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IMPACT OF GUIDED INQUIRY ON TENTH GRADERS' UNDERSTANDING OF CHEMICAL BONDS

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This thesis is submitted in partial fulfilment of the requirements for the degree of Master of Education in Curriculum and Instruction

Under the Supervision of Dr. Hassan Tairab

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Declaration of Original Work

I, Badreya Al-Zarooni, the undersigned, a graduate student at the United Arab Emirates University (UAEU). I am the author of this thesis, entitled "*Impact of Guided Inquiry on Tenth Graders' Understanding of Chemical Bonds*", hereby, solemnly declare that this thesis is an original research work that has been done and prepared by me under the supervision of Dr. Hassan Tairab, in the College of Education at the UAEU. This work has not been previously formed as the basis for the award of any academic degree, diploma or a similar title at this or any other university. The materials borrowed from other sources and included in my thesis have been properly cited and acknowledged.

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Abstract

Students' understandings of scientific conceptions have been of considerable interest to science education researchers and science teachers in recent years. Accordingly, many scholarly studies have been conducted on the students' understandings and misunderstandings, particularly, those concerned with chemistry. For the present study, the term misconception is used to encompass both alternative responses that arise from formal intervention; such as classroom study, as well as those resulted from the students own interactions with, and observations of their surrounding environment.

The main purpose of this study is to investigate the understanding of the Grade-10 students about the concepts and misconception regarding the chemical bonding and types of bonds (covalent, ionic, and metallic). This study focuses on (i) understanding the level of the concepts of chemical bonds and bonding, (ii) gaining some insights into the causes of the misconception, and (iii) investigating the impact of incorporating "guided-inquiry" as an alternative teaching approach in chemistry in secondary schools, and improving the concepts of the students about the chemical bonds and bonding. One hundred forty students (72 females and 68 males) who participated in this study have been drawn randomly from Tenth Grade classes in two public high schools in the Dubai Educational Zone. The data collection is achieved through employing mixed research method, and the data analysis is made possible with SPSS.

The findings revealed that a number of alternative conceptions of chemical bonds that were held by Tenth Grade students. The findings also pointed to the effectiveness of using guided inquiry as an alternative approach to the teaching of chemistry at Tenth Grade, particularly with male students. The study argues that the identification of the common misconceptions will greatly help the chemistry teachers to developing reliable instrumental approaches that could minimize the existing misconceptions about the chemical bonds and bonding.

The findings necessitate recommendations for policy makers and science teachers in order to improve the understanding of these important concepts. It is obvious that more research studies are needed to document student understanding of such concepts. Furthermore, more application of guided inquiry is indeed important to engage students in learning of chemical concepts such as the concepts investigated in this study. Policy makers and curriculum developers should also pay attention to development of illustrative examples in the curriculum to aid understanding.

Keywords: Chemistry education, teaching methods, guided-inquiry, chemical bonds, misconception, Tenth Graders, Dubai

Title and Abstract in Arabic

مستوى فهم طلاب الصف العاشر للروابط الكيميائية

الملخص:

اهتم العديد من الباحثين في السنوات الأخيرة بدراسة مستوى فهم الطلاب لطبيعة المصطلحات العلمية وخصوصا المفاهيم المجردة منها وعلى وجه الخصوص فيما يتعلق بمادة الكيمياء كونها تعتبر حجر الزاوية في كثير من التطبيقات الحياتية الهامة وخصوصا الصناعية منها , كما اهتمت الدراسة الحالية بإلقاء الضوء على الأسباب المحتملة لتكون بعض المفاهيم العلمية الخاطئة عند الطلاب والتي قد تعود نشأتها الى طريقة التعليم التقليدي الذي يعتمد على التلقين والحفظ بالإضافة لملاحظات الطلاب وتفاعلهم مع بيئاتهم . وقد ركزت الدراسة من خلال هدفها الأساسي على الآتي:

- قياس مستوى فهم الطلاب في الصف العاشر لمفهوم الروابط الكيميائية
- التوصل لبعض الاسباب المحتملة لنشأة المفاهيم الخاطئة حول الروابط الكيميائية
- دراسة تأثير استخدام طريقة الاستقصاء كمنهج بديل لتدريس الكيمياء لرفع مستوى تحصيل الطلاب.

شارك في الدراسة 140 طالب وطالبة (72 من الاناث و 68 من الذكور) يمثلون مدرستين حكوميتين في منطقة دبي التعليمية وطبقت الدراسة باستخدام منهج البحث المختلط (الكمي والوصفي) كما تم تحليل البيانات باستخدام برنامج (SPSS) وقد أشارت النتائج الى فعالية اسلوب الاستقصاء الموجهة لرفع مستوى تحصيل الطلاب في الصف العاشر في مادة الكيمياء كما ستساعد الدراسة في تحديد المفاهيم الخاطئة عند الطلاب فيما يخص الروابط الكيميائية وأوصت الدراسة بضرورة مساعدة المعلمين على وضع استراتيجيات جديدة في التدريس بالإضافة لتطوير المناهج العلمية عامة ومناهج الكيمياء وزيادة الأمثلة التوضيحية وربط المنهج بالتطبيقات الحياتية وبصفة عامة تبرز الحاجة للمزيد من الدراسات حول هذا المجال.

الكلمات المفتاحية: اساليب التدريس، الالاتقصاء الموجهة، تعليم الكيمياء، الروابط الكيميائية، المفاهيم الخاطئة، الصف العاشر، دبي

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My very special thanks and gratitude are devoted to my family and beloved sons Hamad and Salem, and daughter Anood for their forbearance and intellect.

Dedication

To my beloved children Hamad, Salem and Anood for their utter love, tender and heartfelt encouragement and continuous support when it was much demanded.

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Glossary

A number of terminologies that are used extensively in the present study are defined as follows:

Alternative framework: Alternative framework is a conceptual framework consisting of many sub-concepts that students apply to the framework in an inappropriate context (Taber, 2000).

Conceptual framework: Conceptual framework describes an individual's general background knowledge about a specific concept, for example, chemical bonds.

Chemical Bonding Instrument: Diagnostic instrument to assess students' understanding of chemical bonding. This instrument consists of 23 two-tier multiple-choice items. It is an integrated two-tier multiple-choice diagnostic instrument based on the work of previous studies such as Peterson, Treagust, and Garnett.'s (1989) two-tier test on *Bonding and Structure* and *Chemical.*

Misconception: Taber's (2000) defines misconception as "a simple conception that is different from the domain-accepted conception or from the desired outcome of teaching and that"; it is in contradiction with the scientifically accepted conception. In this study misconception is used to mean student ideas and beliefs about how the world works that are different than the scientific accepted understanding (Dykstra, Boyle, & Monarch, 1992), or student mistaken answer related to some scientific concepts during the learning process (Uzuntiryaki, 2003).

Reasoning ability: Reasoning ability was used to denote the use of reason, especially to form conclusions, inferences, or judgments (Mifflin, 2000). The ability of human beings to make sense of things, to establish and verify facts, and to change or justify practices, institutions, and beliefs (Wikipedia, 2012).

Guided Inquiry: A teaching technique involves active learning that emphasizes questioning, data analysis and critical thinking as the students follow the methods to investigate the teacher identified problem (McComas, 2014, p.50-53). A practice of student learning independently to develop independent and critical thinking skills, positive attitudes and curiosity toward science and increased achievement in biological content (Einstein, 2012). It is also the practice of using and learning content as a means to develop information-processes and problem-solving skills capabilities (Horton, 2007).

