception	5	10	4	5.3	10	2	7.3	3.8	10	7	6.62
Lack of Knowledge	79	76	80	79	78	60	80	79	80	76	79.3
Misconception	3.8	7	7.3	5	7.5	6.8	4.5	7.5	3.8	6.3	5.97
False Positives	7.3	3	6	7	3.8	3.8	3.8	3.8	5	6.3	4.88
False Negatives	5	3.8	2.5	4	1.3	2.5	3.8	6.3	1.6	5	3.58

4.1. Analysis of the Results of the FTMCT for Both Grades

The results of the analysis for the percentages of scientific conception, lack of knowledge, misconception, false positives and false negatives, scores in all tier of the FTMCT were given in Table 9 and 10. The mean proportions of both false positive and false negatives are less than ten (10%) percent, which was recommended by [58]. Therefore, low percentages of false positives and false negatives would be good evidence for the content validity of the FTMCT test scores. [58] Suggested that estimation of the probability of false positives and false negatives in order to get evidence for the content validity of a test score. According to them, in order to establish content validity, the proportions of false positive and false negatives should be minimized. In this section, students' misconception among the presented concepts in the FTMCT was discussed.

Item 1, the students were requested to explain the properties of ionic compounds. Students believed that when bonding strength between ionic compounds increases, the boiling point of ionic compounds decreases. However ionic compounds has a strong force of attraction between the oppositely charged ions, so a large amount of energy is required to break the strong bonding force between the ions. That is why ionic compounds have high boiling point.

Item 2, the students were requested to what does sodium iodide dissolved in. Students believed that NaI dissolved in nonpolar solvents, since electrons are shared between sodium and iodine atom to form NaI. The misconceptions held by some of students resulted from the assumption that NaI is non polar and it dissolved in nonpolar solvents. The reality ionic compounds are generally soluble in polar solvents because polar solvents can separate and surround the ions and made up of positive and negative ions held together by strong electrostatic forces of attractions. Therefore NaI dissolved in polar solvent.

Item 3, the students were requested to explain the bond held in iron atom. Student believed that metallic bonding consists of molecules. However metallic bonding consists of a lattice of charged ions surrounded by a 'sea' of delocalized electrons. This produces a very strong electrostatic force of attraction between these oppositely charged particles. Therefore Metals are electropositive elements held together by valence electrons or attracted to the positively charged atoms

Item 4, the students were requested to explain the type of bond formed between hydrogen and chloride. Most of students believed that electrons are transferred from one atom to another atom to form covalent bonding. Further students believed that the bond holding the two atoms in HCl is ionic bonding. Students did not explain covalent bond formation in terms of sharing electrons. Students faced confusion between ionic and covalent compounds with learners believing that ionic compounds are molecular in nature. But, the type of bonds formed between hydrogen and chloride is covalent bond and formed sharing of electrons between the atoms.

Item 5, targets to determine the extent to which students could understand and predict the strongest hydrogen bonding of CH_3CH_2OH and $CH_3CH_2NH_2$. Students believed that nitrogen is more electronegative than oxygen, though few of them had misconception about the electronegative of Oxygen and Nitrogen. However hydrogen bonding formed when hydrogen is bonded to the highly electronegative elements such as oxygen, nitrogen, fluorine and therefore, CH_3CH_2OH compound possess the strongest hydrogen bonds since oxygen is more.

In order to determine students' misconception about chemical bonding concept the FTCBT was conducted and the results are summarized. Students' misconception was observed that most of students could not solve the problems on the concept of chemical bonding in their examinations. Even though the students have encountered the topic of chemical bonding, they still have many misconceptions about it. Students passed from grade to grade without fully grasping these concepts and having extra misconceptions. When the student has a misconception in science at an early grade level, this can affect the high school and college years by having impact on other topics learnt.

The content is quite complex as it is associated with many content areas. They did not show the necessary knowledge and were not able to express their answers clearly and logically in chemical bonding. Even though, students had been learning about chemical bonding starting from grade 9 and 11 secondary schools, still they did not clearly understand the conception of it.

