EVALUATING THE POTENTIAL OF DIAGNOSTIC INSTRUMENTS IN INDENTIFYING STUDENTS' MISCONCEPTIONS ON CHEMICAL BONDING: THE CASE OF CHELENKO PREPARATORY AND KERSA PREPARATORY SCHOOLS, EASTERN HARARGE

MSc THESIS

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MARCH, 2018

HARAMAYA UNIVERSITY, HARAMAYA

Evaluating the Potential of Diagnostic Instruments in Identifying Students' Misconceptions on Chemical Bonding: The case of Chelenko Preparatory and Kersa Preparatory Schools, Eastern Hararghe

A Thesis Submitted to the Department of Chemistry, Postgraduate Program Directorate

HARAMAYA UNIVERSITY

In Partial Fulfillment of the Requirements for the Degree of MASTER OF SCIENCE IN CHEMISTRY

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March, 2018

Haramaya University, Haramaya

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POSTGRADUATE PROGRAM DIRECTORIATE

I hereby certify that I have read and evaluated this Thesis entitled: **“Identification of the diagnostic instruments for diagnosis of students’ misconceptions on chemical bonding: The Case of Chelenko Preparatory and Kersa Preparatory Schools, Eastern Hararge”** prepared under my guidance by **Daniel Admasu.** I recommend that it be submitted as fulfilling the Thesis.

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Date of Submission: March, 2018

Place: Haramaya University, Haramaya

ACKNOWLEDGEMENTS

First and for most, I would like to express my deepest gratitude to my advisor Dr. Tesfahun Kebebe, for the immense contributions he has made for the accomplishment of this study. The completion of this study was not imagined without his constructive comments and advises. I would also like to extend my heartfelt thanks to my Co-advisor Dr. Abi Taddesse, for the undeniable support he has made.

My gratitude goes to my beloved spouse W/ro Meskerem Wudineh, my children Kirubel Daniel and Juliana Daniel for their moral support they have given me to carry on this research paper to an end.

Finally, I like to thank Tefera Belayneh for his great contributions for editing and formatting the manuscript.

ABBREVIATIONS

ANCOVA	Analysis of Covariance
ANOVA	Analysis of Variance
CG	Control Group
CV	Covariance
EG	Experimental Group
FN	False Negative
FP	False Positive
LK	Lack of Knowledge
MCT	Multiple Choice Test
MSC	Misconception
OQG	Open ended test group
P4TCBMT	Pilot Four-Tier Chemical Bonding Misconception Test
3TCBMT	Three-Tier Chemical Bonding Misconception Test
4TCBMT	Four-Tier Chemical Bonding Misconception Test
SC	Scientific Conception
VSEPR	Valence shell electrons pair repulsion

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ABSTRACT

This research study aimed to evaluating the potential of diagnostic instruments in identifying students' misconceptions on chemical bonding concepts such as ionic bonding, covalent bonding, and related chemistry concepts like molecular shape, polarity, inter-molecular force of attraction, and intra-molecular attraction force, which may be one of the causes of chemical misconceptions by applying three-tier misconception test for a control group and four-tier misconception test for an experimental group. It was also attempted to test the accuracy and precision of the common diagnostic tests in measuring students' misconceptions and performance in terms of different test standards and standard indicator. To attain these goals, respective data were gathered through open-ended, three-tier and four-tier misconception tests. The earlier was administered to identify major areas of students' misconceptions, and the second was used as reference while the latter was administered twice to different groups as a pilot and revised forms. Using the results of the pilot test some items were rewritten accordingly. The results of this study actually showed that misconceptions largely shared by about 33 % of the sampled students. Finally, the findings of this study indicated that open-ended, multiple choice items, two-tier tests and three–tier misconception tests used for the control group were less valid, reliable and discriminatory than that the four-tier misconception test used for the experimental group.

***KEY WORDS**:-* *Misconception, Chemical Bonding, students' chemical misconception, Multi-tier tests, Experimental Group, Control group, Scientific Knowledge*

1. INTRODUCTION

1.1. Background of the Study

A chemical bond is the attractive force that binds atoms together in a molecule, or a crystal lattice. The force of attraction between oppositely charged ions is called ionic bond. The attractive force between positively charged nuclei of atoms and the shared electrons in a molecule is known as covalent bond. A covalent bond in which the electrons are shared equally between the two atoms is called a non-polar covalent bond. Polarity of bonds is caused by differences in electronegativity of the two atoms forming the bonds. Intramolecular force which is a chemical bond that exists within a particle and affects the chemical property of the species. Whereas, intermolecular force exist between particles and influence physical property. In covalent bonding, the molecular geometry around each atom is determined by VSEPR rules, whereas, in ionic solids, the geometry follows maximum packing rules. According to VSEPR model both bonding and non-bonding electrons pair determine the shape of molecule. Molecular shape affects many properties of the molecule polarity, which in turn influence melting, and boiling points, solubility, and even reactivity.

Chemical bonding concepts are abstract because; students cannot see an atom or interactions between atoms or other elementary particles (Griffiths & Preston, 1999). Because of the abstract nature of this concept, students are faced with difficulties and they have some misconceptions about the chemical bonding that tend to hinder the understanding of modern scientific concepts. Teachers and text books often have difficulties with the term ‘‘ion’’. Ions are introduced at a much later stage in association of the ionic bonding, but not in the sense of already existing smallest particles of salts. Several empirical studies have demonstrated this (Hilbing, *et al.*, 2004). According to Taber Taber, K.S, (2002), students may understand the origin of ions and atoms through electron transfer, but often tend to confuse ionic bonding with this electron transfer and claim that electron transfer is the same as the concept of ionic bonding. Barker, (1998), comments that during the lesson unit on ionic bonding, teachers often use the octet rule, in order to show that some atoms fill their shells through electron transfer instead of sharing electrons in covalent bonding. Students are not capable of understanding how ion lattices are formed solely based on this explanation (Sumfleth, *et al.,* 1999). Based on the above-mentioned students' misconceptions that the ions always arrange in pairs or molecules, it seems understandable that students also have huge problems conceiving the arrangements of ions (Boo, H.K 1998). The works of Butts showed great deficits of students in spatial images of ionic bonds. For this reason, it is important to define and describe these misconceptions to plan special instructional strategies to eliminate these misconceptions by developing appropriate instruments. Therefore, this study was concerned with evaluating the potential of diagnostic instruments in indentifying students' misconceptions on chemical bonding.

On this ground the literature were examined with respect to students' conceptions in science, misconceptions and students' misconceptions in chemical bonds. As cited in Demircioğlu *et al.,* (2013) students develop their concepts and construct their own theories based on their experiences, attitudes, background and abilities before coming to school (Nakhleh and M.B, 1992). These concepts and theories which are brought to classroom by students are usually different from scientific conceptions. Students' self-constructed ideas have been called in literature as misconceptions, alternative conceptions, preconceptions, native conceptions etc (Nakhleh, M.B, 1992). In this study the term "misconception" was used for those conceptions that contradict the scientifically accepted ideas.

There have been many studies on students understanding of basic chemical concepts. Most of studies have revealed that many students have difficulties in understanding chemistry concepts and hold a lot of alternative conceptions (Demircioğlu, *et al.,* 2004), and also as cited in Girma Gebrekidan (2013) many teachers and textbooks are failing to consider the prior experiences and knowledge of the learner as the starting point to their new chemistry lessons. As a consequence, the newly introduced chemical concept will not find an appropriate place to fix itself in the long-term memory of the learner. If the learner tries to store material in long-term memory and cannot find an existing knowledge with which to link it, he/she either bends the knowledge to fit somewhere (may be completely wrong) or he/she tries to store it unattached. The bending process leads to alternative conceptions. The unattached learning is easily lost because it has not been inserted into the learner's mental filing system (Johnstone, 1999).

As seen in O'zmen (2004) learning science is a cumulative process and each new piece of information is added to what students already know about the topic at hand. Researchers have shown that students bring to lessons a lot of pre-existing misconceptions about scientific phenomena that can interfere with student learning of correct scientific principles or concepts (Palmer, *et al.*, 1999, 2001). Thus, understanding has caused science educators to be increasingly concerned about revealing students' difficulties prior to, during, or after the instruction in conceptualizing scientific knowledge and suggesting ways of remediation.

Misconception 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 teachers, other people, or through the media. There have been many studies on students' understanding of basic chemical concepts. Literature showed that both students and teachers can hold alternative conceptions about a number of basic science concepts (Demircioğlu and Baykan, 2012); (Yadigaroğlu and Demircioğlu, 2012). Wandersee *et al.* (1994) claimed that teachers often have similar alternative conceptions with their students. Wilson and Williams (1996) also suggested that teachers can transfer their alternative conceptions to their students. Misconceptions that already exist in learners' mind are considered as barriers in understanding science and they adversely affect subsequent learning. Recent studies on students' conceptual misunderstanding of fundamental concepts have indicated that new concepts can hardly be learned unless existing misconception are corrected, they need to be identified misconception is a very serious problem in learning because of those learner's misperceives the desired concept, but also due to being the fact that each of the chemical concepts has a real world application, like in health, food, construction, and so on. The misleading application of such concepts may turn these basic needs into crisis as disabling or killing million. As mentioned in the Tami Levy *et al.,* (2004) we have assumed that there are several external factors that can generate students' misconceptions. How can teaching strategies and the way these concepts are presented in textbooks mislead students? From this angle, it was being strongly argued that, each part of chemistry learning should involve diagnosis of students' misconception and modifying their mental image wherever and whenever necessary. However, identifying such misconception is not as such easy.

Hence, many are forced to ignore it, though nowadays; researchers devoted their time in developing different methods and examining their effectiveness. These include interviews, open-ended tests, multiple choice tests and multiple-tier (two, three and four) tier tests.

1.2. Statement of the Problem

Internationally, students' misconceptions in many concept areas of chemistry including the understanding of chemical bonding have been identified by chemical education researchers worldwide. Nationally (in our country), there are some studies conducted in identifying misconceptions on *chemical bonding and related concepts* by few researchers. Some of these studies are misconceptions of preparatory and college chemistry students related to some selected basic chemical concepts such as structure of atom, chemical bonds and intermolecular forces by Wondossen (2006), application of three-tier test to assess misconception of few selected chemistry concepts of university students by Israel (2010), investigated preparatory school students' misconceptions of four chemistry concepts namely valence, oxidation state, coordination numbers and formal charges using three-tier misconception test by Abayneh (2012), development of three-tier tests diagnostic instrument to investigate misconception about chemical bonding among grade 11 students by Getachew (2010/11). As Abayneh (2012), cited a number of debates have been rising regarding the reported or diagnosed set of respective misconceptions. The reasons behind such debates were found to be mostly attributed to the type of the diagnostic methods employed in each study. Most of these studies employed the easier diagnostic instruments which are blamed for being less accurate and precise in discriminating misconceptions from lack of knowledge. Also some researchers reported that diagnostic instrument of the first three-tiers have limitations in identifying students' misconception (D. Kaltakci Gurel *et.al*, 2015). All of the studies conducted in our country were focused on the students' misconception using two-tiers, three-tiers and four-tiers and there is no as such study (evaluating the potential of diagnostic instruments in identifying students' misconception on chemical bonding). All these studies lack uniformity (there is no best method recommended). To fill this gap, my study focused on evaluating the potential of diagnostic instruments in identifying students' misconception on chemical bonding. Therefore, it was the intention of this study to investigate the potential of diagnostic instruments by comparing three-tier test with four-tier test in indentifying students' misconceptions on some basic concepts of chemical bonding in selected sample preparatory schools. This research also was aimed to identify students' misconception on chemical bonding and related chemistry concepts which limit students' understanding of the major topics.

Research questions

1. Which diagnostic instrument is the best applicable test for assessing preparatory school students' misconceptions about the selected chemical bonding concepts and other related chemistry concept?
2. Which concepts are misunderstood and therefore cause students' misconception on chemical bonding.