Student centred learning: The term “student centred learning” is used to mean an approach to education focusing on the needs of the students, rather than those of others involved in the educational process. It focusses on putting they become active participants in thinking about their own learning the learners at the centre of the learning process whereby they design implement, gather information, and report conclusions (Jones, 2007).

CHAPTER I - INTRODUCTION

1.1 Background

In recent years, there has been much focus on the student understanding of scientific concepts. This focus has been demonstrated by the large volume of research studies dealing with various levels of understanding of scientific concepts in all scientific disciplines. As such, this area of research has become the most important subject of science education research studies (Talanquer, 2013). Generally, the aim of these studies is to document student understanding first and then finding way to improve students' understanding of science concepts so that they can use them for intended purposes.

Most of these research studies have revealed that many students tend not to learn meaningfully and thus have had difficulty relating what is taught to them in science with other scientific ideas, and with real world experiences (Novak, 2002). Alternative understandings are often viewed as the main impediments to meaningful learning of science. This is because the construction and reconstruction of meanings by learners requires that they actively seek to integrate new knowledge with the existing one in their cognitive structure (Novak, 2002). That is, meaningful learning required to construct integrated knowledge structures, which contain their prior knowledge, experiences, new concepts, and other relevant knowledge (Good, 1984).

Many researchers studied the connection between meaning making and learning. These studies have consistently shown that students come to school with varying experience, ideas, and explanations about the natural world explanations of the natural world. The ideas and explanations that students generate are often different from those of scientists, which has led to the introduction of the term "*misconception*" and its associated derivatives including alternative frameworks, preconceptions, and naïve ideas. The commonality between these terms is that they all tend to reflect understanding that is in contradiction with the scientifically accepted one. As such these understanding tend to be resistant to change, persistent, well embedded in an individual's cognitive ecology, and difficult to extinguish even with instruction designed to address them (Glynn, 1991).

Since new knowledge is linked to existing conceptions, hence students' misconceptions may generally hinder their subsequent learning (Taber, 2000; Palmer, 2001). Thus, misconceptions significantly influence the promotion of meaningful learning among students. Therefore, many studies devoted to investigate the students' understanding of chemical bonding have revealed that students had a considerable degree of misconceptions in various Grade levels. These misconceptions are resistant to change by traditional teaching methods because most of current traditional teaching is focused on the content of the curriculum and on knowledge and information transmission.

Although this will remain an essential aspect of teaching, it is no longer enough for an effective and stimulating learning process because knowledge cannot be transmitted to the leaner's mind by the teacher. Therefore, instructional strategies other than traditional methods to remediate students' misconceptions should be used in the context of the United Arab Emirates (UAE), the students are not immune from such learning problems. Informal observations suggest that students at the secondary school level experience difficulties in learning meaningfully, possibly due to the presence of such misconceptions. In this present study, an attempt is made to investigate the level of understanding of Tenth Grade students in the learning of chemistry- the chemical bonds.

1.2. Study Background

Research studies dealing with student understanding of specific scientific concepts are diverse. Attempts of investigating student understanding among students cover a large range of science concepts. As previously, mentioned, studies focusing on students' understanding of chemical bonding indicated that students had a considerable degree of misconception and low-level understanding in various Grade levels. The research also suggests that it is difficult for misconceptions to be changed by traditional teaching methods because the focus is on the content of the curriculum and on knowledge and information transmission.

Information transmission and content knowledge is of course a critical aspect of teaching. However, to create an effective and stimulating learning as appropriate instructional strategies other than the traditional ones to be used to remediate students' misconceptions. In the current study, we try to create meaningful learning in students about chemical bonding, and eliminate their misconceptions.

Recent research studies showed that students are often unable to integrate facts and formulas, although they can successfully solve mathematical problems (Yager, 2000). For this reason, one of the main aims of science education is to make a meaningful understanding of science concepts. Most curricular around the world seem to believe in current trends of active teaching and learning approaches to provide learners with multiple opportunities to organize and reorganize their knowledge by using these current trends of teaching and learning approaches. This is because the learning process can only take place if the learners relate the new information to the existing knowledge.

At the same time, knowledge cannot be transmitted to the learner's cognitive structure from textbooks or teachers. Instead, students construct their knowledge by making links between their ideas and new concepts through the experience they acquire in school or daily life. These types of experiences can result in assimilation in which new knowledge is incorporated into existing cognitive structure or they can lead to disequilibrium in which experiences cannot be reconciled within the existing structure and accommodation, where cognitive structure is continuously reorganized.

Thus, from this point of view, learning is a process of conceptual change. For this reason, effective teaching requires the teacher to consider the learners' personal knowledge. It is from here that the importance of prior knowledge and the learner's perspective become more important in science education research. Therefore, for meaningful learning to occur there must be a presence of a suitable cognitive level and adequate level of prior knowledge of topics to be learned. In the absence of these conditions, alternative understandings of scientific concepts are more likely to be developed by learners, which could impede further learning.

On the other hand, there seems to be a widespread perception amongst researchers and teachers that many students find chemistry difficult (Carter & Brickhouse, 1987; Nakhleh, 1992; Barrow, 1994; Kirkwood & Symington, 1996; Coll & Taylor, 2001). The reason put forward is that chemistry is a complex subject possessing many abstracts and frequently counter-intuitive concepts (Coll & Taylor, 2001). Furthermore, Hawkes (1996) points out that there are many alternative conceptions in commonly used chemistry textbooks. One of the essential characteristics of chemistry is the constant interplay between the macroscopic and microscopic levels of thought (Coll & Taylor, 2001), and it is this aspect of chemistry (and physics) learning that represents a significant challenge to novices.

Numerous reports support the view that the interplay between macroscopic and microscopic worlds is a source of difficulty for many chemistry students. Examples include the mole concept (Gilbert & Watts, 1983), atomic structure (Zoller, 1990; Harrison & Treagust, 1996), kinetic theory (Abraham, Grzybowski, Renner, & Marek, 1992; Stavy, 1995; Taylor & Coll, 1997), thermodynamics (Abraham, Williamson, & Westbrook, 1994), electrochemistry (Garnett & Treagust, 1992; Sanger & Green-Bowe, 1997), chemical change and reactivity (Zoller, 1990; Abraham et al., 1992), balancing redox equations (Zoller, 1990) and stereochemistry (Zoller, 1990).

In chemistry, the students hold several alternative understandings in many areas such as the mole concept (Staver & Lumpe, 1995), chemical equilibrium (Gussarsky & Gorodetsky, 1988; Camacho & Good, 1989; Pardo & Solaz-Patolez, 1995), solutions (Ebenezer & Ericson, 1996; Abraham, Williamson, & Westbrook, 1994) and electrochemistry (Garnett, & Treagust, 1992). Meaningful understanding of chemical bonds is an example of a topic where students have noticeable difficulty. For example, students often face the difficulty in understanding the theories concerned with the movement of molecules and the formation of chemical bonds. This because of their inability to imagine the movement of atoms and molecules that cannot be seen with the naked eyes. As a result, most teachers depend on the use of models to represent the structure of the atoms.

The chemical bonds topic is one of the topics that require integration of prior knowledge. For example, understanding chemical bonding requires some physics topics such as energy and force in addition to conceptual knowledge of biological concepts such as energy transfer. Furthermore, inability to visualize concepts and to develop mental models for these concepts could be regarded as one of the reasons for difficulties in understanding chemical bonds.