Grade 12 students' misconception given in table 9.

Item 6, the students were requested to explain the polarity of CF_2Cl_2 and BCl_3 molecules. Students believed that CF_2Cl_2 is a non-polar molecules have atoms of similar electronegativities and they missed to explain the concept of polar and non-polar molecules. However, BCl_3 molecule has trigonal planar geometry that provides a symmetrical distribution of the bond dipole moments and the polarities of B-Cl bonds are cancelled by the symmetry of the molecule. Therefore the polarity of a molecule is depends on the polarity of its bonds as well as on its shape.

Item 7, students requested to identify the polarity of H_2S and CO_2. Students believed that H_2S molecule is non-polar that means two lone pair of electrons are balanced and the resultant dipole moment become zero. However, CO_2 is a nonpolar molecule since present's linear geometry providing a symmetrical distribution of the bond dipole moment. Because two C-O bond moment directions is opposite to each other and cancelled each other as a result net total dipole moment becomes zero.

Item 9, students were requested to explain the attractive forces between molecules in a covalent compound. Students believed that the force of attraction between covalent molecules is stronger than the forces of attraction in ionic compounds. However ionic bonds result from the mutual attraction between oppositely charged ions while a covalent bond is a bond that results from a sharing of electrons between nuclei. They tend to be stronger than covalent bonds due to the columbic attraction between ions of opposite charges

Item 10, the students were requested to determine the shape of molecule between Nitrogen and bromine. They wrongly assumed that Nitrogen forms three covalent bonds, which are equally, repel each other to form a trigonal planar shape and the shape of the molecules determined by the repulsion between nonbonding electron pairs only. The reality was the tetrahedral arrangement of the bonding and non-bonding electron pairs around nitrogen results in the shape of the molecule. Therefore the shape of the molecules is determined by the repulsion between nonbonding and bonding pairs of electrons.

Grade 10 Students' misconception given in table 10.

Item 6, students were required to predict the conductivity of NaCl in water. The misconceptions held by students resulted from the concept of electrical conductivity, melting point, boiling points and solubility of substances. Most of students had misconception on NaCl contains molecules that do not conduct a current. However it is not a molecule because the bonding that holds NaCl together is an ionic bond. Therefore NaCl contains ions that carry an electric current when it dissociated in water.

Item 7, the students were requested to explain the stability of inert gas. Most of students believed that noble gases located in the group of eighteen in the periodic table and their stability depends on the location of periodic table. However, Students could not explain stability in terms of outer most shell of electrons. Therefore stability depends on the outer most shell of atoms contains eight electrons.

Item 8, the students were requested to predict the conductivity of metals. Students believed that only ionic compounds have good electrical conductivity, which is wrong assumption. However metallic conductivity is the flow of electricity through metals, and the conduction of electricity through metals is due to the presence of freely moving (delocalized). Delocalized (free) electrons can move rapidly in response to electric fields and transmit heat; hence metals are a good conductor of electricity. This sea of electrons surrounds a lattice of positively charged metal ions.

Item 10, the students were requested to predict the positions of shared electrons and bond polarity. Students believed that equal sharing of electron pairs occurs in all covalent bonds and the polarity of a bond is dependent on the number of valance electrons in each atom involved in the bonding. Therefor hydrogen and fluoride form a covalent bond that electron pair must be centrally located. However the correct position of the electron pair in a bond between hydrogen and fluoride is located nearest to fluoride because fluoride naturally exhibits a stronger attraction for the shared electron identify.