1.3. Hypothesis

H_o1: There is no significant difference between the mean average proportions of students' misconceptions respectively, two-tier, three-tier and four-tier tests.

H_o2: There is no significant difference between the reliability coefficients calculated based on students' misconception for three-tier and four-tier tests.

H_o3: There is no significant difference between the mean average discrimination indexes for two-tier, three-tier and four-tier tests.

1.4. Objectives of the Study

1.4.1. General Objective

The main objective of this study was:-

- To evaluate the potential of diagnostic instruments in indentifying students' misconception on some basic chemistry concepts of chemical bonding and related chemistry concepts, this may be one of the causes for chemical misconceptions and for recommending valuable information towards improving the teaching-learning process as well.

1.4.2. Specific objectives

The specific objectives of the study were

- To compare the effectiveness of three-tier and four-tier misconception tests for assessing preparatory students' misconceptions on a few selected chemical bonding concepts and related chemistry concepts.
- To identify students' misconception on selected concepts which cause students' misconception on chemical bonding.
- To recommend valuable information for improving the teaching-learning process as well.

1.5. Scope of the Study

Specific topics to be taught was restricted to evaluating the potential of diagnostic instruments in indentifying students' misconceptions on some selected chemical bonding concepts such as ionic bonding, covalent bonding, and related concepts like molecular shape, polarity, inter molecular force of attraction, and intra molecular attraction force which may be one of the cause of the misconception (conceptual difficult) by comparing three-tier and four–tier misconception test.

1.6. Significance of the Study

Information about assessing misconceptions by applying four–tier misconception test is particularly useful for the science teaching community in order to assess chemical misconception towards, chemical bonding sub concepts like ionic bonding, covalent bonding, molecular shape, polarity, inter molecular force of attraction, and intra molecular attraction force which may be one of the cause of the misconception (conceptual difficult) for students at secondary and preparatory levels. Therefore, this study is significant in helping teachers and curriculum developer to address and design teaching and learning process. It is also used as starting point for the development of subsequent learning activities based on some common and key misconceptions. Moreover, this study will lay foundation for further studies that aim to investigate the causes of misconception and identify teaching methods appropriate to bring about conceptual changes and develop problem solving skills.

1.7. Limitation of the Study

Due to time limitation, the study was limited to:

1. Unit of chemical bonding in grade 11 chemistry students' text book and teachers' guide.
2. The subject of the study were grade 12 students of Chelenko and Kersa Preparatory Schools, from which sample students to each of the experimental and controlled group were selected in year 2016/2017

1.8. Operational Definition of Terms

- **Chemical bond:-** A link between atoms that leads to an aggregate of sufficient stability to be regarded as an independent molecular species. Chemical bonds include covalent bonds, electrovalent (ionic) bonds, coordinate bonds, and metallic bonds. Hydrogen bonds and Van der waals forces are not usually regarded as true chemical bonds.
- **Content knowledge:-** knowledge about concerned subject matter.
- **Covalent bond: -** A bond formed by the sharing of an electron pair between two atoms. Molecules are combinations of atoms bound together by covalent bonds.
- **Covalent crystal:-** A crystal in which the atoms present are covalently bonded. They are sometimes referred to as giant lattices or macromolecules. The best known completely covalent crystal is diamond
- **Four-tier test:-** is an enhanced version of the two-tier multiple-choice (2TMC) test in which its answer and reason tiers measure students content knowledge and explanatory knowledge, respectively.
- **Intermolecular forces:-** Forces of attraction between molecules rather than forces within the molecule. The intermolecular forces are divided into H-bonding forces and Van der waals forces, and the major component is the electrostatic interaction of dipoles.
- **Intramolecular forces:-**Forces of attraction within molecules rather than forces between the molecules.

- I**onic bond (electrovalent bond):-** A binding force between the ions in compounds in which the ions are formed by complete transfer of electron from one element to another element or radical.
- **Ionic crystal:-** A crystal composed of ions of two or more elements. The positive and negative ions are arranged in definite patterns and are held together by electrostatic attraction. Common examples are sodium chloride and cesium chloride.
- **Misconceptions or Alternative conceptions:-**conceptions that are often differ from scientific conceptions.
- **Polar bond:** A covalent bond in which the bonding electrons are not shared equally between the two atoms. A bond between two atoms of different electro negativity is said to be polarized in the direction of the more electronegative atom
- **Polar molecule:** A molecule in which the individual polar bonds are not perfectly symmetrically arranged and are therefore not 'in balance'.

2. REVIEW OF RELATED LITERATURE

In this part, an effort was made to gather and systematically arrange the review of related literature on concepts and empirical studies relevant to the objective of this study gathered from different sources.

2.1. Identification of Misconception

As cited in D. kaltakci Gurel *et al.* (2015) students learn about the world around them formally through school education or informally through their everyday experiences, they often tend to form their own views. Because of this concern, several studies have been conducted to depict students' understanding. The different forms of student understandings have been called by a number of different terms such as "alternative conceptions" Wandersee, Mintzes and Novak (1994); Klammer (1998) "misconceptions" Driver and Easley (1978); Helm (1980); Clement, Brown and Zietsman (1989); "children's ideas" Osborne, Black, Meadows and Smith (1993), and so forth. Despite variations, all the terms stress differences between the ideas that students bring to instruction and the concepts by the current scientific theories. There have been many studies on students' understanding of basic chemical concepts. The studies have revealed that many of students have difficulties in understanding chemistry concepts and hold a lot of alternative conceptions (Demircioğlu *et al.*, 2004). As Demircioğlu (2004) stated one of the most important reasons for this is that chemistry concepts are abstract in nature and require abstract reasoning. Another reason is that chemistry concepts generally require that students must be able to use representations in three different levels: macroscopic, microscopic, and symbolic levels (Johnstone, 2000). Macroscopic level refers to what we can observe with our senses. We can observe the macroscopic events. Microscopic level refers to what is actually taking place at the particulate level in a chemical reaction involving the movement of electrons during bond breaking and bond forming. We cannot observe chemical changes taking place in this level. For this reason, students have difficulty explaining chemistry phenomena at the microscopic level and tend to attribute the macroscopic properties of matter to its microscopic particles (Ben-Zvi, Eylon and Silberstein, 1986). Symbolic level refers to the symbolic representations of atoms, molecules, and compounds used in writing chemical formulae and equations.

Students have more difficulty in learning microscopic and symbolic representations than macroscopic one because these levels are invisible and abstract. As pointed by Pfundt and Duit (1991) students' alternative conceptions are highly resistant to change rather strongly influencing new learning. Moreover, if students are unable to construct an appropriate understanding at the beginning of their studies, they may lack the necessary grasp of fundamental ideas on which to build further knowledge needed to understand advanced concepts (Mulford and Robinson, 2002). As a consequence, much science education research has focused on the determination of students' alternative conceptions, in order to subsequently develop a more scientifically acceptable views of science concepts in students (Acar and Tarhan, 2007); (Chandrasegaran, Treagust, and Mocerino, 2007). In the present review, the term "misconception" is going to be used for those conceptions that contradict the scientifically accepted theories because of its common usage in the literature.

Therefore, as cited in Kaltakci Gurel *et.al.* (2015) the identification of misconception in a valid and reliable way becomes a prominent first task of the teacher in order to make the students' conceptual change easier. Because of this, a careful user of a diagnostic instrument such as a classroom teacher or a researcher would be aware of the diagnostic instruments and selects the most effective one for his/her purposes. .

2.1.1. Interviews

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. In fact, interviews have been found to be one of the best Osborne and Gilbert (1980b); Franklin (1992) and the most common Wandersee *et al.* (1994) approach used in uncovering students' views and possible misconceptions. Interviews may be conducted with individuals or with groups La Rosa, Mayer, Paqtirxi and Vincentini, (1984); Eshach, (2003); Galili and Goldberg, (1993); Olivieri, Totosantucci and Vincentini, (1988); Van Zee, Hammer, Bell, Roy and Peter (2005). Duit, Treagust and Mansfield (1996) stated that the group interviews have the strength of studying the development of ideas in the interaction process between students. The purpose of interviewing was stated by Frankel and Wallen (2000) as finding out what is on people's mind, what they think or how they feel about something. As stated by Hestenes, Wells and Swackhamer (1992) when skillfully done, interviewing is one of the most effective means of dealing with misconceptions-advantage; gaining in-depth information and flexibility; disadvantages a large amount of time is required to interview a large number of people in order to obtain greater generalizibility. Also training in interviewing is required for the researcher. In addition, interviewer bias may taint the findings. The analysis of data is a little bit difficult and cumbersome (Sadler (1998), Mahooana, (1999), Adadan and Savasci (2012), Rollnick and Tongchai *et al.* 2009).

2.1.2. Open-Ended Tests

In order to investigate students' understanding, open-ended free-response tests were also used commonly in science education. This method gives test takers more time to think and write about their own ideas, but it is difficult to evaluate the results (Al-Rubayea, 1996). Also because of language problems, identification of students' misconceptions becomes difficult Bouvens as cited in Al-Rubayea (1996) since students are generally less eager to write their answers in full sentences. Andersson and Karrqvist, (1983); Palacious, Cazorla and Cervantes, (1989); Ronen and Eylon, (1993); Langley, Ronen and Eylon, (1997); Wittman, (1998); Colin, Chauvet and Viennot, (2002) investigated misconceptions of students with open-ended questions or tests as a diagnostic instrument.

2.1.3. Ordinary Multiple Choice Tests

In order to overcome the difficulties encountered in interviewing and open-ended testing processes, diagnostic multiple-choice tests, which can be immediately scored and applied to a large number of subjects, have been used to ascertain students' conceptions. These tests have been used either following in-depth interviews or alone as a broad investigative measure. The development of multiple-choice tests on students' misconceptions makes a valuable contribution to the body of work in misconception researches', assists in the process of helping science teachers more readily use the findings of research in their classrooms (Treagust, 1986). Results from diagnostic multiple-choice tests have been reported frequently in misconception literature. The validity evidence for this format is strong (Downing, 2006). From the point of view of teachers' usage, valid and reliable, easy-to-score, easy-to-administer, paper-and-pencil instruments enable teachers to effectively assess students' understanding of science. A science teacher can get information about students' knowledge and misconceptions by use of the diagnostic instruments. Once the student misconceptions are identified, teachers can work to remedy the faulty conceptions with appropriate instructional approaches. Advantages of using multiple-choice tests over other methods have been discussed by several authors Caleon and Subramaniam, (2010a); Iona, (1982); Tamir, (1990); Çataloğlu & Robinett, (2002).

To sum up, some of the advantages of multiple-choice tests are: (1) They permit coverage of a wide range of topics in a relatively short time. (2) They are versatile, and can be used to measure different levels of learning and cognitive skills. (3) They are objective in terms of scoring and therefore more reliable. (4) They are easily and quickly scored. (5) They are good for students who know their subject matter but are poor writers, and (6) They are suitable for item analysis by which various attributes can be determined. In spite of the advantages of multiple-choice tests mentioned above, there are some criticisms of them. Chang, Yeh and Barufaldi (2010) and Bork (1984) stated certain limitations and drawbacks of multiple-choice questions, such as: (1) Student guessing contributes to the error variance and reduces the reliability of the tests; (2) Selected choices do not provide deep insights into student ideas or conceptual understanding, (3) Students being forced to choose each answer from among a very limited list of options, which is preventing them from constructing, organizing and presenting their own answers and (4) It is extremely difficult to write good multiple-choice questions. Another very common criticism that was described by Rollnick and Mahooana (1999) is that multiple-choice tests do not provide deep enough insight into students' ideas on the topic and students may give correct answers for wrong reasons. In other words, ordinary multiple-choice tests cannot differentiate correct answers due to correct reasoning from those that are due to incorrect reasoning (Caleon and Subramaniam, 2010a).