The topic of “chemical bonds” itself is an essential topic in chemistry in order to comprehend the nature of chemical reactions and some physical properties such as boiling point. It is therefore important for student to understand this concept comprehensively so that they can expand their cognitive structure. In the UAE, science curricula and the education system in general are not quite different from those of other countries worldwide; students suffer at all academic levels from difficulties in learning science subjects in general and in learning chemistry in particular.

1.3. Statement of Research Problem

The students who have difficulty in learning chemistry, in particular, chemical bonds, are the core of the research problem of this study. Therefore, this study is mainly concerned with examining the understanding of Tenth Grade students regarding their concept of chemical bonds within the context of the UAE science curriculum of secondary education. The current research in association with my personal teaching experience in chemistry has indicated that high school students are facing difficulties in understanding many chemical concepts; importantly chemical bonds.

In addition, many local newspapers and some radio and television programs have discussed these problems. A former UAE Minister of Education highlighted the efforts of the educational reform as the UAE educational system suffers from many problems. Among these stated problems are low-level of student achievement, highly centralized administration, low levels of output in high schools, etc. Therefore, about 90% of the secondary students need further academic programmes when entering tertiary education. The burden of these prerequisite programmes cost more than AED 300 million (UAE Ministry of Education, 2009).

Many local newspapers, such as Gulf News and The Emirates Today, have highlighted the difficulties the student had in recent year’s educational forums (Emirates Today, 2010). These difficulties not only affect the level of their understanding and academic achievement, but also their future study of chemistry. This can be seen in results of the terminal examinations of secondary schools certificate, which showed a decline in the performance of student in chemistry and indeed other subjects compared to other subjects. This decline might be due to the inability of the students to comprehend the concepts of the chemical bonds and their interrelations to other scientific concepts in learning mathematics and physics. Therefore, the decline in academic performance suggest that students experience difficulties in understanding chemistry including the topic of the chemical bond.

On the other hand, Abu Dhabi Educational Council (ADEC) has given a considerable attention to the problem of science education in the Emirate. ADEC, therefore, has proposed to implement effective teaching methods and strategies for improving the academic performance of the students, as well as adhering to the goals and policies established by the Ministry of Education (Emirates Today, 2009). In addition, the Council published a report on the reasons for low levels of students’ achievement in the emirate of Abu Dhabi, which is due to the existence of difficulties in reading and writing among students (Emirates Today, 2009).

As stated by the former Minister of Education, H.E. Hammed Al Qatami "*The Ministry of Education is taking effective measures to raise the achievement level of students therefore the Ministry has established a centre for the preparation of school leaders in collaboration with a British institution, University of Hampton. This Centre aims to develop the performance of the educational leaders for making them more capable of improving the academic performance of their students*" (Gulf News, 2010).

Many educators talk about the possible reasons for low levels of students achievement in different stages in the local media such as the newspaper of Emirates Today, moreover many web site talk about the same point (level of achievement), especially in the science subjects (Dubai District, 2011). The Dubai Educational Zone began introducing an inspection system to raise student achievement levels in English and science subjects similar to those used globally. There is appreciable difference in the science curriculum between private and public schools. This is noticeable when a student transfers from the private to public schools and vice versa, since every school curriculum is independent and not linked to other schools.

Some reasons for declining the achievement levels of the students are summarized herein below according to my own observations that are based on the works of Welty (1989), Harrison & Treagust (2000), and Hilton & Nichols (2011):

- Traditional teaching methods used by teachers
- Limited sources of learning in some schools especially in isolated area
- Lack of financial support to some schools

- The absence of special programs for gifted and talented students
- Lack of involvement of teachers in important educational decision processes
- The use of limited assessment tools that can be described as authentic and the reliance on traditional assessments
- Lack of communication between home and school

1.4. Purpose of the Study

The purpose of this study is to explore levels of understanding of Tenth Grade students in relation to selected chemical bonds concepts. In particular, the study will try to find answers to questions about:

1. Levels of understanding of Tenth Grade students in relation to chemical bonds.
2. The nature of the alternative conceptions of students regarding the chemical bond concepts
3. The impact of student centred and guided-inquiry approach as a teaching strategy on the achievement of students of chemical bond concepts
4. Effects of student gender on the level of chemical bonds understanding and concepts
5. The relationship between student reasoning ability and understanding of chemical bond concepts

1.5. Research Questions

This research aims to answer the following questions on the Chemical bonds' conceptions of the Tenth Grade students in Dubai secondary schools:

1. What are the alternative conceptions of chemical bonds by the concerned students?

2. What is the nature of the alternative conceptions?
3. How did guided-inquiry influence students' achievement?
4. Are there any significant differences in achievement attributed to student gender in guided-inquiry and traditional contexts?
5. How does student reasoning ability affect their achievement?

1.6. Significant of the Study

The significance of the study is threefold. First, the research has shown that understanding of chemistry in general, and chemical bonds in particular is difficult for students (Furió & Calatayud, 1996; Peterson, Treagust, & Garnett, 1989). Inaddition, the literature largely reveals that students' understanding of chemical bonds is limited (Boo, 1998; Harrison & Treagust, 2000; Nicoll, 2001; Taber, 2000).

However, the reviewed studies were almost conducted outside of the United Arab Emirates (UAE). As a result, the UAE students' understanding of chemical bonds and its associated misconceptions remain unclear. The findings therefore are expected to unearth quantitatively these understandings and misconceptions and thereby can provide database that may guide future teaching and learning processes.

This study employs a mixed research method approach (quantitative and qualitative methods) to investigate students' understanding about chemical bonds, and how these understanding are impacted by the reasoning process of these students. In this way, the present study goes beyond the simple identification of conceptions regarding the chemical bonds, as it aims to provide explanations of the possible impact of the reasoning process of students on determining understanding level of chemical bonds.

On the other hand, the significance of the present study can be linked to the topic of the investigation itself- the chemical bonds. The concept of chemical bonds taught in the Tenth Grade students is one of the most basic concepts, which is linked to other concepts that students will study in subsequent years, and as such, it is regarded as a prerequisite for many important concepts such as solubility, sedimentation, the types of solutions and chemical reaction. It is therefore important to identify level of understanding of students at this Grade level so that appropriate measures can be introduced to alleviate any shortcomings related to student meaningful understanding of chemical bonds.

Furthermore, an analysis of final examinations of the Tenth Grade students in the past four years in six secondary schools in Dubai Educational Zone including males and females was carried out. It was found that the results of academic achievement for students in chemistry ranged between medium and weak compared to the same students in other subjects such as physics, biology and mathematics for the same years. It is more appropriate therefore to undertake a study to deal with the problem of the low level of understanding and academic achievement for these students. Evidence-based findings similar to the findings of this study acquired through systematics data collection and analysis will most likely provide an evidence-based solution. It is from here that the significance of the present study can be seen.

1.7. Scope and Limitations

This study is limited to measure the level of understanding and comprehension in chemistry according to the concept of chemical bond for the Tenth Grade students in two secondary schools in the Dubai Education Zone. However, the study took place over a limited time for one month.

1.8. Summary

The focus on student understanding of scientific concepts has begun to gather momentum in recent years judging by the large volume of research studies dealing with various levels of understanding of scientific concepts in all scientific disciplines. Recent research studies also showed that students are experiencing difficulties in learning scientific concepts, particularly chemical concepts. This has stemmed from the widespread perception amongst teachers that many students find chemistry difficult. The reasons suggested are that chemistry is a complex subject possessing many abstract, frequently counter-intuitive concepts.