Table11. Identified students' misconceptions using four-tier multiple choice test from grade 10

Key concepts	**Misconceptions associated with bonding and structure sub-topics**
Bond Polarity	HF bonding is formed by the transfer of electrons from one atom to another atom. Equal sharing of the electron pair in all covalent bonds. Polarity of a covalent bond is due to ion formation through electron transfer. Hydrogen and fluoride form a covalent bond and the electron pair must be centrally located.
Octet rule	Noble gases located in the group of eighteen in the periodic table and their stability depends upon the location of periodic table.
Lattices energy	The bond held in iron atom exists as molecular.
Intramolecular forces	High electronegativity increases the ability of atom to share electron with another atom to association of bond. There is no relationship between high electro negativity and type of bond association

Table 12. Identified students' misconceptions using four-tier multiple choice test from grade 12

Key Concepts	**Misconceptions associated with bonding and structure sub-topics**
Strength of Bonds	Strength of a covalent bond in a molecule determines inter-molecular forces between them. Forces of attraction between covalent molecules are stronger than the forces of attraction in ionic compounds.
Molecular Shape	The shape of a molecule is due to only equal repulsion between the bonding pairs. The shape of molecule between Nitrogen and bromine forms three bonds, which equally repel each other to form a trigonal planar shape.
Polarity of Molecules	Nonpolar molecules formed only when atoms in the molecule have similar electro negativities. Molecules of the type CF_2Cl_2 are nonpolar, since present's trigonal bipyramidal geometry that makes a symmetrical distribution of the bond dipole moments The NaCl molecules can be dissolved in nonpolar solvents.
Intermolecular forces	Hydrogen bonds between molecules are not chemical bonds but are only forces. Intermolecular forces are the forces within a molecule. Strong intermolecular forces exist in a continuous covalent solid.

4. 2. Analysis of the Interviews Results for Both Grades Students

Interview questions were used to identify the source of students' misconception. Students' responses to the items on the interview questions were grouped together according to their answer types in the first tiers, reasoning in the third tiers and their confidence in the first tier and in confidence the third tier. The first trend is expected the students acknowledge who mutual dependence between their answer and reason, with the answer being chosen by applying the principle given in the reason and the reason being chosen supports the choice of answer.

Source of students' misconceptions from both grades

The data of interview transcript attached on the Appendix 3 for both grades students whose answer were classified in the category of partial understanding with specific misconception incorrectly described two types of covalent bonding or presented incorrect examples of compounds for each type of covalent bonding although they correctly distinguished the types of covalent bonding as polar and nonpolar covalent bonding.

Item 1, Most of students were absolutely confident on their answers and reasons. But they couldn't provide reliable reasons with their confidence rating. During the interview, most of students said that problematic observed in chemistry textbook is lacks proper explanations of the subject matter and scientific facts. Some of them believe that the reasons for their misconception were difference between the scientific and daily language. The prerequisite knowledge of the students couldn't relate one topic to another because of their misconceptions. The information that teachers taught and that students were expect to learn in a given topic was not match.

Item 5, Most of students were unconfident about their answer tier and reason tier. During the interview, most of students said that the activity found in text book were not suitable implemented by their teacher; unfamiliarity with topic of chemical bonding; poor understanding of the concept; teacher fail to notice important prior concept relations within the scientific concept. However the teacher plays a key role in this whole process by engaging students in learning process by different constructive strategies. So, the teachers should be familiar with the possible misconception that students might hold and they should consider it while as it is main characteristic of constructivist teaching.

Source of students' misconceptions from grade 12 students

Item 10, most of the students' reason-tier might not exactly correspond to the answer-tier. During the interview, most of students said that the teacher's to pass information to students was not constructive idea and the instructional method considered only teacher centered method and they had no chance to participate and information transmitted from students to teacher. Some of them said that their parents we are not much attentive to academic progress of their children. However during teaching-learning process the teacher should be facilitating group discussions, encouraging students' participation, using active learning strategies.

Source of students' misconceptions from grade 10 students

Item 3, most of students answered just guessing for their answer-tier. But they sounded so Confident for their reason-tier. During the interview, the problems indicated by most of the students were based on their everyday experience rather than on scientific information learnt at school; majority of students said that the teacher didn't give the chance to them to ask questions and didn't give their remarks on the presentation of a particular group. However the teacher was expecting to motivate them to create a favorable condition for the teaching learning process for achieve skillful concept on chemical bonding topic and considering how to reduce source of student's misconceptions

General Sources of students' misconceptions: The interview results revealed that students had some common misconceptions about chemical bonding discussed in the works. Over all identified students misconceptions are: Using every day meaning to draw incorrect conclusions about chemical bonding or daily experience, parents, text books, teachers, language difficulty or lack of English language skills during daily communications, lack of construct own mental structure, students' themselves, content knowledge and chemistry instructional methods.