To overcome the limitations of multiple-choice tests, tests with multiple-tiers have been developed. Researchers recognized the difficulty in uncovering misconceptions by ordinary multiple-choice tests since the reason behind a students' selection is not evident (Griffard and Wandersee, 2001). Therefore, they extended multiple-choice tests into tests with two, three, or four tiers in order to compensate for the limitations of the ordinary multiple-choice tests used in diagnosing students' conceptions

2.1.4. Two-Tier Multiple Choice Tests

In order to gather data from more students than is possible by interviews, justifications to multiple-choice items were used Hrepic (2004); Tamir (1989) in which students were required to justify their selection of answers in multiple-choice items in the form of short answers. These justifications were recommended to be used as raw material for the construction of two-tier tests. Generally, the two-tier tests were described as diagnostic instruments with first tier, including multiple-choice content questions, and second tier, including multiple-choice set of reasons for the answer to the first tier Treagust (1986); Griffard and Wandersee (2001); Chen, Lin and Lin (2002); Adadan and Savasci (2012) students' answers to each item were considered correct when both the correct choice and reason are given. Distracters were derived from students' misconceptions gathered from the literature, interviews, and open-ended response tests. Two-tier test were considered a great improvement over the previous approaches in that these tests consider students' reasoning or interpretation behind their selected response and link their choices to misconceptions of the target concept Wang (2004) and also as stated by Adadan and Savasci (2012) two-tier diagnostic instruments are relatively convenient for students to respond to and more practical and valuable for teachers to use in terms of reducing guesswork, allowing for large-scale administration and easy scoring, and offering insights into students' reasoning.

2.1.4.1. Advantages of the two tier tests

Two-tier tests are advantageous in that it is easy to administer, score them and analyze their results. In addition, such tests help teachers to get information on prior knowledge of their students, and how their existing knowledge is influenced by their respective prior knowledge (Tsai and Chou, 2002).

For example, they can tutor the students in their weak areas individually or assign the students into heterogeneous cooperative leaning teams. If teachers use the diagnostic tests for summative assessment; they will see impact of their instruction method as positive or negative that which can serve as feedback for later on instructions. However, it is important to say that results of the diagnostic tests cannot be used for assigning grades of the students. Because, the main purpose of the test is to diagnose, not to assess achievement of the students.

2.1.4.2. Development process of two-tier tests

As seen in Israel (2010) developing reliable and valid conceptual diagnostic tests is a struggling process and requires great efforts. The development process of a two-tier test was defined by Treagust in three main phases Odom and Barrow (1995):

Phase 1: The content boundaries were defined with a list of propositional knowledge statements, and content validity of prepositional knowledge statements was determined.
Phase 2: Students misconceptions were identified by interviews. And multiple choice questions with free response and reasons were constructed and administered.
Phase 3: Final test questions were constructed based on multiple choice questions free response reasons, the final test questions were revised and a pilot study was conducted and final content and face validity of each test item were determined with the assistance of a specification grid.

Finally, the final version of the test was administered. Some two-tier diagnostic tests were developed based on this process in different fields of science education. Most of the developments of two-tier diagnostic tests include both interviews and open-ended questionnaires or multiple choice tests to identify the misconceptions of the students which will be used for discracters of two-tier test. Including interview method give a chance forvthe researcher to probe the students mind deeper and ask the questions with more flexibility.

On the other hand, including open-ended or multiple choice tests gives a chance to the researcher to deal with more subjects to generalize the results (Beichner, 1994). In the following part, some studies including development process of two-tier tests are presented.

Tan *et al.* (2002) developed and applied a two-tier multiple choice diagnostic instrument to assess high school students understanding of inorganic chemistry. Their methodology was very similar to Odom and Barrow's study (1995) in which they used (Treagust, 1998 model). Chen *et al.* (2002) investigated the high school students' misconceptions about image formation by a plane mirror. They developed a two-tier diagnostic test based on Treagust model. There are two differences in this study from the previews study described above. First, an open-ended questionnaire, not a multiple-choice test with free response, was used to identify students' misconceptions which could serve as distracters for the later construction of the multiple choice instruments. Second, interviews were conducted after open-ended questionnaires administered, not before. In analyzing the results, they also calculated discrimination index and difficulty level for each item.

Beichner (1994) developed a diagnostic multiple-choice test to identify the misconceptions of the students in kinematics graphs. The construction process of the test was very similar to the Treagust Model. The difference was that in defining boundaries of the study, he wrote specific objectives instead of concept map or propositional statements.

2.1.4.3. Disadvantages of the two-tier tests

Although, diagnostic tests are very helpful for teachers to identify the misconceptions of the students, some researchers criticize them. In physics, for example, forced choice instruments like two-tier tests give clues to the students to select correct answers that they would not have had in interviews and open-ended questions. (Griffard and Wandersee, 2001) investigated the effectiveness of a two-tier instrument. The test was given to the students and wanted them to think aloud while they were answering the items. They found that using unnecessary wording of the test. Moreover, these unnecessary wording can cause create a new misconception in students mind. They also stated that students consider the second tier as a distinct multiple-choice item and finalize their choice on the basis of whether it logically follows from their response to the first tier. Therefore, two-tier test seemed to measure the students test taking skills rather than their understanding. Moreover, the feelings of the students are very important. Students bring to these types of tests different amounts of sincerity, persistence and meticulousness which can confound the test results. They also criticize the two-tier test about the estimating proportions of the misconceptions. According to them, two-tier tests overestimate the proportions of the misconceptions boarding to them; two-tier tests overestimate the proportions of the misconceptions because gap in knowledge cannot be discriminated by two-tier tests.

Therefore, a third tier is necessary to be sure that whether a wrong answer for the first two-tiers is a Misconception or a mistake due to lack of knowledge.

2.1.5. Three-Tier Multiple Choice Tests

The limitations mentioned for the two-tier tests were intended to be compensated by incorporating a third tier to each item of the test asking for the confidence in the answers given in the first two tiers Kutluay (2005); Türker (2005); Aydin (2007); Caleon and Subramaniam (2010a); Peşman and Eryılmaz (2010); Eryılmaz, (2010). In three-tier tests, researchers constructed a multiple-choice test; the first tier of which included an ordinary multiple-choice test, the second tier of which was a multiple-choice test question asking for the reasoning, and the third tier of which was a scale asking for the students' confidence level for the given answers for the above two students' answers to each item were considered correct when both the correct choice and reason are given with a high confidence. Similarly, students' answers were considered as misconceptions when a wrong answer choice is selected with an accompanied wrong reasoning and with a high confidence. Three tier tests are considered to be more accurately eliciting the student misconceptions, since they can detect lack of knowledge percentages by means of the confidence tiers. This helps the test users such that the obtained percentage of misconception is free from false positives, false negatives and lack of knowledge, since each requires a different remediation and treatment.

2.1.5.1. Advantages of the three-tier tests

Holds all the strengths provided with three-tier MCT. Three tier tests had the advantage of discriminating the students' lack of knowledge from their misconceptions. Hence, they were considered to assess student misconceptions in a more valid and reliable way compared to ordinary multiple-choice tests and two-tier tests Kutluay, (2005); Türker, (2005); Aydin (2007); Eryilmaz (2010); Peşman and Eryılmaz, (2010).

2.1.5.2. Disadvantages of the three-tier tests

In three-tier tests, students were asked for their confidence for the choices in the first two tiers covertly; this might underestimate proportions of lack of knowledge and overestimate student scores. For this reason, four-tier tests in which confident ratings were asked for the content and reasoning tiers separately are introduced more recently.

2.1.6. Four-Tier Multiple Choice Tests

As seen in Derya Kaltakcil *et.al*. (2015) four-tier tests are very similar to three-tier tests. A question in a four-tier test comprises the content tier, which measures content knowledge; the reason tier, which measures explanatory knowledge; and the confidence tier, which measures the strength of conceptual understanding of the respondents. The only difference is an item has one additional tier which asks students confidence about the answers to the former two-tiers. Even though, three-tier tests were thought to be measuring misconceptions free from errors and lack of knowledge in a valid way, they still have some limitations due to the covert rating of the confidence for the first and second tiers-test. This situation may result in two problems: one is the underestimation of the lack of knowledge proportions, and the other one is the overestimation of the students' misconception scores and the correct scores Derya Kaltakcil *et.al*. (2015). To explain these problems in three-tier tests, one can look at Table 1 and Table 2 below.

Table 1: Comparison of four-tier tests and three-tier tests in terms of determining Lack of knowledge (Lk)

Four Tier Test			**Three tier test**	
Confidence for the 1st tier	Confidence for the 3rd tier	Decision researcher for LK in four tier	Corresponding possible student selection in three tier test	Decision researcher for LK in three tier
Sure	Sure	No LK	Sure	No Lk
Sure	Not sure	LK	Not sure	No LK if sure
Not sure	Sure	LK	Sure	No LK if not sure
Not sure	Not sure	LK	Not sure	LK

D. Kaltakci Gurel *et.al*, 2015

Table 1 provides the comparison of decisions for four-tier and three-tier tests in determining the lack of knowledge based on the possible student rating of confidence in four-tier tests. 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 four-tier test, the researcher can decide "lack of knowledge" for that item. However, in the corresponding three-tier form of the same item the student may indicate his confidence for the main and reasoning tiers either as "sure" or "not sure". As a result, depending on the rating of confidence, the researcher may have a decision of "lack of knowledge" if he is "not sure"; or "no lack of knowledge" if he is "sure". Hence, proportion of lack of knowledge may be underestimated in three-tier tests. Similarly, in the decision of misconception scores and correct scores, three-tier tests overestimate the proportions of those scores compared to the four-tier tests

Table 2: Comparison of decision in four-tier tests and three-tier tests

1st tier	2nd tier	3rd tier	4th tier	Decision for four-tier test	Decision for three-tier test
Correct	Sure	Correct	Sure	SC	SC
Correct	Sure	Correct	Not sure	LK	SC if “sure” LK if “not sure”
Correct	Not sure	Correct	Sure	LK	SC if “sure” LK if “not sure”
Correct	Not sure	Correct	Not sure	LK	LK
Wrong	Sure	Wrong	Sure	MSC	MSC
Wrong	Sure	Wrong	Not sure	LK	MSC if “sure” LK if “not sure”
Wrong	Not sure	Wrong	Sure	LK	MSC if “sure” ” LK if “not sure”
Wrong	Not sure	Wrong	Not sure	LK	LK

D. Kaltakci Gurel *et.al.* (2015)

Table 2 compares the decisions for three and four-tier tests. For instance, in a four tier test, 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 “lack of knowledge” because there is doubt about at least one tier of the student’s answer. However, in a parallel three-tier test in which the confidence rating is asked for two tiers together, the same student may select “sure” or “not sure” since he is not sure for at least one of the tiers. If he chooses “not sure” the researcher’s decision would be that student has a “lack of knowledge”, but if the student chooses “sure” then the researchers’ decision for that student’s answer for this item would be he has a “scientific knowledge” on this item. Hence, his correct score would be overestimated.

2.1.6.1. Advantages of the four-tier tests

- Holds all the strengths provided with three-tier MCT.
- Truly assesses misconceptions which are free of errors and lack of knowledge.

2.1.6.2. Disadvantages of the four-tier tests

Even though four tier multiple-choice tests seem to eliminate many problems of the aforementioned instruments, they still possess several limitations such as: requiring a longer testing time, not advisable for using in achievement purposes Caleon, I. S. and Subramaniam, R. (2010a).