Meaningful understanding of chemical bonds is an example of the topics where students have noticeable difficulty. For example, the students often face difficulty in imagining movement of molecules and formation of chemical bonds, as they cannot be seen with the naked eyes. Thus, most of the teachers depend on using models representing the structure of atoms. Thus, the topic of chemical bonds itself is an essential topic in chemistry in order to comprehend the nature of chemical reactions and some physical properties such as boiling point.

It is therefore important for the students to understand this concept comprehensively, so that, they can expand their cognitive structure and schema. Therefore, it is intended in this study to explore the levels of understanding of Tenth Grade students in relation to selected chemical bonds concepts. This investigation aims at finding relevant answers to questions about students' levels of chemical bonds understanding and concepts with respect to the nature of alternative conceptions, student gender effects, impact of student-centred inquiry approach teaching on the students' achievement, and the relationship between student reasoning ability and understanding of chemical bond concepts.

As mentioned previously, it is envisioned that the findings of this study will provide some quantitatively answers related to understanding and misconceptions and thereby providing research data that may guide teaching and learning processes in the UAE education system and context.

CHAPTER II - LITERATURE REVIEW

2.1. Introduction

In order to take an in-depth view of student understanding of chemical bonds, this chapter shows some important studies concerned with the same topic with more details related to students understanding of chemical bonds and related concepts, such as nature and characteristics of chemical bonds, misconceptions shown by students at different educational level. The context and the factors that may affect the student's level of understanding of these chemical bond concepts such as the reasoning ability, prior knowledge and practical work are also presented and discussed.

This chapter reviews the scholarly literature that focuses on the importance of the new global educational trends, which aims to strengthen the students' academic performance in science subjects, in general, and to minimize the level of alternative conceptions related to some basic concepts in chemistry such as the concept of chemical bonds. Many research studies have shed light over the new trends in using innovative teaching methods to shift the educational process from teacher-centred approaches to student-centred learning to help students in different levels to achieve higher performance, gain more self-confidence and have a deep understanding in chemistry.

This chapter presents a review of the retrieved relevant literature, which is sub-headed to cover specific related topics on the chemical bonds theme; these are i- level of students' understanding and misconceptions, ii- nature of the students' alternative conceptions, iii- effects of gender differences, iv- effects of student reasoning ability, student-centred learning and guided inquiry, and v- students related to the local and regional context.

2.2. Level of the Student's Understanding and Misconceptions

As early as the 1960s, science education research suggested that the teaching and learning of scientific content are greatly enhanced if the students' pre-existing conceptual framework is considered when pedagogic strategy is planned (Ausubel, 1968; 2000). This is because the new content has to be subsumed into the existing cognitive structure of the student.

Many studies have revealed that students bring with them to science lessons certain ideas, notions and explanations of natural phenomena that are inconsistent with the ideas accepted by the scientific community (Osborn & Wittrock, 1985). These existing ideas are often strongly held, resistant to traditional teaching and form coherent though mistaken conceptual structures (Driver & Easley, 1978). Students may undergo instruction in a particular science topic, do reasonably well in a test on the topic, and yet, do not change their original ideas pertaining to the topic even if these ideas are in conflict with the scientific concepts they were taught (Barmby, 2008).

Haidar (1991) and Metz (1996) suggested the need to modify the methods used in science curriculum teaching as a need for giving the students more opportunities and responsibilities for the participation in different activities in the classroom. Students should be given the opportunities to ask questions about any unclear points during the lessons and should focus on developing practical work to support theoretical framework and make abstract concepts more clear and simple for the students to understand the real meaning and connect the concepts together.

Thus, students' conceptions have to be identified so that measures can be taken to help students in replacing them with more scientifically acceptable concepts. Students' understanding of chemical bonds and related concepts have been the focus of many researchers worldwide (Barker & Millar, 2000; Harrison & Treagust, 2000; Pedrosa & Dias, 2000; Schmidt, 2000; Taber & Watts, 2000; Taber, 2001; Coll & Taylor, 2010).

Most of the above-mentioned studies have been conducted in North America and European countries to suggest that students suffer from many alternative conceptions related to the topic of chemical bonds. Despite the fact that chemistry is very important interdisciplinary subject, a few studies have been conducted in the Arab countries (Sirhan, 2007). Unfortunately, the ideas among students at different education levels are that chemistry is the most difficult subject to pursue **(**Carter & Brickhouse, 1987; Nakhleh, 1992; Barrow, 1994; Kirkwood & Symington, 1996; Coll & Taylor, 2001**).** As such, students don obtain a sound and coherent understanding of chemistry concepts due to the difficulties may experience when they learn about chemistry.

Many researchers worldwide tried to investigate this problem as a part of a new revolution that aims to enhance educational systems in general and students' achievement in science subject, in particular. This is because the researchers consider chemistry as a heart of industrial processes. Many studies have proved that students show a low level of understanding of some of the important and basic concepts in chemistry, such as the topic of chemical bond (Peterson & Treagust, 1989). They cannot understand the relationship between intermolecular bonding and boiling point, which is considered as one of the most important physical properties (Taber, 1995).

Sirhan (2007) used qualitative method to link the result of previous studies about the level of student understanding of chemistry over the past two decades and tried to obtain reason for the low level of students' achievement in chemistry. Sirhan found that i- low levels of student motivation to study, ii- the way teachers communicate curriculum materials to students, and iii- students' working memory space were the main reasons behind low student performance. Therefore, Sirhan suggested that, in order to improve students' attention, a greatest emphasis is needed on the preparation and student motivation so that they achieve better results.

NaKhleh (1992), in his study of the impact of teaching methods used in high school to build a good understanding of chemical boding and to correct misconceptions, came across a number of misconceptions that had an impact on students' conceptual understanding. NaKhleh included high school students and used the written test to assess student level of understanding of the concept of ionic and covalent bonds.

NaKhleh (2006) concluded that this subject showed a variety of misconceptions regarding the concepts of chemical bonds. Nakhleh suggested that reasons for the formation of these misconceptions included:

i- Traditional ways of teaching are mostly focused on memorization and low level of understanding ii- The assessment system such as teacher examinations over the years with respect to chemical bonds that also focus on memorization

iii- The chemistry curriculum itself at the secondary, which does not link the previous concepts students have with new concepts.

Moreover, NaKhleh proposed a solution to increase students' level of understanding in chemistry regarding the concept of chemical bonds and helped to reduce the level of misunderstanding such as the following:

1) Improving methods of assessment and evaluation, and minimizing the number of direct questions that focus on the keep-in-mind only

2) Linking concepts and previous experience for the students with new experiences in different educational levels not only at the secondary level but also at the university level

3) Preparing the teachers to use effectively methods of teaching, where most of the teachers are using traditional methods that prepare students for the examinations only and not for learning

Gabel (1999) focused on the same concept of ionic bonding, and conducted investigation the students' level of understanding and misconceptions in chemistry regarding the concept of chemical bonds. Gabel used a two – tier multiple-choice test to identify students' knowledge about the concepts of chemical bonds .The participants of the study were 151students who were involved in studying chemistry at the University of Brunei Darussalam at different levels in forth year. Gabel regarded his subjects as having correct understanding if the students select both the content and the reason correctly. Gabel found that students had partial knowledge of the concepts and they had exhibited misconceptions about the bond polarity.

Many students thought that the polarity of the covalent bonds is due to ion formation through electronic transfer and the partial charge on covalent bonds is the result of electron transfer. Dhindsa and Anderson (2004) suggested that the chemistry curriculum should have a link between students' prior knowledge and current knowledge. They further contended that secondary school teachers should develop and use effective instructional strategies to minimize students' misconceptions and increase level of understanding in chemistry.