CHAPTER FIVE

5. CONCLUSION AND RECOMMENDATION

5.2. Conclusion

The following conclusions have been reached based on the findings of the study. From four-tier tests mechanisms, misconceptions in some basic concepts of covalent, ionic, metallic bonding and intermolecular forces were identified. The result showed that students did not show the necessary knowledge and were not able to express their answers clearly related chemical bonding.

The common misconceptions were identified as follows:-

- Non polar molecules formed only when atoms in the molecule and have atoms of similar electro-negativities.
- Metallic bonding consists of molecules held together by intermolecular forces.
- Equal sharing of electron pairs occurs in all covalent bonds.
- Only Ionic Bonds are conduct electric current when dissolved in water.
- Stability is only depends on the location of periodic table.
- Ionic bonds are the transfer of electrons, rather than the attractions of the ions that from the transfer of electrons.
- The largest atom exerts the greatest control over the shared electron pairs.
- Polar covalent compounds contain charged species.
- An ionic bond only occurs between the atoms involves in the electron transfer. Thus sodium ion forms one ionic bond to a chlorine ion in solid NaCl.
- The strength of a covalent bond is related to intermolecular force (between molecules) and not to intermolecular force (within the molecule i.e. between atoms)

This study showed that four-tier test is useful in assessing students' misconception and used to identify students' difficulty, particularly about the chemical bonding. The results from interview questions shown that daily experience, text books, teachers, English language skills and chemistry instructional methods were the major source of students' misconception about chemical bonding.

5.3. Recommendation

Based up on the findings of this study, the following recommendations were formulated for chemistry teachers, researchers, educators and policy makers.

- ✓ Better if chemistry teachers be mindful and consider students' misconception on the chemical bonding and design their lesson plans by considering on how to avoid source of students' misconception
- ✓ Teachers should note the seriousness of misconceptions on chemical bonding, and are encouraged to develop and use FTMCT to assessing misconception of their students.
- ✓ Well if chemistry curriculum designers and stakeholders redesign the educational materials by considering different the teaching methods or active learning methods in the programs.
- ✓ Well if chemistry curriculum designer attention on the conceptual changes methods teaching to minimize student's misconstruction on the chemical bonding.
- ✓ Researchers, policy makers and educators are highly advised to focus on developing FTMCT, evaluate its effectiveness and look for effective methods to bring about the desired conceptual change.

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7. APPENDICES

7.1 A. The Four-tier Chemical Bonding Diagnostic Mechanism 12th Grade

WOLKITE UNIVERSITY Time Allowed: 50 min

SCHOOL OF GRADUATE STUDIES

Dear students!

This part Harmonizes of the questions that diagnose misconceptions related to the concept of chemical bonding. The point of this test will not affect your classroom points in any way. The Data will be used only for research purpose. Each question has four parts. Hence, you are kindly requested to attempt all questions carefully.

Thank you for your cooperation!

General information:

School's name _____

Sex: M__ F___ (mark with '√') Grade and section_____

Instruction: This test has Ten items. Each item is classified in to Answer tier (A-tier) and Reason tier (R-tier). Both tiers are followed by confidence ratings ranging from just guessing to absolutely confident (a-f). The answer and reason tiers measure your content knowledge and explanatory knowledge, respectively. The two additional tiers measure the level of your confidence in the correctness of your chosen options for the answer and reason tiers, respectively. Encircle the letter of your choice for each of the A-tier and R-tier and encircle the letter that represents your level of confidence for the answers you give for each tier.

a b c d e f

Just guessing Very unconfident unconfident Confident Very confident absolutelyConfident

Question 1

1.1. Which of the following are not the properties of ionic compounds?

A. Toughness B. High melting point. C. Low boiling point. D. Good conductors of electricity

1.2. Confidence rating for answer: a b c d e f

1.3. Reason

A. Bonding strength between ionic compounds raises the boiling point. B. Bonding strength between ionic compounds reduces the boiling point. C. Ionic compounds do not have fixed properties. D. The ionic and covalent compounds have the same characteristics.