2.2. Some students' misconception in Chemistry

Students develop their concepts and construct their own theories based on their experiences, attitudes, background, and abilities before coming to school (Nakhleh, 1992). These concepts and theories which are brought to classroom by students are usually different from scientific conceptions. Students' self-constructed ideas have been called in literature as misconceptions, alternative conceptions, preconceptions, naïve conceptions etc (Nakhleh, 1992). There have been many studies on students' understanding of basic chemical concepts. The studies have revealed that many of students have difficulties in understanding chemistry concepts and hold a lot of alternative conceptions (Demircioğlu *et al.*, 2004. One of the most important reasons for this is that chemistry concepts are abstract in nature and require abstract reasoning. Another reason is that chemistry concepts generally require that students must be able to use representations in three different levels: *macroscopic, microscopic, and symbolic levels* (Johnstone, 2000). Macroscopic level refers to what we can observe with our senses. We can observe the macroscopic events. Microscopic level refers to what is actually taking place at the particulate level in a chemical reaction involving the movement of electrons during bond breaking and bond forming. We cannot observe chemical changes taking place in this level. For this reason, students have difficulty explaining chemistry phenomena in the microscopic level and tend to attribute the macroscopic properties of matter to its microscopic particles (Ben-Zvi, Eylon and Silberstein, 1986). Symbolic level refers to the symbolic representations of atoms, molecules, and compounds used in writing chemical formulae and equations. Students have more difficulty in learning microscopic and symbolic representations than macroscopic one because these levels are invisible and abstract.

2.2.1. Bond and Bonding

Boo (2000) in interviews with trainee-teachers enrolled in a post-graduate diploma in education course found that many did not seem to know the subtle differences in meanings between the terms ‘bond’ and ‘bonding.’ To them, the term ‘ionic bonding’ is synonymous with the term ‘ionic bond’ and the term ‘covalent bonding’ is synonymous with the term ‘covalent bond’. She maintains that the subtle difference between the terms ‘bonding’ and ‘bond’ needs to be pointed out, since chemistry/science is after all a subject which stresses on precision and accuracy. The term ‘bonding’ refers to the process of bond formation whereas the term ‘bond’ refers to the attractive force which holds ions or atoms or molecules together. More specifically, the term ‘covalent bonding’ refers to ‘the sharing of electrons between atoms of non-metallic elements, generally resulting in a noble gas electronic structure in the valence shell of the atoms involved.’ In contrast, the term ‘covalent bond’ refers to ‘the electrostatic force of attraction between the positively charged nuclei involved and the shared electrons. ‘Similarly, the term ‘ionic bonding’ refers to ‘the transfer of electrons from the metallic atom to the non-metallic atom generally resulting in a noble gas electronic structure in the valence shells of the ions formed,’ while the term ‘ionic bond’ refers to ‘the electrostatic force of attraction between the oppositely charged ions formed as a result of the process of electron transfer.’

2.2.2. Students’ Misconceptions of Ionic and Covalent Bonding

Previous research has identified a range of students’ difficulties in understanding of ionic bonding. Butts and Smith (1987) found that most Grade 12 chemistry students associated sodium chloride with ionic bonds and the transfer of electrons from sodium to chloride, but many did not understand the three dimensional nature of ionic bonding in solid sodium chloride. A few students thought sodium chloride existed as molecules and these molecules were held together in the solid by covalent bonds. Others thought that sodium and chlorine atoms were bonded covalently but that ionic bonds between these molecules produced the crystal lattice. A three dimensional ball-and-stick model of sodium chloride also caused confusion among the students as many interpreted the six wires attached to each ball (ion) as each representing a bond of some sort. Boo (1998) interviewed 48 Grade 12 students and found that some students thought that the attraction between oppositely charged ions in an ionic compound results in the neutralization of the charges, leading to the formation of a lattice consisting of neutral molecules. Taber (1994) in interviews involving Grade 12 students, found that many students adopted a molecular framework for ionic bonding. He found that many students believed that:

1. The atomic electronic configuration determines the number of ionic bonds formed. For example, a sodium atom can only donate one electron, so it can form only one bond.

2. Bonds are only formed between atoms that donate/accept electrons. For example, in sodium chloride, the chloride is bonded to the specific sodium atom that donated an electron to it.

3. Ions interact with the counter ions around them, but for those not ionically bonded these interactions are just forces. For example, in sodium chloride, a chloride ion is bonded to one sodium ion and attracted to a further five sodium ions, but just by forces and not bonds. These findings were supported further by the data obtained in a later study of (Taber, 1997). The study involved the administration of a thirty 'true or false 'item test, 'Truth about Ionic Bonding Diagnostic Instrument' to Grade 10 to 12 chemistry student.

2.2.3. Intermolecular and Intramolecular Forces

- Covalent bonds are broken when a substance changes shape.
- Strong inter-molecular forces exist in a continuous covalent solid.
- Inter-molecular forces are the forces within a molecule.
- Strength of a covalent bond in a molecule determines inter-molecular forces.
- Metals and non-metals form molecules with weak intermolecular forces.
- The strength of intermolecular forces is determined by the strength of the covalent bonds present in the molecules.
- Covalent bonds are broken when a substance changes state.
- Molecular solids consist of molecules with weak covalent bonding between the molecules.

The misconceptions identified by Peterson, Treagust and Garnett (1989) using the same instrument on Bond Polarity, Molecular shapes, and Octet Rule were summarized as followed.

2.2.4. Bond Polarity

- Equal sharing of the electron pair in all covalent bond.
- Polarity of a covalent bond is due to ion formation through electron transfer
- The polarity of a bond depends on the number of valence electrons in each atom involved in the bond.
- Ionic charge determines the polarity of the bond
- The polarity of molecule is determined by the most electronegative atom.
- The polarity of a molecule is only determined by the electro-negativity

2.2.5. Molecular shapes

- The shape of a molecule is due to equal repulsion between the bonds.
- The shape of a molecule is due to repulsion between non-bonding electrons repulsion between two bonds in a 3 atom molecule to give it a linear structure depends upon the electronic configuration on the atoms
- Bond polarity determines the shape of a molecule. The shape of a molecule is due to equal repulsion between atoms in a molecule.
- The shape of the N_2Cl_4 molecule is determined by the repulsion between 5 electrons pairs on the nitrogen atoms.
- The V-shape in a molecule of type SCl_2 is due to repulsion between non bonding electron pairs.

3. RESEARECH METHODOLOGY

3.1. The Experimental Design

The main objective of this study was to investigate the potential of four-tier test to assess students' misconception on chemical bonding. To conduct the study, quasi-experimental design was employed. The main instruments of data collection were 3TCBMT and 4TCBMT. The standard of the each items were evaluated by using parameters like validity (construct and content), reliability, item difficulty, and discrimination index. In the application process four test groups were formed; open ended, pilot four-tier, a three-tier and four-tier chemical bonding misconception test groups. The purpose of the earlier was to identify major areas of students' misconceptions, the pilot four-tier test was administered to examine standard of each item, the third was used as control group while the last was used as experimental group. The quantitative data were analyzed using percentage, average, mean, standard deviation and t-test. Independent samples of two-tailed t-test was used to see significance difference between the mean scores of experimental and control group to test hypothesis. The data were taken three different time.

Table 3: Research design of the study

Group	**Treatment**	**Purpose**
Open-ended group	OQG	to identify major areas of students' Misconceptions
Pilot Group	P4TCBMT	to examine standard of each item
Experimental group	4TCBMT	to investigate the potential of four–tier test
Control group	3TCBMT	used as reference in comparison process

3.2. Sources of Data

3.2.1. Sampling Techniques

As seen in Wondesson (2011) there is no fixed number of percentage of samples that determine the size of an adequate sample. It is suggested that the sampling size depends upon the nature of population of interest to be gathered and analyzed (Best *et al.*, 1993). However, Cohn and Manion (1994) as cited in Ashebir (2009) noted that a sample of 30% from the population is appropriate if the number of population is known. The target populations of this study were taken from grade 12 natural science students of 2016/2017 academic year learning in the two preparatory schools of Eastern Hararghe. The proximity of the Chelenko preparatory school to my work place and also other one is Kersa preparatory school where I am working in: The schools are Chelenko preparatory school and Kersa preparatory school. These two schools were purposely selected due to the reasons that, since both of them are governmental schools and their students are expected to have similar economic and social status. In the year 2016/2017, in these two preparatory schools, a total of 210 students were registered to attend in grade 12. Out of these, 30% of total population 63 students were selected by random sampling technique from their school list in order to get sample population. Then, these sample population randomly classified into control group and experimental group. And two additional groups were also formed. Randomly around 30% of the CG and EG were selected as open-ended group.

Table 4: Population of grade 12 students and number of samples from each school

No.	School's name	Total no. of students	Samples taken
1	Chelenko Preparatory school	142	43
2	Kersa Preparatory school	68	20
	Total	210	63

Source: Own survey data, 2016/2017

3.3. Variable

This study employed two types of variables which are dependent and independent variables as described below.

3.3.1. Independent Variables

The independent variables were two different types of treatment based on Four-tier Chemical Bonding Diagnostic Instrument and Three-tier Chemical Bonding Diagnostic Instrument.

3.3.2. Dependent Variables

The dependent variables were students' understanding of chemical bonding concepts and their attitudes toward chemistry as a school subject.

3.4. Method of Data Collection

In order to collected data the four-tier chemical bonding diagnostic instrument was developed based on the following procedures.

3.4.1. The Four-Tier Chemical Bonding Misconception Test (FTMT)

3.4.1.1. Defining content boundaries of the study

To define content boundaries of the study, propositional statements were drafted referring to the chemistry textbook and teacher guide of grade 11. The propositional statements were carefully examined by experienced chemistry teachers. The statements mainly had focused to assess students' chemical misconceptions towards concepts of selected chemical bonding concepts such as ionic bonding, covalent bonding, and related chemistry concepts like molecular shape, polarity, intra molecular and inter molecular force of attraction.

3.4.1.2. Exploratory phase

In the course of the study, related literatures were exhaustively consulted to find existing students' misconceptions towards the selected chemical bonding and related concepts. Next, an open-ended test comprising of 6 main questions was accordingly prepared and administered for 25 students.

3.4.1.2.1. Open Ended Test

As already addressed, the purpose of this test was just to identify major areas of students' misconceptions Al-Rubayea *et al.*, (1996) as cited in Abayneh (2012). The test comprised of 5 open-ended questions which were assigned to investigate students' understanding and to determine about students' chemical misconceptions towards some selected `chemical bonding concepts such as ionic bonding, covalent bonding, and related chemistry concepts like molecular shape, polarity, intra molecular and intermolecular forces of attraction with students who were chosen randomly from the sample population. Item one offered how students could predict what type of bond is formed between sodium ion and chlorine ion in solid sodium chloride and explain their reason. Item two focused on student's reasoning how covalent bonding is formed within a given molecule. Item three was intended to probe how students could determine the positions of bonding electrons in polar and non polar covalent bonding and find out their reasons. Item 4 prompted to let students examine why H_2S is a gas at room temperature, while H_2O is a liquid at room temperature, with a higher melting point and let them explain this fact in terms of the forces within or between molecules. Through this item, it was aimed to investigate students' wit whether or not they could predict the type of intra-molecular and intermolecular forces. Item 5 was aimed to explore the extent to which students could be able to predict about molecular shape. Based on related misconceptions found in the literature and students' responses for items in the open ended test, the gathered information were grouped into two categories, Focusing only on those categories indicating misconceptions and correct responses, Table 11 was organized as follows. The purpose of table 11 was to organize the distracters and correct response that were used to construct pilot 4TCBMT. In this table, categories indicating misconception are those denoted by **'M'**, and those indicating correct answers were marked as **'*'**. Only frequencies of categories showing correct answers and misconceptions were considered so that the remaining differences could be accounted for lack of knowledge.