Topal, Oral, and Mustafa (2007) investigated students' misconceptions regarding aromatic compounds. Their study aimed to investigate whether there are significant statistical differences between the First and Third Grades in Chemistry Department in Dicle University and the students in secondary Grade in Turkey. The sample consists of 65students from secondary school and 214 students from science faculty. They used a descriptive survey method and written examination to collect the data. At the end of the study, they found that there is a statistical significant difference in the student level of understanding regarding aromatic compounds.

The students at university level showed a high level of achievement, whereas the secondary students showed high level of misconceptions. Topal, Oral, and Mustafa suggested that if policy makers who are interested in the educational processes want to raise the level of academic achievement for students and minimize the level of misconceptions in science in general and in chemistry in particular regarding specific topics such as aromatic compounds, chemical bonds and chemical reaction, the curriculum should be reviewed and more examples and details should be emphasized.

Taber (1993) on the other hand aimed to illustrate how student level of understanding of chemical bonds concepts increased and the level of misconceptions decreased over the time. He used a qualitative method through interviews with four volunteer students at three stages in their first level of chemistry course. The interview was carried out at three different times, i.e. at the end of the first term, at the end of the second term and before the final examination. At the end of his study, Taber (1993) found students' level of understanding increased before the final examination because most of the students studied for the examination and not for learning. This trend could be one of the possible reasons for students' misconceptions regarding chemical bonds.

In another study, Taber (1994) investigated the students' conception regarding ionic bonds. He found that students showed good level of understanding about the formation of ionic bonds because of donating and accepting electrons; however, he found the students were confused about the structure of ionic compounds. Smith (1987) had similar findings when he aimed to measure Twelfth Grade students' level of understanding of the properties of ionic compounds. Most of the students showed misconceptions about three-dimensional nature of ionic bonds.

Treagust (1999) supported the same findings of Smith (1987), and Taber (1994). Treagust's participants consisted of 119 students aged around 14-16 years old students. He used his personal experience, a multiple choice question (MSQ)-based examination and concept maps to measure student level of understanding and misconceptions. At the end of the study, Treagust (1999) found that the common misconceptions included:

1. Misunderstanding of how metallic and non-metallic elements combine to form chemical bonds.

2. How the valence electrons participate to form chemical bonds.
3. The impact of the type of bond on the properties of chemical compounds such as hardness, melting point, boiling and electrical conductivity.

Various studies were devoted to helping students achieve higher levels of understanding in chemistry and chemical bonds. For example, the study of Uzuntiraki (2003) focused on the effect of the constructive approach on the students' level of understanding regarding the concept of chemical bonds. Uzuntiraki (2003) used the descriptive methods to summarize the previous studies about student misconceptions in chemistry.

Uzuntiraki (2003) defined the word misconception as student ideas, which have been caused as a result of misunderstanding of commonly accepted scientific understanding. He suggested possible reasons for misconceptions such as i- the weakness of the students' ability to visualize the relations between the atoms and molecules that can be seen with the naked eye and ways to configure the interdependence of chemical compounds, and ii- the teaching methods used and the nature of the chemistry curriculum.

Boo (1998) showed other possible causes of the misconceptions in Twelfth Graders regarding the concepts of chemical bonds conducting interviews with students in the secondary schools. Boo found ubiquitous misconceptions among students in the secondary schools, as most of the students believed that the existence of chemical bonds to be a physics property. Nicoll (2001) added more reasons, which cause misconception such as bonding structure, polarity and octet rule. These findings were supported by the findings of previous research studies such as those of Peterson, Treagust, and Garnett (1989), and Birk and Kurtz (1999).

Coll and Taylor (2010) tried to focus on some other alternative conceptions related to the same topic of chemical bonds. The sample study consisted of secondary school students and tertiary level chemistry students from New Zealand and Australia. The total sample number is about 30students at the age of 17-18 in secondary schools at the age of 19-20 at university level and postgraduate students at age of 23-26 years. The study included both male and female students. The researchers used the inquiry approach and depended on discussion between the researchers and the students.

Furthermore, the researchers analysed in-depth the chemistry curriculum, lesson plans, students' lecture notes and final examinations for the study sample to measure students mental understanding to the topic of ionic and covalent bonds. The study methods focused on electron transfer between different atoms, octet rule and molecular orbital theory. At the end of the study, the researchers found that students in all levels showed alternative conception related to the topic of chemical bonds.

Most of the students especially in secondary schools believed that ionic bond that holds ionic compounds are weak because they observed NaCl, which is considered as an ionic compound. It is dissolved easily in water or crushed easily. Moreover, some students believed that the covalent bond is stronger than the ionic bond. They thought that more bond formation leads to a stronger compound because covalent bonding forms single, double and triple bonds. Others alternative conceptions came from the size of the ion.

Some students thought that the bigger the size of ions the more electrons they have and this leads to stronger bonds. The study also showed some alternative conceptions among the students at different levels related to metallic and non-metallic nature, which has in effect, affects the expectation of kind of bonds formed between metallic and non-metallic compounds.

2.3. Nature of Students' Alternative Conceptions

Many research studies have been focusing on the effects of alternative conceptions on students' achievement as new global trends. Consequently, many educational researchers are relentlessly seeking to find the possible sources of alternative conceptions in scientific subjects, particularly in chemistry. These conceptions are believed to affect students' achievement, along with their level of understanding in different academic levels.

Talanquer (2006) on the nature of alternative conceptions in science revealed that many science teachers do not adequately discuss the concepts and understanding of their students about natural phenomena. However, many of the students' alternative concepts in chemistry appear to be due to an incomplete, limited and superficial explanatory framework about chemical substances and phenomena.

Christopher and Worcester (2004) findings were in agreement with the previous study; both authors believed that learning is an active process since students from different levels of achievement reflect on their previous knowledge and experience and connected them to new concepts. This accumulated knowledge might cause alternative conceptions for some students, especially with the abstract concepts they have difficulty imagining. Moreover, the reversibility of chemical reaction is considered as a source of alternative concepts because many students fail to see the changes of state, dissolution, and .other physical states as a reversible phenomenon. Their study concluded the following points: the teachers should design the lessons around positive goals, which should be built around the models of fundamental concepts of chemistry to be mastered and understandable.

Chiu (2007) investigated other possible reasons that might cause alternative conceptions to the students in relation to other scientific concepts. The study examines the factors that are related to alternative conception, these are: i- personal experience (background , observation, peer interaction, media, scientific language used inside the classroom, textbook , laboratory work), ii- teacher level of understanding of the chemical concepts, and iii- teaching methods because all of those factors affect students level of understanding and misconception.

Taber (1998) investigated some teaching methods being used, which were not helping the students to meet scientific standards; these things might lead towards presence more alternative conceptions in science; moreover, the scarcity of clear examples and models that could assist in understanding the scientific concepts in the chemistry textbook are considered as a source of alternative conceptions in science.

Ozmen (2011) conducted interviews with Turkish primary students of the age between 10 and 14 from Fourth Grade to Sixth Grade. The study concluded that i- the difficulty of scientific language used in the concerned Grades was responsible for causing students alternative conceptions in science, ii- lack of formal operational development and poor visualization ability of abstract concepts such as the space between atoms and atoms size make science subjects more difficult to understand, and iii- the presence of alternative conceptions in the primary level will affect students' achievement in secondary schools.