1.4. Confidence rating for reason: a b c d e f

Question 2.

2.1. The compound sodium iodide can be dissolved in:

A. Polar solvents as water B. non polar solvents C. whatever solvent

2.2. Confidence rating for answer:

Confidence rating for reason: a b c d e f

2.3. Reason

A. It does not dissolve in water, because is a network with covalent bonds between sodium and iodine atoms.

B. It dissolves in non-polar solvents, since sodium transfers its valence electron to iodine to form a molecule of NaI.

C. It dissolves in water, since consists of a network of ions. The Na^+ cations are attracted to the negative side of the dipole of water molecules and I anions to the positive, weakening the ionic bonds and dissolving.

D. NaI is soluble in both polar and non polar solvents because it is an instantaneous process.

2.4. Confidence rating for reason: a b c d e f

Question 3

3.1. The elemental form of iron is held together by metallic bonding. A. True B. False

3.2. Confidence rating for answer: a b c d e f

3.3. Reason

A. Metallic lattices contain neutral atoms. B. Continuous metallic or ionic lattices are molecular. C. Metal to non-metal bonding in alloys is electrostatic. D. Metals are electropositive elements held together by valence electrons.

3.4. Confidence rating for reason: a b c d e f

Question 4

4.1. In hydrogen chloride, HCl, the bond between hydrogen and chloride is a/an

A Covalent B. ionic

4.2. Confidence rating for answer: a b c d e f

4.3. Reason: A. Electrons are shared between atoms. B. Electrons are transferred. C. It contains different atoms. D. It contains Cl atom.

4.4. Confidence rating for reason: a b c d e f

Question 5

5.1. Which of the following compounds possess the strongest hydrogen bonds?

A. CH_3CH_2OH B. $CH_3CH_2NH_2$

5.2. Confidence rating for answer: a b c d e f

5.3. Reason:

A. B, because nitrogen is more electronegative than oxygen. B. A, because its molar mass is higher. C.A, because oxygen is more electronegative than nitrogen D. B, because contains more hydrogen atoms.

5.4. Confidence rating for reason: a b c d e f

Question 6

6.1. Which molecule is non-polar? A. CF_2Cl_2 B. BCl_3

6.2. Confidence rating for answer: a b c d e f

6.3. Reason:

A. A, since present's tetrahedral geometry that provides a symmetrical distribution of the bond dipole moments. These are cancelled and the total dipole moment is zero.

B. B, since present's tetrahedral geometry that provides a symmetrical distribution of the bond dipole moments. These are cancelled and the total dipole moment is zero.

C. A, since present's trigonal bipyramidal geometry that provides a symmetrical distribution of the bond dipole moments. These are cancelled and the total dipole moment is zero.

D. B, since present's trigonal planar geometry that provides a symmetrical distribution of the bond dipole moments. These are cancelled and the total dipole moment is zero.

6.4. Confidence rating for reason: a b c d e f

Question 7

7.1. Which molecule is non-polar? A. CO_2 B. H_2S

7.2. Confidence rating for answer: a b c d e f

7.3. Reason:

A. B, given that the two lone pair electrons are balanced and the resultant dipole moment is zero.

B. B, since presents linear geometry providing a symmetrical distribution of the bond dipole moments. These are cancelled and the total dipole moment is zero.

C. A, since present's linear geometry providing a symmetrical distribution of the bond dipole moment. These are cancelled and the total dipole moment is zero.