Table 5: Categories of students' responses showing correct answers and misconceptions towards the open-ended test

Item	Categories	Proportion (%)
1	[M]sodium chloride exists as molecules of "NaCl" because sodium and chlorine both have electrovalencies of one; a sodium atom loses one electron which is gained by a partner chlorine atom and the two ions form a discrete pair.	52
	*The positive and negative charges are "all over" the ions, so depending on the packing arrangements ions form ionic bonds with more than one ion of opposite charge at a time, forming a giant structure we call a crystal.	43
2	[M]Covalent bond is the process of sharing electron between non-metal atom [M] Equal sharing of electron pairs occurs in all covalent bonds.	48
	* 'covalent bond' refers to 'the electrostatic force of attraction between the positively charged nuclei involved and the shared electrons.	39
3	[M] *Bonding electrons are attracted equally by the two atoms in H*F, *because* Equal sharing of electron pairs occurs in all covalent bonds	48
	**Bonding electrons are closer to fluorine atom in HF, because fluorine is more electronegative than hydrogen atom*	43
4	[M] At room temperature, water is a liquid and hydrogen sulphide is a gas. The bonds in hydrogen sulphide are easily broken whereas those in water are not.	52
	*The difference in state is due to forces between molecules because the forces between water molecules are stronger than those between hydrogen sulphide molecules.	48
5	[M] The V-shape in a molecule of type SCl_2 is due to repulsion between non bonding electron pairs.	43
	*The shape of a molecule is determined by repulsion between both non bonding electron pairs and bonding electron pairs.	39

* = correct answer [M] = Misconception

Then, based on the misconceptions found in the literature and open ended questions, four-tier chemical bonding misconception test (4TCBMT), consisting of 12 main items, were developed as a pilot test.

3.4.1.3. Content validation and piloting

The accuracy and relevance of the pilot test were evaluated by experienced preparatory and high school chemistry teachers and then approved by experienced university lecturer. The test has twelve items. Each item is classified into: Answer tier, A-tier, and Reason-tier, R-tier. Both tiers are followed by confidence ratings. The answers and reason tiers measure content knowledge and explanatory knowledge, respectively. The two additional tiers measure the level of Confidence in the correctness of chosen options for the answer and reason tiers, respectively. The pilot test was administered to 25 students of grade 12 that were not included in the main study.

3.4.1.3.1. The Pilot Four-Tier Misconception Test

In this test, the average proportions of students' misconceptions were respectively 44%, 40%, 35 and 31% for one, two-three and four-tier tests. On the other hand, the values of each parameters of the test standard are summarized in Table 12 as follows

Table 6: The values of standared indicators of pilot four-tier Misconception Test in terms of each parts of the tier

		One-tier	Two-tier	Three-tier	Four-tier
Reliablity	**α score**	**0.53**	**0.62**	**0.67**	**0.71**
	α misconception	**0.54**	**0.59**	**0.65**	**0.72**
Valdity	**Construct**	Mean proportion of score Vs confidence level =0.56			
	Content	Mean proportion of false negative is 9 Mean proportion of false postive is 13			
Item analysis	**D'**	**0.32**	**0.45**	**0.57**	**0.70**
	P^f	**0.42**	**0.37**	**0.33**	**0.28**

α **score-** Reliability coefficient calculated based on students' scores

α **misconception** -Reliability coefficient calculated based on students' misconceptions

D'-Average item discrimination index

$\mathbf{P^f}$-Average item difficulty level

The average values of item difficulty level and discrimination index estimated from this pilot test fulfill the requirement of reported standards by Marx, J. D. (1988) as cited in Abayneh (2012). However, some deviations were found in the case of individual values of some items. The item discrimination indices of items 1, 2 and 6, for example, are respectively 0.25. These values are less than that of the minimum acceptable value (0.30). As a result, these items were carefully reconsidered and revised. Such reconsiderations enabled the researcher to omit some hint-giving alternatives of the respective items. In addition, the difficulty levels of item 6 and 12 were respectively found to be 0.32 and 0.36. These values are less than that of the minimum acceptable value (0.40), in the same way these items were carefully reconsidered; some doubtful alternatives were found and rewritten.

3.4.1.4. Construction, administration and validation of the 4TCBMT

The results of pilot four-tier test were used to develop the 12-item final version of the four-tier misconception test. Based on the respective values of these variables, proportions of students' scores and misconceptions were computed in terms of each tier of the test. Related parameters like validity (construct and content), reliability, item difficulty, and discrimination index were used to evaluate the standard of the items. The same set of parameters was used to compare the potential of each part of the tier as a separate diagnostic instrument. During the administration of the 4TCBDT, students were asked to focus solely on the correctness of their responses for the A-tier when giving their first confidence rating, and to focus on the formulation of their R- tier response for the second confidence rating. The time allotted for the test was 50 min. They were told that the test is a diagnostic test, and not an achievement test. Further, they were informed that the results of the test would not affect their school grades, but would be used by their teachers in planning their remedial lessons. This reassurance is essential so that students express their confidences genuinely.

3.4.2. The Three-Tier Chemical Bonding Misconception Test (3TCBMT)

The three-tier chemical bonding misconception test was developed similar to four-tier chemical bonding misconception test. The difference is the three-tier chemical bonding misconception test has only one confidence level for both first-tier multiple choices and tier-two reasoning part.

3.5. Instructional Tools / Treatment

Four test groups were formed; open ended, pilot four-tier, a three-tier and four-tier chemical bonding misconception test groups. The purpose of the earlier was to identify major areas of students' misconceptions, the pilot four-tier test was administered to examine standard of each item, the third was used as control group while the last was used as experimental group.

3.5.1. Open-Ended Test Group

After finding the misconception from literature open-ended test were prepared on the basis of the literature results. In this phase randomly 30% CG and EG students were allowed to take the test. In this test item, students were asked to justify their answer by explaining the reasons.

Table 7: Sample students who took the open-ended test

Name of school	**Proportion of students in no.**
Chelenko Preparatory	15
Kersa Preparatory	8
Total	**23**

3.5.2. The Control Group and Experimental Group

3.5.2.1. Pilot Test Group

Pilot study was carried out on 32 students of the same background but not in the sample group to test standard of each items that were randomly from sample school. After the open-ended results were analyzed and major areas of students' misconceptions were identified, four-tier chemistry misconception tests were developed and then conducted at pilot stage. This test was developed based on the open-ended test results and misconceptions found in the literature.

Table 8: Sample students who took the four-tier test as pilot test group

Name of school	**Proportion of students in no.**
Chelenko Preparatory	21
Kersa Preparatory	11
Total	**32**

3.5.2.2. Experimental Group (the final four-tier chemical bonding misconception test group)

Randomly 32 students out of 63 were selected and allowed to sit for the final four-tier chemical bonding misconception test. After analyzing the results of the pilot test, some items were revised accordingly. Then the revised version of the four-tier chemical bonding misconception test (4TCBMT) was administered.

Table 9: Sample students took the final four-tier chemistry misconception test

Name of school	**Proportion of students in no.**
Chelenko Preparatory	22
Kersa Preparatory	10
Total	**32**

3.5.2.3. Control Group (the three-tier chemical bonding misconception test group).

Randomly 31 students out of 63 were selected to sit for taking the three-tier chemical bonding misconception test. The three-tier misconception test was conducted as control group simultaneously; when four-tier chemical bonding misconception test were conducted to experimental group. The experimental groups took all four-tier chemical bonding misconception tests, while the control group at the same time took only three-tier chemical bonding test.

Table 10: Sample students who took the three-tier misconception test as control group

Name of school	**Proportion of students in no.**
Chelenko Preparatory	21
Kersa Preparatory	10
Total	**31**

3.6. Data Analysis

We used MS-Excel application to analyze the collected data. The data was converted to binary system instead of naming the answers A, B, C, and D. The right answer was then coded as 1 and the wrong ones as 0.

1. When first-tier, (F1) was scored only First-tier considered correct answer scored 1 and incorrect answer scored 0.
2. For second-tier, only reason tier considered, correct answer scored 1 and incorrect answer scored 0.
3. For two-tier (T_2), both answer tier and reason tier considered. Correct combinations were scored 1 and other combination scored 0.
4. For three-tier all tiers scores were considered correct combination with confidence were scored 1 other combination were scored 0.

Table 11: Decision making in Three-tier test

1st tier	**2nd tier**	**3rd tier**	**Decision**
Correct	Correct	Confidence	SN
Correct	Incorrect	Confidence	FP
Incorrect	Correct	Confidence	FN
Incorrect	Incorrect	Confidence	MSC
Other combination considered – lack of knowledge			

For four-tier test, all tier scores were considered. Correct combinations with both confidences were scored 1 and all other combinations were scored 0.

Table 12: Decision making in Four-tier test

1st tier	**2nd tier**	**3rd tier**	**4th tier**	**Decision**
Correct	Sure	Correct	Sure	SC
Wrong	not sure	Wrong	not sure	MSC
Correct	Sure	Wrong	Sure	FP
Wrong	Sure	Correct	Sure	FN
Other combinations considered lack of knowledge				

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The binary data were used to calculate total scores, psychometrics such as item difficulty, item discrimination and reliability coefficient. The data collected as such were analyzed using both quantitative and qualitative analysis. Thus, after collecting and tabulating the necessary data, the analysis and interpretation was made using the data in terms of the mean, standard deviation, frequency distribution and percentage. t-test was used to test significance mean difference between average proportion of students' misconception respectively for three-tier CG and four-tier EG, at which the significant at 0.05 significance level using the following formula:

$$t_{Experimental} = \frac{\bar{x}\sqrt{n}}{SD}$$

$t_{Experimental} > t_{critical}$ at 0.05 significant level was indicated that the presence of strong evidence between mean proportion 3TCBMT, CG and 4TCBMT, EG the reliability of 4TCBMT was checked using Cronbach alpha (α), to see internal consistency. Cronbach's alpha was calculated using:

$$\alpha = \frac{K}{K-1}(1-\frac{\Sigma pq}{\delta^2}) \quad \text{for binary data} \quad \sum pq = \sum p(1-p)$$

as cited in Abayneh Lemma (2012); Fraenkel *et al.*, (2001). If the obtained value is greater than 0.70, the correlation between item is acceptable. Lower value indicates weak correlation between items. The Cronbach alpha values were 0.69 and 0.75 for three-tier and four-tier students' score respectively. Those results indicated that the correlation between items of 4TCBMT mostly acceptable instruments and covariance and Pearson's correlation was checked to see test retest reliability.

Covariance of two variables X and Y, $Cov_{xy} = \frac{\Sigma(xi-\bar{x})(y_1-\bar{y})}{n-1}$, the Pearson product moment correlation coefficient for pair of variables, $r = \frac{Cov_{xy}}{S_x S_y}$, S_x and S_y standard deviation of X_1 & Y was significant at 0.01 level. The result can be interpreted as, less 4.0 low, 0.40 - 0.600 enough, above 0.600 (Arikunto and Suharsimi, 2013). The value of item difficulty interpreted into some categories such as difficult, medium and easy. The best item to be tested to students is an item with item difficulty of $0.30 \leq P \leq 0.7$ categorized as medium (Arikunto and Suharsimi, 2013).

Analysis of Discrimination items were conducted by dividing the students into groups of upper and lower, and calculated using the following formula:

$$D = \frac{P(UG) - P(LG)}{G}$$

P (UG) – Proportion of Upper Group, P (LG) - Proportion of Lower Group, G – Group size Item discrimination greater than 0.30 accepted, 0.10-0.29 revised and less 0.10 rejected (Surapranata, 2004).

4. RESULTS AND DISCUSION

4.1. Results

4.1.1. The Final four-tier chemical bonding misconception Test

This section presents the results of analyses of hypotheses stated earlier. The hypotheses were tested at a significance level of 0.05. Independent samples of two-tailed t-test were used to test the hypotheses to see significance difference between the mean scores of experimental and control group. In this study, statistical analyses were carried out, students' scores and their respective misconceptions of two tier and three tier (control group) were compared to that of the four-tier test (experimental group) results to evaluate the potential of the four tiers test towards overestimation of students' scores and misconceptions.