Tan, Goh, Chia, and Boo (2001) conducted their study in 12th Grades looking for the reason behind the presence of alternative conceptions related to the abstract concept of chemical bonds (both ionic and covalent). The study appreciated the importance of teaching methods used and revealed that the lack of conceptual map to link different abstract concepts in science and chemistry may cause alternative conceptions

2.4. Effect of Gender Differences

Studies on the effects of student gender have produced ambiguous findings. Generally, the gender factor may cause an effect on students' level of understanding towards science subjects in general and chemistry in particular. In fact, intensive researches have taken place in respect to gender differences to gain some insights into the roles of intelligence, arts skill, language and reading literacy in science education.

Meece and Jones (1996) probed the potential factors that might cause differences between the male and female students based on their respective academic achievements in Turkey. The candidate factors were motivation, students' ability, and biological differences. Meece and Jones also analysed the students' GPA in the university and their previous scores in high schools. Students participated in the study were (10343) and they were chosen equally. The study found that the female students generally showed a high degree of achievements as most of them were determined to join the university in contrast to the male students who showed less interest in joining university. Hillman and Rothman (2003) got similar findings when they investigated the effect of gender differences regarding academic motivation as a factor that may have a direct link to students' achievement.

Rusillo and Arias study (2004), even though concerned with language aspect, found that female students showed better achievement both in language and in arts. Furthermore, the female students showed intrinsic motivation, whereas the male students showed extrinsic motivation. On the other hand, both female and male students showed the same performance in mathematics. Yet, Naderi, Abdullah, Aizan, Sharir, and Kumar (2010) investigated the effect of gender differences on both intelligence and student achievement. The sample of the study consisted of 105 male and 48 female students.

All of the participants were Iranian undergraduate students in Malaysian universities. Praatm (1999) found that there were no significant differences between males and females regarding the intelligence. Moreover, there were no relationships between intelligence and academic achievement. The findings of this study however contradicting both Lee (1996), and Mullis, Martim, Gonzales, and Kenned (2003) who found different results related to the significant relationship between the variables investigated; however, the study of Praatm (1999) had some limitations because they only focused on Cumulative Grade Point Average (CGPA) to measure students' achievement. In addition, the study participants only included Iranian students.

Eceles, Adler, and Mecce, (2003), summarized the previous literature about gender differences and academic achievement toward literacy because it may cause an effect on students' academic achievement on different subjects, when they suffer from difficulties in reading or writing as it will directly affect their results in both oral or writing examinations. Stafslien (2001) found that there are significant differences between males and females in academic achievement. Most of the time boys showed better level in science and mathematics but in reading and writing females showed better achievement.

The study of Fassinger (1995) supports the same idea. According to Fassinger the highest achievement of girls in reading and writing is due to biological factors because the ability of girls to spell the word and talk is found higher than of the boys in the early childhood. This skill may affect their achievement in academic life. Lackland and Lisi (2001) investigated the effect of gender on the students' attitudes in Switzerland towards science as a factor that may affect students' academic achievement. The participants chose randomly from three different regions in Switzerland covering about 1000 of adults from Grade 12 and over 473 males and 527 females

Lackland and Lisi (2001) used quantitative methods by applying a telephonic survey to find that in Switzerland, the men showed higher level of scientific knowledge and positive attitude towards science subjects than women did. Tobin (1994) supported the hypothesis of gender differences towards science and academic achievement. The report published by the National Research Council (NRC) in 1996 and in 1998 showed that boys did better in mathematics and science subject in general than girls in the USA.

Rittle (2001) measured the level of basic skills of problem solving strategies and the effect of gender and Grade level on the acquisition of the problem solving. The researcher used 141 voluntary students from all levels to participate in the study.

At the end of the study female participants showed high level of basic skills regarding problem solving in physics than males in Turkey. Moreover, the student gender affected the strategies, which the participants used.

The findings of Hu and Kuh (2002) supported previous findings; they investigated the same topic (effect of gender) and their study concluded that there were significant differences between males and females regarding science subject in general because science subjects need higher levels of mental and thinking skills to find a relationship between causes and effects. In addition to this, they contended that some parts in science such as problem solving and classification are complex problems. Each step needs different skills. These causes have direct effects on students' level of understanding, students' attitude toward science and leads to the formation of some misconceptions such as most of the student believe that science is complex and difficult.

2.5. Effect of Student Reasoning Ability

Many researchers in the recent years have focused on the students' reasoning ability as a factor that may affect students' achievement and level of understanding of science subjects. Chastain (1992) investigated students' reasoning ability as a factor that may affect student achievement in the secondary school especially in Twelfth Grade of science track. The study dealt with three major points:

1. If there is any relationship between students gender and their academic achievement
2. If there is any relationship between students gender and their reasoning ability
3. If there is any relationship between students (GPA) and their reasoning ability

The participants selected randomly and consisted of 115 students from science track in Twelfth Grade. Chastain (1992) applied a test of logical thinking and students had to choose both correct answers and the reasons for these answers; the study revealed that i- female students showed high academic achievements than males; ii- males show a higher performance related to the reasoning ability test, and iii- related to the student (GPA), females showed a higher achievement in mathematics, physics and chemistry. However the study has limitations in the sample number because males have greater in number than females (82 boys and 33 girls); some participants were also absent during the survey study.

Engle, Tuholski, Laughlin, and Conway (1999) selected randomly 120 students from both genders to participate in their study. Each participant subject to the American College Test (ACT) to measure the student's achievement; the collected data were quantitatively analysed. Their study unveiled a direct relationship between students reasoning ability in science and mathematics and that their academic achievement largely depends on this.

Moreover, the researchers focused on other factors that may affect the results such as age of the students, number of hours each participant studies per week, and if the participants had children. All of this information was collected from the personal data sheet. At the end of the study, Dearya and Stough (1996) found that there were significant differences between student achievement in science and their reasoning ability but this study also had a limitation because it focused only on African American students.

Clement (2001) aimed at investigating if there is any relationship between students reasoning ability and academic achievement. The study sample was selected randomly from elementary and secondary schools (8^{th}, 10^{th}, and 11^{th} Grades), and consisted of 30 students from each Grade. Clement found that reasoning ability affects student achievement in different Grades and most of the students, will do better, if they are examined on recent information rather than if the test contains information from two or three years earlier.

2.6. Student-Centred Learning and Guided Inquiry

Student-centred learning can be viewed as an approach in which the learners are the centre of learning process while the teacher takes on the role of facilitator than instructor. In this approach teachers and textbook, only guide and manage the teaching strategy and direct the learning process during the class time. Student-centred learning is considered as one of the most important strategies used to involve student in the classroom and lead him towards self and in depth learning (Welty, 1989).

Jones (2007) tried to define a student-centred classroom as a new teaching approach aimed to help students towards meaningful learning and high performance in his study. He suggested that students do not depend on their teachers all the time; they only wait for instructions, advice or words of approval. Students get most benefits by communicating with other, as well as learning from each other to enhance their achievement. Jones summarized the conclusion of many studies related to the same topic (student-centred learning) and provided many advices for both students and teachers to help them to achieve academic success.

The guided inquiry approach would help students to increase their self-confidence, all students in the classroom are recognized, their presence inside the classroom is valued and they are welcome. Moreover, teachers will have high expectations from their students. All teachers should believe that all students in their classrooms having different levels; therefore, they are participating in different ways such as in reading, reflective writing, group discussion, group activities and practical work.

Many studies suggest different learning strategies to help in raising student participation to be active in the classroom and help them to be the centre of learning process in both school and classroom environment. So as to increase their level of understanding and achievement, especially in science subjects as chemistry. This is because many students often show low level of performance and they believe that chemistry is the most difficult subject in science because it deals with the abstract concepts (Flick & Bell, 2000).