D. A, since the four bonds adopt tetrahedral geometry and symmetry so that all bond dipole moments are cancelled

Confidence rating for reason: a b c d e f

Question 8

8.1. At room temperature, sodium chloride, NaCl, exits as a molecule. A. True B. False

8.2. Confidence rating for answer: a b c d e f

8.3. Reason: A. The sodium atom shares a pair of electrons with the chlorine atom to form a simple molecule. B. After donating its valance electron to the chlorine atom, the sodium ion form a molecule with the chloride ion. C. Sodium chloride exists as a lattice consisting of sodium ions and chloride ions. D. Sodium chloride exists as a lattice consisting of covalently bonded sodium and chlorine atoms.

8.4. Confidence rating for reason: a b c d e f

Question 9

9.1. The attractive forces between molecules in a covalent compound:

A. Stronger than the forces of attraction in ionic compounds B. Weaker than the attractive forces in ionic compounds. C. Equal to the attractive forces in ionic compounds. D. Equal to zero.

9.2. Confidence rating for answer: a b c d e f

9.3. Reason

A. Ionic bonds are weaker than covalent bonds B. Ionic bonds are stronger than covalent bonds C. Ionic bonds equal to the covalent Association in force. D. Difference in electro negativity between ionic and covalent compound equals zero.

9.4. Confidence rating for reason: a b c d e f

Question10

10.1. Nitrogen (a group 5 element) combines with bromine (a group7 element) to form a molecule. This molecule is likely to have a shape, which is best described as:

A. trigonal planar B. trigonal pyramidal C. tetrahedral

10.2. Confidence rating for answer: a b c d e f

10.3. Reason

A. Nitrogen forms three bonds, which equally repel each other to form a trigonal planar shape

B. The tetrahedral arrangement of the bonding and non-bonding electron pairs around nitrogen results in the shape of the molecule. C. The polarity of the nitrogen–bromine bonds determines the shape of the molecule D. The difference in electro negativity values for bromine and nitrogen determine the shape of the molecule.

10.4. Confidence rating for reason: a b c d e f

Appendix figure 2. Grade 12 students during examination of FTCBT

7.2 B. The Four-tier Chemical Bonding Diagnostic Mechanism 10th Grade

WOLKITE UNIVERSITY Time Allowed: 50 min

SCHOOL OF GRADUATE STUDIES

Dear students!

This part Harmonizes of the questions that diagnose misconceptions related to the concept of chemical bonding. The point of this test will not affect your classroom points in any way. The data will be used only for research purpose. Each question has four parts. Hence, you are kindly requested to attempt all questions carefully.

Thank you for your cooperation!

General information:

School's name _____

Sex: M__ F___ (mark with '√') Grade and section_____

Instruction: This test has Ten items. Each item is classified in to Answer tier (A-tier) and Reason tier (R-tier). Both tiers are followed by confidence ratings ranging from just guessing to absolutely confident (a-f) the answer and reason tiers measure your content knowledge and explanatory knowledge, respectively. The two additional tiers measure the level of your confidence in the correctness of your chosen options for the answer and reason tiers, respectively. Encircle the letter of your choice for each of the A-tier and R-tier and encircle the letter that represents your level of confidence for the answers you give for each tier.

a b c d e f

Just guessing Very unconfident unconfident Confident Very confident absolutely Confident

Question 1

1.1. Which of the following are not the properties of ionic compounds?

A. High melting point. B. Toughness C. Low boiling point. D. Good conductors of electricity

1.2. Confidence rating for answer: a b c d e f

1.3. Reason:

A. Bonding strength between ionic compounds raises the boiling point. B. Bonding strength between ionic compounds reduces the boiling point. C. Ionic compounds do not have fixed properties D. The ionic and covalent compounds have the same characteristics.

1.4. Confidence rating for reason: a b c d e f

Question 2.