Table 13: Proportion of students' scores and misconception CG and EG

	Response proportion							
Item	First-tier		Two-tier		Three-tier (CG)		Four-tier (EG)	
	Score (%)	MSC (%)	Score (%)	MSC (%)	Score (%)	MSC (%)	Score (%)	MSC (%)
1	31	59	28	56	25	22	22	50
2	38	41	34	34	28	25	25	25
3	34	47	28	44	25	22	22	38
4	53	38	50	34	47	44	44	25
5	47	34	44	31	41	38	38	22
6	41	56	38	53	31	28	28	47
7	56	34	53	31	50	47	47	22
8	31	47	28	44	25	22	22	38
9	31	56	28	53	25	22	22	47
10	50	41	47	38	44	41	41	31
11	50	34	44	31	41	38	38	25
12	44	34	41	31	38	34	34	22
Average	**43.92**	**45.31**	**40.60**	**42.12**	**37.35**	**39.1**	**34.35**	**35.95**

As seen in table 13 the study revealed that the average percentage of Students' scores and students' misconceptions were decreased as number of the tier of the test increased from one to four-tier test. This clearly showed that the potential of tier test increased as number of the tier test increased from one tier to four-tier test in identifying Students' scores and students' misconceptions from lack of knowledge.

Null Hypothesis 1: To test hypothesis 1 which states that there is no significant difference between the mean average proportions of students' misconceptions respectively for two tier, three-tier and four-tier tests. Independent samples of two-tailed t-test at 0.05 significant level was used. Table 14 summarizes the results of this analysis.

Table 14: Proportions of students' misconception and percent by which the three tiers overestimate students' misconception

Item	**Msc-1(%)**	**Over Estimation (%)**	**Msc-2(%)**	**Over Estimation (%)**	**Msc-3(%)**	**Over Estimation (%)**	**Msc-4(%)**
1	59	9	56	6	53	3	50
2	41	16	34	9	31	6	25
3	47	9	44	6	41	3	38
4	38	13	34	9	31	6	25
5	34	12	31	9	28	6	22
6	56	9	53	6	50	3	47
7	34	12	31	9	28	6	22
8	47	9	44	6	41	3	38
9	56	9	53	6	50	3	47
10	41	10	38	7	34	3	31
11	34	12	31	9	25	3	22
12	34	12	31	9	28	6	22
Average	**45.31**	**9.36**	**42.12**	**6.17**	**39.1**	**3.15**	**35.95**

As seen in the table 14 the two tier test overestimate students misconception by 9.36% and the three-tier test overestimate students misconception by 3.15%. The findings revealed that there was strong evidence that show significant mean difference between the average proportions of students' misconceptions respectively for three-tier (CG) and four-tier tests (EG) in which $t_{\textbf{experimental}}$ (10.39) $>$ $t_{\textbf{critical}}$ (2.2035) at 0.05 significant level. The mean proportions of students' misconceptions were 39.13 for CG and 35.95 for EG. Hence, the null hypothesis is rejected. As a result compared to 4TCBMT (EG), the two tiers and the three-tier, (CG) tests have not enough potential to discriminate misconception from lack of knowledge.

Null Hypothesis 2: To analyze hypothesis 2, which states that there is no significant difference between the reliability coefficient calculated based on students' misconception for two tier, three-tier and four-tier tests, independent samples of two-tailed t-test at 0.05 significant level was used. On the other hand, values of the respective parameters for each part of the final three-tier and the Final four-tier Misconception Tests are presented in Table 15.

Table 15: The value of standared indicators of final four-tier Misconception Test in terms of each parts of the tier

		One-tier	Two-tier	CG	EG
Reliablity	α score	0.52	0.59	0.69	0.75
	α misconception	0.59	0.66	0.73	0.83
Valdity	Construct	Mean proportion of score Vs confidence level is 0.90			
	Content	Mean proportion of false negative is 6 % Mean proportion of false posetive is 9 %			
Item analysis	D'	0.51	0.59	0.66	0.78
	P^f	0.43	0.40	0.37	0.34

α score - Reliability coefficient calculated based on students' scores

α misconception - Reliability coefficient calculated based on students' misconceptions

D' - Average item discrimination index P^f - Average item difficulty level

The results showed that there was a significant mean difference between the reliability coefficient calculated based on students' misconception three-tier and four-tier tests (t = 9.38) at 0.05 significant level $t_{experimental} > t_{critical}$, 2.179, at degree of freedom (0.05, 11). There is strong evidence for significance difference between Reliability coefficient calculated based on students' misconceptions between CG and EG. Table 16 illustrates both three-tier, CG and four-tier test, EG that the values of test standard measuring parameters fulfill the minimum requirements of the respective acceptable values Marx, J. D. (1988) as cited in Abayneh (2012). The reliability coefficient, α, calculated based on students' scores and misconceptions of the three-tier test are respectively 0.69 and 0.73 for CG although 0.75 and 0.83 for EG. These are greater than the reported acceptable value, which is 0.70 Fraenkel *et al.* (2001) as cited in (Abayneh, 2009). The first implies that about 69% of the variance of students' score is due to the variance of the true students' scores, and about 73% of the diagnosed students' misconceptions are due to the variance of the true students' misconceptions as reported by Abayneh (2012) for CG. While, the latter shows that about 75% of the variance of students' score is due to the variance of the true students' scores, and about 83% of the diagnosed students' misconceptions are due to the variance of the true students' misconceptions as reported by Yasin K. (2004) for EG. This indicates that the four-tier test, (EG) is better than two tier and the three-tier test, (CG) to diagnose of the variance of students' score is due to the variance of the true students scores, and students' misconceptions are due to the variance of the true students' misconceptions Abayneh (2009).

Null Hypothesis 3: To test hypothesis 3 which claims that there is no significant difference between average discrimination index for two tier, three-tier (CG) and four-tier tests(EG), independent samples of two-tailed t-test was run. $t_{experimental}$, 7.42 is > $t_{critical}$, 2.179, at degree of freedom (0.05, 11). The results showed that there is significant differences between average discrimination index for three-tier and four-tier tests are 0.66, and 0.78, respectively. This implies that of four-tier misconception test were more discriminatory. This significant test was supported by Sreenivasulu (2013), as cited in D. Kaltakci Gurel *et. al*., (2012). The mean average item difficulty levels, which are 0.43, 0.40, 0.37 and 0.34 for one-tier, two-tier, three-tier and four-tier tests respectively, and these values fulfill the minimum accepted value, Arikunto and Suharsimi (2013). The correlation of students' score (Score-2) and confidence level, which is 0.90 at 0.01 significant level, is positively significant. This can assure that high scorers are more confident in their answer than low scorers-an indication for the attainment of construct validity Rollnick, M. and P. P Mahooana (1999). The mean proportion of false negative, which was found to be 6%, falls in the domain of acceptable range (1% to 10%). And the mean proportion of false positive was found to be 9%, according to Rollnik and Mahooana (1999) as cited in Abayneh (2012). The last two parameters show that a content validity of the four-tier misconception test was successfully maintained.

4.2. Discussion

Item 1, 3, 10 investigates students' ideas about ionic bond formation

Table 16: Proportion of students' scores in each item and tier with corresponding misconception about ionic bond formation of CG and EG

Item No	Response proportion							
	Control group				Experimental group			
	Correct		Misconception		Correct		Misconception	
	f	%	F	%	f	%	f	%
1	8	25	17	53	7	22	16	50
3	8	25	13	41	7	22	12	38
10	14	44	11	34	13	41	10	31

Item 1 investigates whether or not students could predict the basic ideas associated with ionic bond formation involving the transfer of electron (s) between two electrically neutral atoms to make ions with overall positive and negative charges. The positive and negative charges are "all over" the ions, so depending on the packing arrangements, ions form ionic bonds with more than one ion of opposite charge at a time, forming a giant structure, which we call a crystal. As seen in Table 16, 22% of the experimental group students gave correct answer whereas 25% of the students in the control group responded correctly with full confidence that the positive and negative charges are "all over" the ions, so depending on the packing arrangements ions forming ionic bonds with more than one ion of opposite charge at a time, forming the giant structure (crystal). However, 50% of the EG and 53% of the CG students exhibited misconception respectively. This implies that the CG test overestimate students' misconception by 3%. These students wrongly assumed that sodium chloride exists as a molecule, being convinced that one sodium ion and one chloride ion can form an 'ion-pair molecule' (Taber, 1994). A sodium atom can only donate one electron, so it can form only one bond. Bonds are only formed between atoms that donate/accept electrons. For example, in sodium chloride, the chloride is bonded to the specific sodium atom that donated an electron to it. It seems that students could not grasp the formation of ionic bonds within the context of a three dimensional ionic lattice.

Item 3 aims to determine to what extent students could predict ideas about ionic bond formation. As seen in Table 16, in the experimental group, 25% of the students gave correct answer whereas 28% of the students in the control group responded correctly with full confidence that in potassium Bromide, KBr, the bond between potassium and bromide is ionic because electrons are transferred from potassium to bromine, while 38% of EG and 41% of CG students developed misconception, respectively. This implies that the CG test overestimates students' misconception by 3%. The misconception held by the students was that an ionic bond could be formed when electrons are shared unequally between potassium and bromide.

Item 10 aims to determine the extent to which students could predict ideas about ionic bond formation. As seen in Table 16, in the experimental group, 41% of the students gave correct answer whereas 44% of the students in the control group responded correctly with full confidence that Sodium chloride, NaCl, does not exist as a molecule because it exists as a lattice consisting of sodium ions and chloride ions. While, 38% of EG and 41% of CG exhibited misconception, respectively. This implies that the CG test overestimate students' misconception by 3%. The misconceptions held by the students were that after donating its valence electron to the chlorine atom, the sodium ion forms a molecule with the chloride ion.

Items 7 and 12 investigate students' understandings about how covalent bonding is formed

Table 17: Proportion of students' scores in each item and tier with corresponding misconception of CG and EG about how covalent bonding is formed

Item No	Response proportion							
	Control group				Experimental group			
	Correct		Misconception		Correct		Misconception	
	f	%	f	%	f	%	f	%
7	16	50	9	28	15	47	7	22
12	12	38	9	28	11	34	7	22

Item 7 investigates students' understandings of formation of covalent bonding is formed, as seen in Table 17. Accordingly, 47% of the experimental group of students gave correct answer, whereas 50% of the students in the control group responded correctly with full confidence. In hydrogen bromide, HBr, the bond between hydrogen and bromide is a covalent one because it is the electrostatic force of attraction involved between the positively charged nuclei of both H and Br and the electrons shared among them. In this regard, 38% of the EG and 41% of the CG students exhibited misconception, respectively. This implies that the CG test overestimate students' misconception by 3%. The misconception held by the students were that the students considered the sharing of electrons as the 'force' holding the atoms in a molecule together instead of electrostatic attraction between the shared electrons and the nuclei involved. This finding is corroborated the findings by Boo (2000) in which some of her students held similar misconception that a covalent bond is due to sharing of electron pairs between atoms. Item 12 aims to determine the extent to which students could predict about how covalent bonding is formed. As seen in Table 17, in the experimental group, 34% of the students gave correct answer whereas 38% of the students in the control group responded correctly with full confidence in all types of covalent bonds, there is no equal attraction of shared electrons by atoms participating in the bond because there is a difference in electronegativity for different atoms that participate in the covalent bond. While 22% of EG and 28% of CG developed misconception, respectively. This implies that the CG test overestimate students' misconception by 6%. The misconceptions held by the students were that in all types of covalent bonds, there is an equal attraction of shared electrons by atoms participating in the bond.

Items 2, 5 and 6 investigates students' understandings about intramolecular and intermolecular forces of attraction

Table 18: Proportion of students' scores in each item and tier with corresponding misconception of CG and EG about intramolecular and intermolecular forces of attraction

Item No	Response proportion							
	Control group				Experimental group			
	Correct		Misconception		Correct		Misconception	
	F	%	f	%	F	%	F	%
2	9	28	10	31	8	25	8	25
5	13	41	9	28	12	38	7	22
6	10	31	16	52	9	28	15	47

Item 2 aims to determine the extent to which students could predict the ways intramolecular and intermolecular forces of attraction are operational. As seen in Table 18, in the experimental group, 25% of the students gave correct answer whereas 28% of the students in the control group stated correctly with full confidence the fact that water (H_2O) and hydrogen sulphide (H_2S) have similar chemical formulae and structures, yet water is a liquid and hydrogen sulphide is gas at room temperature. This difference in state is due to strength of forces between molecules; forces between water molecules are much stronger than those between hydrogen sulphide molecules. Nevertheless, 25% of the EG and 31% of the CG students are found to have developed misconception, respectively. This may imply that the CG test overestimates students' misconception by 6%. The misconception held by the students can be accounted for failure of the students to recognize the difference of attraction forces between the water molecules and the hydrogen sulphide molecules which arise because of the difference in strength of the O–H and S–H covalent bonds. In consequence**,** the bonds in hydrogen sulphide can easily be broken whereas those in water cannot.