Nwagno (2006) suggested a number of strategies for increasing student performance and minimizing the level of misconceptions that related to the basic concepts in chemistry. Among the suggested strategies are:

1. Giving students enough time to think and answer the questions.
2. Acknowledging and discussing aides in the classroom
3. Leading students towards right answer and an in-depth learning
4. Encouraging students to ask question inside or outside the classroom
5. Making sure that all groups have a clear direction in different activities
6. Providing students with different mental ability the same opportunities to interact with the teacher in an individual way

Shymansky, Hedges, and Woodworth (1990) tried to investigate the best ways for increasing student achievement and leading students of different abilities towards active participation in the classroom. Turner and Patrick (2004) suggested that student participation is one of the best ways that leads most of the students towards in-depth learning. They also suggested motivation as the best way to guide students towards a higher achievement, especially with students who are poorer achieves in science subjects and chemistry.

Turner and Patrick (2004) focused on the effect of the participation of two students in mathematics class during both Sixth and Seventh Grades on the level of performance during the year. They employed motivation to enhance student participation and guide them towards a high performance. Their study aimed to observe and code student participation in attempt to link it with student achievement. Turner and Patrick concluded that more positive and active participation in the classroom (e.g., more student-centred activities) would lead the students towards high achievement and decrease level of alternative conceptions related to the basic information in the science subjects. However their findings can be questioned in a sense that they might be affected by many factors such as motivation, teaching methods used inside the classroom, school and classroom environment.

Combs and Miller (2006) focused on the same point of that the effect of students' participation and teacher's guidance in the classroom on the student performance. Their study carried out with twenty students who were classified into two major groups: i- active students, those who participated greater during different class activities and, ii- passive students, those who are kept themselves away from any classroom discussions or activities. Both groups completed a three-part questionnaire consisting of 24 questions, along with a demographical question. Combs and Miller concluded that student-centred learning and teacher guidance noticeably increased not only the level of understanding and achievement, but also the student self-esteem. Furthermore, the level of understanding and participation in the classroom will continually increase when teachers plan lessons and activities, which are relevant to student's culture and environment.

Prensky (2007) reached a conclusion similar to that of Rallis (1995) that student centred learning is the best way to increase student achievement and decrease level of misconceptions in science subjects. Darling and Bransford (2005) introduced what the term "*deeper learning*", which is an idea based on student-centred learning as one way to help students to accelerate their learning and achievement. In addition, Hmelo-Silver, Duncan, and Chinn (2007) considered students-centred learning as a critical and creative way to increase student achievement because it reduces stress in the classroom and gives students more self-confidence.

Kramarski (2003) reviewed many studies on student-centred learning conducted in different settings. Kramarski acknowledged the studies of Johnson and Smith (1991), Tier, Roth and Kampmeier (2001), and Mazur (1997), which highlighted the potential benefits of student-centred approach to both teachers and students. Student-centred learning maintains teacher-student class interaction within a guided-inquiry environment. In addition, teacher-student class interaction found to have an impact on the student performance and learning outcomes.

Kriewaldt, (2006) considered active participation in classroom as a valuable behaviour because it provides students with different opportunities to learn and practice new learning knowledge; it allows students to explain their reasoning behind their answers and behaviour inside the classroom, and thereby become more active and engaged in learning. In addition, student participation in student-centred learning might provide teachers with clear ideas about students' level of understanding and give them more opportunities to evaluate teaching methods used in the classroom (Land & Hannafin, 2000).

2.7. Studies Related to Local and Regional Contexts

The literature review revealed that there is a scarcity of scholarly studies on this thesis topic in the context of the UAE. However, a few studies were conducted in some Arab countries, which are similar to the UAE context. The studies that were conducted in the Arab world focusing largely on the problems experienced by learners, which have led to low levels of understanding and academic achievement because many researchers believed that by diagnosing the causes of the problems, it will help them in finding appropriate solutions to these problems (Abdulaziz, 1971).

Malkawi (1994) focused of the importance of changing the traditional teaching methods to meet the need of students by using attractive teaching strategies, and focusing on the students as the centre of learning process because it improves cognitive skills, and develop creative thinking. According to this study, the researcher said, "*the low level of understanding and academic achievement is a reflection of what both teachers and students suffering, believe convictions, and practices about learning*" (p: 28). The most important finding of the study was that the teachers must be convinced that they should also learn from their students since classroom interaction is considered as a two-way learning process between teacher and students. In addition, teachers have to cooperate with students instead of giving them harsh orders in the classroom

Al Deeb and Ali (1973) studied potential factors related to the low levels of understanding among Egyptian secondary students and concluded that two factors might be the causes of low-level performance, these were personal and environmental factors. They suggested for further studies to investigate students' level of intelligence, reasoning ability, and unwillingness in relation to academic performance and achievements in science subjects.

Zytoon (1986) emphasized the importance of scientific concepts in respect of using those concepts as a source of understanding the surrounding natural phenomena, interpretation and contribute to solving everyday problem. Jamal (1988) conducted a question-based study on the abstract concepts of secondary students. The intention of Jamal's study was to develop a better understanding and improving mental abilities about abstract concepts regarding the scientific subjects. Therefore, it is easy to link the new concepts to the old ones when the science teachers use teaching strategies that help students to participate actively in the educational process by using a guided-inquiry approach.

Employing inquiry approaches in the laboratory activities have drawn the attention of many researchers. Zogrob (1990) confirmed that the use of the inquiry approaches in laboratory work is considered as the foundation of the education process not only at the secondary level, but also at the university level. Those approaches could assist in helping abstract concepts to be clearer and understandable through the experiments and direct observation in terms of using the senses.

Noor (1998) focused on the subject of scientific reasoning because it is considered as a good indicator of student level of understanding. Noor studied 190 students in Eleventh Grade in Yemen to answer three questions related to students' reasoning ability and examining its influence on students' level of understanding and level of misconceptions. Noor found a positive association between students' level of reasoning ability and academic achievement. In addition, the researcher found a positive relation between the uses of scientific reasoning as a teaching method and the development of student scientific skills because when students know the real reason for different scientific phenomenon it reduces the level of misconceptions in science and leads them towards high level of achievement and thereby enriching their understanding.

Zakaria and Sadeik (2000) focused on the importance of the evaluation process of the scientific concepts that used by the student for the following reasons i- to measure the student's ability to connect new concepts with the previous concepts, ii- to measure student's ability to apply scientific concepts in learning process, iii- to measure student's ability in the interpretation of scientific phenomena using concepts learned, and to measure the student's ability to applied scientific concepts in problems solving. Al Hur (2001) investigated the level of students' achievement in Saudi Arabia. Thisstudy showed the importance of determining the levels of success in the classroom interaction of students corresponding to the learning resources available in the classroom environment.

Al Qutaami (2005) investigated the potential roles of the science teachers in designing effective lessons at Al Mosel secondary schools (Iraq) for encouraging the students to actively participating in the classroom activities. The study found that that the design of effective lessons could assist in attracting more students to participate in classroom activities and collaborative work to achieve effective learning and increase their level of understanding of the scientific concepts.

Al-Dagani (2008) focused on the same topic the level of scientific reasoning but among university students. He also studied the association between gender, teaching levels and specializations and the development of reasoning abilities. The Lawson test for reasoning ability was applied randomly to 320 male and female students. At the end of the study, the researcher concluded that there were significant differences in student ability of scientific reasoning according to their specializations; their study levels based on their prior knowledge and experience.