2.1. The compound sodium iodide can be dissolved in:

A. Polar solvents as water B. non polar solvents C. whatever solvent

2.2. Confidence rating for answer:

Confidence rating for reason: a b c d e f

2.3. Reason

A. It does not dissolve in water, because is a network with covalent bonds between sodium and iodine atoms.

B. It dissolves in nonpolar solvents, since sodium transfers its valence electron to iodine to form a molecule of NaI.

C. It dissolves in water, since consists of a network of ions. The Na^+ cations are attracted to the negative side of the dipole of water molecules and I anions to the positive, weakening the ionic bonds and dissolving.

D. NaI is soluble in both polar and non polar solvents because it is an instantaneous process.

2.4. Confidence rating for reason: a b c d e f

Question 3.

3.1. The elemental form of iron is held together by metallic bonding. A. True B. False

3.2. Confidence rating for answer: a b c d e f

3.3. Reason:

A. Metallic lattices contain neutral atoms.

B. Continuous metallic or ionic lattices are molecular.

C. Metal to non-metal bonding in alloys is electrostatic.

D. Metals are electropositive elements held together by valence electrons.

3.4. Confidence rating for reason: a b c d e f

Question 4

4.1. In hydrogen chloride, HCl, the bond between hydrogen and chloride is a/an

A Covalent B. ionic

4.2. Confidence rating for answer: a b c d e f

4.3. Reason: A. Electrons are shared between atoms. B. Electrons are transferred.

C. It contains different atoms. D. It contains Cl atom.

4.4. Confidence rating for reason: a b c d e f

Question 5

5.1. Which of the following compounds possess the strongest hydrogen bonds?

A. CH_3CH_2OH B. $CH_3CH_2NH_2$

5.2. Confidence rating for answer: a b c d e f

5.3. Reason:

A. B, because nitrogen is more electronegative than oxygen.

B. A, because its molar mass is higher.

C.A, because oxygen is more electronegative than nitrogen

D. B, because contains more hydrogen atoms.

5.4. Confidence rating for reason: a b c d e f

Question 6

6.1. NaCl in water conducts electricity A. True B. False

6.2. Confidence rating for answer: a b c d e f

6.3. Reason:

A. It contains ions that carry an electric current. B. It contains molecules that do not conduct a current. C. It contains covalent bonds between molecules. D. Covalent bonds are broken in solution.

6.4. Confidence rating for reason: a b c d e f

Question 7

7.1. One of the main groups of the periodic table known as a chemically inert (stable):

A. Alkali metals. B. Halogens. C. Noble gases. D. Lanthanide group.

7.2. Confidence rating for reason: a b c d e f

7.3. Reason

A. Because it is located in the group of eighteen in the periodic table.

B. Because the external level contains eight electrons

C. because they tend to share electron

D. Because it is chemically active

7.4. Confidence rating for reason: a b c d e f

Question 8

8.1. Metals are good conductors of electricity because they;

A. Form ionic bonds B. contain mobile electrons

8.2. Confidence rating for answer: a b c d e f

8.3. Reason: A. Ionic compounds have good electrical conductivity.

B. Metals have positive ions in a ‘sea of electrons’.

C. Electrons flow from positive and negative ions.

D. Electrons are negative charged particles.

8.4. Confidence rating for reason: a b c d e f

Question 9

9.1. The most difference in electro negativity between two atoms leads to association of:

A. Covalent bond. B. Ionic bond. C. Metallic bond. D. Hydrogen bond

9.2. Confidence rating for answer: a b c d e f

9.3. Reason

A. High electro negativity increases the ability of atom to attract electrons from another atom to association of bond.

B. High electro negativity increases the ability of atom to share electrons with another atom to association of bond

C. There is no relationship between high electro negativity and type of bond association.

D. Because metals tend to gain electrons through a bond association.

9.4. Confidence rating for reason: a b c d e f

Question 10

10.1Which of the following best represents the position of the shared electron pair in the HF molecule? A. H :F B. H: F

10.2. Confidence rating for answer: a b c d e f

10.3. Reason:

A. Non-bonding electrons influence the position of the bonding or shared electron pair.

B. As hydrogen and fluorine form a covalent bond the electron pair must be centrally located.

C. Fluorine has a stronger attraction for the shared electron pair.

D. Fluorine is the larger of the two atoms and hence exerts greater control over the shared electron pair.

10.4. Confidence rating for reason: a b c d e f

Appendix figure 3. Grade 10 students during examination of FTCBT

7.3C. Interview Questions on Chemical Bonding for Grade 10 and 12

WOLKITE UNIVERSITY

SCHOOL OF GRADUATE STUDIES

This interview will be used only for this research purpose so respondents kindly give your responses freely. When you give your response please write your answers on the provided place clearly and tiedly, you are requested. Thank you for your cooperation!