Item 5 aims to determine the extent to which students could understand and predict the strengths of intramolecular and intermolecular forces of attraction. As seen in Table 18, 38% experimental group students attempted to give the correct answer 41% of the students in the control group correctly responded with full confidence the fact that, though the boiling point of nitrogen apparently is very low (-147^{0}C), the diatomic molecule (N_2) does not decompose even at high temperatures because of the strong N≡N (intramolecular) bond. Triple bond failed as compared to the intermolecular, Vander Waals, forces. Unfortunately, 25% of the EG and 31% of the CG students to differentiate between the two forces for developing misconception. The CG test as well, overestimates students' misconception by 6%. Most of the students therefore confused intermolecular and intramolecular forces, by assuming that since N_2 molecule exhibits strong intermolecular forces it does not decompose even at high temperatures.

Item 6 aims to determine how much students could understand and compare the extents of intramolecular and intermolecular forces of attraction between NH_3 and CH_4 molecules as seen in Table 18. In the experimental group 28% of the students were able to give the correct answer, whereas 31% of the students in the control group responded correctly with full confidence by comparing the attributes causing the boiling point of NH3 to be higher than that of CH4. They understood the fact that the strength of intermolecular force is determined by the strength of the Vander Waals forces that exist between molecules. On the other hand, 47% of the EG and 50% of the CG students misconceived. In this regard, the CG test helps to overestimate students' misconception by 3%. The misconception held by the students could possibly arise from the assumption that the strength of intermolecular force is determined by strength of the covalent bonds present within molecules, and in consequence of this the covalent bonds within a molecule are broken when the substance undergoes change in its physical state.

Item 4, 8 and 9 investigates students' ideas about bond polarity

Table 19: Proportion of students' scores in each item and tier with corresponding misconception of CG and EG about bond polarity

Item No	Response proportion							
	Control group				Experimental group			
	Correct		Misconception		Correct		Misconception	
	f	%	F	%	f	%	f	%
4	15	47	10	31	14	44	8	25
8	8	25	13	41	7	22	12	38
9	8	25	16	50	7	22	15	47

Item 4 aims to determine to what extent students could be able to visualize and associate ideas of bond polarity with molecular substances. As seen in Table 19, 44% of the students in the experimental group were able to give correct answer about bond polarity. While, 47% of the students in the control group correctly responded with full confidence using the example that the bonds in H_2S are polar as shared electrons concentrate more around the S atom. On the other hand, 28% of EG and 34% of CG students appeared to have developed misconception. This implies that the CG test overestimates students' misconception by 6%. The misconception held by most students may be considered because students generally assume that equal sharing of electrons occur in all types of covalent bond and only differences in the number of valence electrons between the atoms determine bond polarity. Item 8 investigates students' perception about the position of bonding electrons between covalently bonded atoms. In addition, this item aims to probe students' understanding and prediction about the position of bonding electrons between two nonmetal atoms whose electronegativities differ significantly from each other. As seen in table 19, while 22% of the students in the experimental group, answered correctly about bond polarity, 28% of the students in the control group responded correctly with full confidence the difference in bond polarities between CH_3C1 and the CH_4. The bond in CH_3C1 is polar while the bond in CH_4 is non-polar owing that polarity of a molecule depends on the polarity of its bonds as well as on its shape. On the other hand, 38% of EG and 41% of CG were found to have developed a wrong understanding misconception about the concept of polarity. It can be seen that CG test overestimates students' misconception by 3%. One of the misconceptions held by most of students the investigated may be attributed because of their assumption that molecule is non polar, only if atoms of molecule have same electro negativities. The others include the assumptions that if a molecule has tetrahedral shape, it is generally non polar, and if on the other hand a molecule contains polar bonds it is always a polar molecule.

In the same manner item 9 aims to determine students' understanding and predictions about the positions of shared electrons and bond polarity. Table 19 also shows that 25% of the students in the experimental group predicted this relationships correctly; for obvious reason 28% of the students in the control group responded correctly with full confidence that position of the bonding pair or the pair of electrons shared between F and H is located nearest to Fluorine because Fluorine naturally exhibits a stronger attraction for the shared electron pair than the H atom. For the same item, 44% of EG and 47% of CG students failed to deliver the correct answer for developing misconception. In this respect the CG test overestimates students' misconception by 3%. The misconceptions held by most students resulted from the assumption 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. It seems that students could not be able to grasp the fact that stronger attraction of fluorine atom for a shared electron pair is responsible for the overall polarity of the H-F bond.

Item 11, investigates students' ideas about molecular shape

Table 20: Proportion of students' scores in each tier with corresponding misconception of CG and EG about molecular shape

Item No	Response proportion							
	Control group				Experimental group			
	Correct		Misconception		Correct		Misconception	
	F	%	F	%	f	%	f	%
11	13	41	9	28	12	38	8	25

Item 11 aims to determine to what extent students could predict about molecular shape. As seen in Table 20, in the experimental group, 38% of the students gave correct answer whereas 41% of the students in the control group responded correctly with full confidence. Nevertheless, 25% of the EG and 28% of the CG students appeared to have developed misconceptions regarding molecular shapes. Besides, the CG test overestimates students' misconception by 3%. The general misconceptions held by the students may be attributed from assumption that the shape of a molecule is due to equal repulsion between the bonds thus ignoring the influence of non-bonding electron pairs on the shape of the molecule. These data suggest that students lacked knowledge or the understanding of the valence shell electron pair repulsion theory (VSEPR).

5. SUMMARY, CONCLUSIONS AND RECOMMENDTIONS

5.1. Summary

As already mentioned the main objective of this study was to investigate the potential of diagnostics instrument to identify students' misconception about basic chemistry concepts of chemical bonding and related chemistry concepts and recommend valuable information for improving the teaching-learning process as well. Particularly, the specific objectives of the study were:

- To compare the effectiveness of three-tier and four-tier misconception test for assessing preparatory students' misconceptions on about a few selected chemical bonding concepts (topics) and related chemistry concepts.
- To identify students' misconception on selected concepts which cause students' misconception on chemical bonding.
- To recommend valuable information for improving the teaching-learning process as well.

To achieve these objectives quasi experimental design was used. The subjects of the study were grade twelve grade students of the selected two preparatory schools. Randomly selecting sampling method was employed to select students for the four test groups. These are Open-ended, Pilot 4TCBMT, 3TCBMT and 4TCBMT. The purpose of the first group was to identify major area of misconception that used to prepare distracters and correct response for construction of pilot 4TCBMT. The second was used to test the standard of each item. Whereas the third was used as a reference to compare with 4TCBMT, while the last one was used as experimental group. After related literatures were consulted to find misconceptions towards the selected chemical bonding and related concepts, an open-ended test comprising of 5 main questions was prepared and administered to identify major areas of students' misconceptions. Then, based on the misconceptions found in the literature and open ended questions, four-tier chemical bonding misconception test (4TCBMT), consisting of 12 main items, was developed and administered as a pilot test. To examine standard of each item so, the main data gathering instruments were three-tiers and four tiers chemical bonding misconception tests. The data obtained were analyzed in terms of the mean, standard deviation, frequency distribution and percentage. t-test was used to test the null hypothesis at 0.05 significant level. The respective values of standard indicators of each item were also calculated. From the result of the diagnosis, evaluating the potential of diagnostic instruments in identifying students' misconceptions on chemical bonding ,proportion of about 45.31%,42.12%, 39.1% and 35.95% of the students have the suspected misconceptions from one tier, two tier, three tier(CG) and four tier(EG) respectively. The reliability coefficient of the test was calculated based on students' scores were 0.69 and 0.75 for CG and EG respectively, whereas, the misconceptions were 0.73 and 0.83 for CG and EG respectively. Item difficulty level were found to be 0.43, 0.40, 0.37 and 0.34 for one tier, two tier, three tier(CG) and four tier(EG) respectively. Whereas, average discrimination index were found to be 0.66 and 0.78 for CG and EG respectively. Concerning the validity parameters, the mean proportion of false positive was found to be 9%. While that of false negative were found to be 6%. The correlation of students' score (score-2) and their confidence level resulted 0.67and 0.90 for CG and EG respectively at a 0.01 significance level.Due to the covert rating of the confidence (has only one confidence rate) for both answer tier and reason tiers in tests, in the decision of misconception scores and correct scores, three-tier tests overestimate the proportions of those scores and under estimate lack of knowledge compared to the four-tier tests. For this reason, four-tier tests in which confidence ratings were asked for the content and reasoning tiers separately are used.

5.2. Conclusions

The following conclusions were drawn based on the findings of the study.

1. The average percentage of students' misconceptions were decreased as number of the tier test increased from one tier to four-tier test, or two tier test over estimate students' misconceptions greater than three tier test, and three tier test over estimate students' misconceptions greater than four tier test. This clearly showed that as the number of tier test increased from one tier to four-tier test potential of tier test also increased in identifying students' misconceptions from lack of knowledge. Hence, I conclude that the first three tiers tests as compared to that of (relatively) to the the four-tier test is better method in reducing misconception over estimation in identification of misconception on chemical bonding.
2. Using four-tier misconception test on chemical bonding the following students' misconception tests were identified.
   - The students believed that sodium chloride exists as molecules, and thought that one sodium ion and one chloride ion form an 'ion-pair molecule. A sodium atom can only donate one electron, so it can form only one bond. It seems that students could not grasp the formation of ionic bonds within the context of a three dimensional ionic lattice.
   - The students considered the sharing of electrons as the 'force' holding the atoms in a molecule together instead of electrostatic attraction between the shared electrons and the nuclei involved.
   - The difference in the forces attracting water molecules and those attracting hydrogen sulphide molecules is due to the difference in strength of the O–H and S–H covalent bonds. The bonds in hydrogen sulphides are easily broken whereas those in water are not. Covalent bonds within molecule are broken when a substance change their physical state.
   - Most of the students thought that the boiling point of N_2 is very low, on the other hand at high temperatures, it does not decompose because N_2 had strong intermolecular forces, and thus it did not decompose at high temperatures. They did

not understand that as the triple bond of N_2 is the force within molecule which is very strong compared to intermolecular force. Most of the students confused with intermolecular and intramolecular forces.

- Equal sharing of the electron pair 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 bond.
- It seems that students could not grasp stronger attraction of more electronegative atom for shared electron pair.
- The shape of a molecule is due to equal repulsion between the bonds thus ignoring the influence of nonbonding electron pairs on the shape of the molecule.

5.3. Recommendations

Based up on the findings of this study, the researcher recommends the following:

- Teachers should be encouraged to develop and use four-tier misconception test to diagnose misconception of their students on chemical bonding.
- Curriculum planner, researchers, and teachers should lay emphasis on developing four-tier misconception test, evaluate its effectiveness in other topics and look for effective methods to bring about the desired conceptual change.
- Every stakeholder should be sure enough of not intermixing misconception with lack of knowledge. In fact, using four-tier misconception tests have enough potential to discriminate misconception from lack of knowledge on chemical bonding.

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APPENDIX 1: THE FOUR-TIER CHEMICAL BONDING DIAGNOSTIC INSTRUMENT, 4TCBMT
HARAMAYA UNIVERSITY

POSTGRADUATE PROGRAM DIRECTORIATE

THE FOUR-TIER CHEMICAL BONDING DIAGNOSTIC INSTRUMENT 4TCBMT

Questionnaire to be filled by grade 12 students

Dear students!

The purpose of this questionnaire is to diagnose misconceptions related to the concept of Chemical bonding. The result of this test will not affect your classroom results in any way.
The data will be used only for research purpose. Hence, you are kindly requested to attempt all questions carefully.

Thank you for your cooperation!

General information:

School's name ______________________________

Sex: M__ F___ (mark '√') Grade and section______

Instruction: This test has twelve items. Each item is classified into: Answer tier, A-tier, and Reason-tier, R-tier. Both tiers are followed by confidence ratings ranging from 1, just guessing, to 6, absolutely confident. 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 number that represents your level of confidence for the answers you give for each tier.

1	2	3	4	5	6
Just guessing,	Very unconfident,	unconfident,	Confident,	Very confident,	absolutely confident

Question 1

1.1. The number of ionic bond (bonds) formed by sodium ion in sodium chloride, NaCl, crystal?

A.1 B. 3 C. 5 D. 6

1.2. Confidence rating: 1 2 3 4 5 6

1.3. Scientific reason for my answer

A. Sodium atom can only donate one electron to chlorine atom. So it can form only single bond.

B. Bonds are only formed between atoms that donate/accept electrons.

C. The chloride ion is bonded to one sodium ion and attracts to further five sodium ions, but just by force and not bonds.

D. Sodium ion and chloride ion assembled in regular repeating manner extending in three dimensions throughout the crystal.

E.…………………

1.4. Confidence rating: 1 2 3 4 5

Question 2

2.1 Water, H_2O, and hydrogen sulphide, H_2S, have similar chemical formulae and structures. At room temperature, water is a liquid and hydrogen sulphide is a gas. This difference in state is due to:

A. forces between molecules **B.** forces within molecules

2.2. Confidence rating: 1 2 3 4 5 6

2.3. Scientific reason for my answer

The difference in the forces attracting water molecules and those attracting hydrogen sulphide molecules is due to the difference in strength of the O–H and the S–H covalent bonds.

B The bonds in hydrogen sulphide are easily broken whereas those in water are not.

C The hydrogen sulphide molecules are closer to each other, leading to greater attraction between molecules.

D The forces between water molecules are stronger than those between hydrogen sulphide molecules.

E.____________________________

2.4. Confidence rating: 1 2 3 4 5 6.

Question 3

3.1. In potassium Bromide, KBr, the bond between potassium and bromide is a/an

A. Ionic B. covalent

3.2. Confidence rating: 1 2 3 4 5 6

3.3. Scientific reason for my answer

A. Electrons are shared equally between atoms

B. Electrons are shared un equally between atoms

C. Electrons are transferred

D. Electrons are more freely move

E. ______________

3.4. Confidence rating: 1 2 3 4 5 6

Question 4

4.1. The bonds in H_2S are

A. Polar A. non-polar

4.2. Confidence rating: 1 2 3 4 5 6

4.3. Scientific reason for my answer

A. Equal sharing of electrons in all covalent bond.

B. Due to ion formation through electron transfer

C. shared electrons concentrate around one atom

D. valence electrons in each atom determine Polarity

E. ________________

4.4. Confidence rating: 1 2 3 4 5 6

Question 5

5.1 The boiling point of N_2 is very low (-147^0C), on the other hand, at high temperatures, it does not decompose due to:-

A. intramolecular bonds B. intermolecular bonds

5.2. Confidence rating: 1 2 3 4 5 6

5.3. Scientific reason for my answer

A. Intermolecular forces between N_2 molecules are very strong.

B. Nitrogen atoms cannot achieve stable octet.

C. Intramolecular forces are weaker than intermolecular

D. Triple bond is very strong compared to intermolecular, Vander Waals, forces

E.____________________

5.4. Confidence rating: 1 2 3 4 5 6

Question 6

6.1. Which of the following has higher boiling point?

A. NH_3 B. CH_4

6.2. Confidence rating: 1 2 3 4 5 6

6.3. Scientific reason for my answer

A. The strength of intermolecular force is determined by strength of the covalent bonds present within molecules

B. Covalent bonds within molecule are broken when a substance change their physical state

C. The strength of intermolecular force is determined by the strength of, Vander Waals, force between molecules

D. Strength heat energy that cause the breaking down of covalent bonds between molecules

E.__________________________

6.4. Confidence rating: 1 2 3 4 5 6

Question 7

7.1. In hydrogen bromide, HBr, the bond between hydrogen and bromide is a/an

A. Covalent B. ionic

7.2. Confidence rating: 1 2 3 4 5 6

7.3. Scientific reason for my answer

A. It is the process of transfer of electrons from Hydrogen atom to Bromine atom to attain noble gas electronic configuration

B. It is the electrostatic force of attraction between the positively charged nuclei involved and the shared electrons

C. It is the electrostatic force of attraction between oppositely charged ions formed as result of the process of electron transfer

D. It is sharing of electron between hydrogen atom and bromine atom

E. ____________

7.4. Confidence rating: 1 2 3 4 5 6

Question 8

8.1. What can be said about the polarities of CH_3Cl and CH_4?

A. both of them are polar

B. both of them are non polar

C. CH_3C1 is polar and the other CH_4 is non polar

8.2. Confidence rating: 1 2 3 4 5 6

8.3. Scientific reason for my answer

A) A molecule is non polar, only if atoms of molecule have same electro negativities.

B) If molecule has tetrahedral shape, it is non polar

c) If molecule contains polar bonds it is a polar molecule.

D) Polarity of molecule depends on the polarity of its bonds and shape of the molecule

E.___________________

8.4. Confidence rating: 1 2 3 4 5 6

Question 9

9.1. Which of the following best represents the position of the shared electron pair in the HF molecule?

A. H :F B. H : F

9.2. Confidence rating: 1 2 3 4 5 6

9.3. Scientific reason for my answer

(A) Nonbonding 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. E._______________

9.4. Confidence rating: 1 2 3 4 5 6

Question 10

10.1 Sodium chloride, NaCl, exists as a molecule.

A. True B. False

10.2. Confidence rating: 1 2 3 4 5 6

10.3. Scientific reason for my answer

A/. The sodium atom shares a pair of electrons with the chlorine atom to form a simple molecule.

B/ After donating its valence electron to the chlorine atom, the sodium ion forms 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.

E.______________________

10.4. Confidence rating: 1 2 3 4 5 6

Question 11

11.1. The molecule SF_2, is likely to be

A. V-shaped B. linear C. pyramidal D. square planar

11.2. Confidence rating: 1 2 3 4 5 6

11.3. Scientific reason for my answer

(A) Repulsion between the bonding and non-bonding electron pairs results in the shape.

(B) Repulsion between the non-bonding electron pairs results in the shape.

(C) The two sulfur-fluorine bonds are equally repelled to linear positions.

(D) The high electro negativity of fluorine compared with sulfur is the major factor influencing the shape of the molecule. (E)____________________________

11.4. Confidence rating: 1 2 3 4 5 6

Question 12

12.1. In all types of covalent bonds, there is an equal attraction of shared electrons from atoms participating in the bond: A. Yes B. No

12.2. Confidence rating: 1 2 3 4 5 6

12.3. Scientific reason for my answer:

a. Each atom shares the same number of electrons.

b. There is a difference in electro negativity for atoms that participate in the covalent bond.

c. Both atoms have the same number of valence electrons.

d. Each atom attracts its own electron(s) more than other electron(s) from the other atom

E.______________________________

12.4. Confidence rating: 1 2 3 4 5 6

APPENDIX 2: THE THREE-TIER CHEMICAL BONDING DIAGNOSTIC INSTRUMENT, 3TCBMT

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B. Bonds are only formed between atoms that donate/accept electrons.

C. The chloride ion is bonded to one sodium ion and attracts to further five sodium ions, but just by force and not bonds.

D. Sodium ion and chloride ion assembled in regular repeating manner extending in three dimensions throughout the crystal. E…………………

1.3. Confidence rating: 1 2 3 4 5 6

Question 2

2.1 Water, H_2O, and hydrogen sulphide, H_2S, have similar chemical formulae and structures. At room temperature, water is a liquid and hydrogen sulphide is a gas. This difference in state is due to:

A. forces between molecules **B.** forces within molecules

2.2. Scientific reason for my answer

A. The difference in the forces attracting water molecules and those attracting hydrogen sulphide molecules is due to the difference in strength of the O–H and the S–H covalent bonds.

B The bonds in hydrogen sulphide are easily broken whereas those in water are not.

C The hydrogen sulphide molecules are closer to each other, leading to greater attraction between molecules.

D The forces between water molecules are stronger than those between hydrogen sulphide molecules.

E.____________________________

2.3. Confidence rating: 1 2 3 4 5 6.

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3.1. In potassium Bromide, KBr, the bond between potassium and bromide is a/an

A. Ionic B. Covalent

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B. Electrons are shared unequally between atoms

C. Electrons are transferred D. Electrons are more freely move E. ______________

3.3. Confidence rating: 1 2 3 4 5 6

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B. Due to ion formation through electron transfer

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E. ________________

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C. It is the electrostatic force of attraction between oppositely charged ions formed as result of the process of electron transfer

D. It is sharing of electron between hydrogen atom and bromine atom

E. _____________

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8.1. What can be said about the polarities of CH_3Cl and CH_4?

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E.____________________

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(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. E.________________

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10.1 Sodium chloride, NaCl, exists as a molecule. A. True B. False

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B After donating its valence electron to the chlorine atom, the sodium ion forms 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.

E.______________________

10.3. Confidence rating: 1 2 3 4 5 6

Question 11

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A. V-shaped B. linear C. pyramidal D. square planar

11.2. Scientific reason for my answer

(A) Repulsion between the bonding and non-bonding electron pairs results in the shape.

(B) Repulsion between the non-bonding electron pairs results in the shape.

(C) The two sulfur-fluorine bonds are equally repelled to linear positions.

(D) The high electro negativity of fluorine compared with sulfur is the major factor influencing the shape of the molecule.

(E)____________________________

11.3. Confidence rating: 1 2 3 4 5 6

Question 12

12.1. In all types of covalent bonds, there is an equal attraction of shared electrons from atoms participating in the bond: A. Yes B. No

12.2. Scientific reason for my answer:

A. Each atom shares the same number of electrons.

B. There is a difference in electro negativity for atoms that participate in the covalent bond.

C. Both atoms have the same number of valence electrons.

D. Each atom attracts its own electron(s) more than other electron(s) from the other atom

E. ______________________________

12.3. Confidence rating: 1 2 3 4 5 6

APPENDIX 3: THE OPEN-ENDED QUESTION FOR GATHERING INFORMATION ABOUT CHEMICAL BONDING

HARAMAYA UNIVERSITY

POSTGRADUATE PROGRAM DIRECTORIATE

THE OPEN-ENDED QUESTION FOR GATHERING INFORMATION ABOUT CHEMICAL BONDING

Questionnaire to be filled by grade 12 students

Dear students!

The purpose of this questionnaire is to diagnose misconceptions related to the concept of Chemical bonding. The result of this test will not affect your classroom results in any way.

The data will be used only for research purpose. 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 five items. Try to explain the items according to the instructions given below.

Item 1: Describe what would happen when sodium atom combines with chlorine atom? Please explain your reason in terms of type of bond formation?

Item 2: What type of chemical bond (s) is formed in given compound below? Please explain your reason? A) H_2O B) NH_3 C) KCl

Item 3: Could you determine the position of bonding electrons between the atoms in the given compounds? Please explain your answer by drawing?

A) N_2 B) Cl_2 C) HF

Item 4: H_2S is a gas at room temperature, where as H_2O is liquid at room temperature. Please explain these differences in physical state in terms of the force that exist within molecule or force between molecules?

Item 5: Describe the molecular shape of the following given molecule. Please explain your reason by considering the factors that affect the molecular shape?

A) SCl_2 B) H_2O