General information: Q = question, S=student, R= researcher

School's name _____ Sex: M__ F__ (mark'√') Grade and section_____

First Interview Question: In Q 1, you were absolutely confident on your answer and reason. Could you please explain your thinking and reasoning consistent with your confidence levels? Grade 10 and 12

S1: When I read it somewhere before or I haven't memories or notes study it, because in the chemistry textbook the concept do not stated properly.

R: Why did you choose A (in reason of Q 1), why not other?

S2: I can't remember this. I chose randomly, because difficulty of English language skills.

R: You are unconfident on your answer and reason (in Q 1). Could you please explain your thinking and reasoning?

S3: Because I haven't concept about the formation of Ionic bond and covalent bond.

R: what is your problem?

S4: The way of instructional methods of our teacher used was not clear.

R: Your reason may not exactly correspond to the answer (in A-tier Q 1), can you explain it?

S5: I don't know the reason, but I know the answer. In these responses some of the learners could not make a clear distinction between the descriptions of a covalent and Ionic bonding.

Second Interview Question: In Q.3, you answered Just guessing', but you sounded so confident! Why? (Grade 10^{th})

S1: This one is my own philosophy

R: What is the source of your doctrine?

S2: Information

R: What would make you sure of your answer?

S3: I don't know the answer, because I spend my time by playing football and watching movie.

R: In Q. 3, you are not confidence about your answer-tier. Can you explain it?

S4: I haven't concept on this topic. Because I gather information about the topic from my classmate and I don't know the concept clearly.

Third Interview Question: In Q. 5, what made you unconfident about your answer and reason-tier? (Grade 10^{th} and 12^{th})

S1: The activities found in text book were not sufficiently implemented by our teacher

R: What made you very confident in your answer and reason?

S2: because nitrogen is more electronegative than oxygen

R: What made you less confident on your answer and reason?

S3: Because all essential practical works were not taught by our teacher theoretically or demonstrated practically

R: You mean that your reason may not exactly correspond to the answer (A-tier). Why?

S4: I know the answer, but I don't know the reason. Because most of the time my family Don't give me time for study and I spend my time on working.

R: Could you please explain hydrogen bond?

S5: Hydrogen bond is the intramolecular force between atoms

R: Would you tell me examples of hydrogen bond?

S6: HCl, H2O, HBr, CH4

R: Why did you chose C (in A-tier of Q. 5), not B?

S7: Because oxygen is more electronegative than nitroge

Fourth Interview Question: Why did you choose B (in answer-tier in Q. 10,)? grade 12^{th}

S1: Because the same in electro negativity values for bromine and nitrogen.

R: Why it take on this geometry?

S2: Because they considered that only the nonbonding electron pairs influence the shape of the molecule

R: Your reason may not exactly correspond to the answer-tier. What is your evidence?

S3: have no idea, because our teacher didn't teach this topic effectively and with incorrect use of language in class

R: Could you tell me the shape of NBr_3?

S4: Trigonal planar

Fifth Interview Question: In Q.10, you choose B (in answer-tier). Could you please explain why NBr_3 take on trigonal pyramidal geometry? grade 12^{th}

S 3: nitrogen has two nonbonding electrons and three bonding.

R: You choose C (in reason of Q.10). What is your justification?

S5: I don’t know the reason. This topic is not clear, because my family not give attention for learning.

R: Why did you choose C (in answer of Q. 10), not B?

S 6: Because the same in electro negativity values for bromine and nitrogen