There were no significant differences between students' gender and scientific reasoning ability. The study recommended that teachers should use active learning strategies such as inquiry and student centred approaches and design attractive classroom activities to enhance the reasoning skills of different science subjects, which develop positive attitudes towards active learning; and establish good interactive relationships among the students.

Khtayba (2005) showed that the most important reasons for the formation of alternative conceptions among students were results of wrong teaching methods and absence of linkage between the curriculum and a student real-life and student's motivation to learn, which in turn is reflected in the students’ level of performance and lead to the reluctance of students to enrol in major scientific disciplines.

Al-Khlili (1995) recommended to the science teachers to ensure that there is a proper balance in-class and outclass activities in terms of time management. This time management was found to play a crucial role in increasing the students' academic achievement. The study provided some important recommendations for both students and teachers to raise the level of academic achievement as the following:

1. Teachers must be intuitively ready to take appropriate decisions in a short time to ensure the continuity of the educational process in the classroom.
2. Students and teachers should think in depth about skills now and in the future.
3. Teachers should focus on three key points while planning a lesson, interest, learning by fun and interaction between teacher and student.
4. Teacher to be realistic in the duties required by the student inside and outside the classroom.
5. Teachers and students should organize priorities and tasks to be accomplished and requested by the school administration.

Time management is an important part of planning for the future, which was the topical theme of Al-Hur’s study (2001) that focused on the ways to raise the level of understanding and academic achievement for students, especially at the secondary school level. In this study, Al-Hur argued the behaviour of students, teachers and educators would determine the future of the learning process. They must realize that changing the curriculum, especially in science subject along with teaching methods and learning techniques is indeed necessary to cope with the future challenges. All curricula must be based on the development of students' skills, both in the private and public schools. Therefore, these curricula should fulfil the requirements of future labour markets in order to avoid the problems of unemployment its consequences within the community.

Moreover, Al-Hur emphasized that teachers and students should develop reciprocal and mutual respect. The teachers should be just in treating all learners equally, especially the slow learners. It is important for teachers to motivate and teach them with mainstream students by applying different learning methods. Al-Hur suggested several recommendations including:

- Focusing on the comprehensive development of students mentally, physically and emotionally.
- Understanding students and their concerns and fully engage them in classrooms.
- Diversifying technological literacy and developing the skills of students in the field of information communication technologies.
- Activating the role of the family and community institutions in the educational process.
- Encouraging creative thinking and scientific innovation of the students and teachers.

Al Deep (1998) supported the previous points suggested by Al-Hur (2001). Al Deep (1998) focused on the importance of the use of a method of reward and encouragement for all students despite the differences in students' level of achievements. Zafer (2009) showed that continued encouragement helps to increase the student's self-confidence and motivation to learn, especially when students having learning difficulties.

On the other hand, Emarh (2001) focused on the need for building the curriculum on the ideas of integrated science to help students to build their knowledge through the entire science subject because most students complain about the lack of correlation between the science curriculum in different subjects or in same subject in different Grade. The educators therefore must focus on aspects when developing science curricula that really make meaningful learning achievable and realistic. Curricula should present science not just as abstract concepts far from our daily life activities, but also as a source of inventions that helped to make our life easy (Al-Hur, 2001).

Awajy (2009) pointed out that the organization of a large number of interrelated concepts is based on the existence of relationships between these concepts of atom, element and compound. These relationships will lead to better achievement, because the process of building interrelated concepts passes through three steps:

1) Discovering the concepts through experiment or observation,

2) Organizing the concepts, and

3) Dividing the concepts on basis of common characteristics.

Kuthr (2012) stressed the importance of developing scientific curricula in Jordan to increase students level of performance in science as a result of the new revolution in education field all over the world; moreover, she recommended to included more example and models for the abstract concepts to be easy to understand, students in all level should apply their knowledge and connect the scientific concepts to find the scientific solution for daily problem.

Mansour (2014) focused on the importance of studying the scientific concepts and the impact of misconceptions on the students' achievement. The study confirmed that the scientific concepts is not a word, but is connected in logical way with other concepts to illustrate specific phenomenon more over the teachers must gradually the present concepts such as atoms, molecular, element and compounds so as to facilitate the process of linking different concepts in the scientific way.

2.8. Summary

This chapter presents findings of previous research studies related to the present study. Many of the reviewed studies were found to be concerned with the topic of students' level of understanding, misconceptions, and related factors that might have an impact on student variables such as students' gender, reasoning ability and teaching methods. They found that those interfered with student performance. The reviewed literature argues that teachers should deal with the student's mind just as a computer deal with information, which needs to organize files and input data. Teachers must make efforts to link the concepts in the mind of the students using familiar examples from the environment or through scientific explanations.

The studies reviewed above showed that students often suffer in chemistry and in concepts associated with chemical bonds as a result of many factors such as curriculum, teaching methods used, evaluation tools, social and personal factor (Carter & Brickhouse, 1987; Nakhleh, 1992; Barrow, 1994; Kirkwood & Symington, 1996; Coll & Taylor, 2001; Dhindsa & Anderson, 2004; Topal 2007). Student gender was also considered as one of the important factors that may affect student level of understanding.

A number of research studies have focused on the factors, which might have a direct effect on the students’ differences' toward academic achievement between the two genders. Among these effects are motivation, students’ ability and biological differences. Some studies show that male students reached to a high level of achievement in science and math and female students got high achievement in art and language (Dayioglu & Asik, 2004; Rusillo & Arias 2004; Naderi, Abdullah, Aizan, Sharir, & Kumar, 2010).

Reasoning ability is another factor that contributed to student understands level of chemistry and chemical bond concepts; it is also affected by the teaching strategies used. Many research studies found a direct relation between student reasoning ability and their academic achievement. For example, students who have high reasoning ability were found to reach higher level of academic achievement much faster than students who have lower level of reasoning ability (Yilmaz & Alp 2006).

The study reviewed above also showed the importance of student centred teaching and guided-inquiry as a viable approach to teaching science and chemistry in particular. The reviewed research studies have clearly established a link between student performance in science and the student centred approaches and guided-inquiry used by teachers (Welty, 1989; Jones, 2007).

The research studies reviewed and presented in this chapter served as a foundation to support the design and implementation of the present study by providing a framework through which analyses of student understanding of chemical bonds concepts can be viewed. Learning chemical bonds concepts is a vital to all students as it represents a core foundation to understanding other chemical and scientific concepts.

Furthermore, the synthesis of research presented in this chapter revealed that the understanding level of students could be raised and improved by using additional viable teaching approaches such as student centred and guided-inquiry approaches. It is intended in this study, therefore to reveal how students conceive the concepts of chemical bonds, their nature of these conceptions and the value of using student centred and guided-inquiry as an alternative teaching method to raise the level of understanding of these concepts.

CHAPTER III - METHODOLOGY

3.1. Introduction

Research methodology directs the researcher in planning and implementing the study in a way that is most likely to achieve the intended goal. It is a blueprint for conducting the study (Walker, 2005). This chapter describes the research design and methodology, including the context, the participants, the design, instruments used, and the data collection and analysis and procedures.

This study investigates students' level of understanding and misconceptions related to the topic of chemical bonds in the context of two public secondary schools in Dubai Educational Zone. This chapter introduces the methodology of the study. The chapter is divided into sections. The first section of this chapter describes the context of the study. The second section describes the population involved in this study whereas the third section deals with research tools used to implement the study. The final section provides details about how data were analysed and presented.

3.2. Context

This study focuses on measuring the level of students' understanding of both male and female students in Tenth Grade at two secondary schools in Dubai Educational Zone. The investigation aims at exploring the possible reasons for students' low achievement in chemistry. The concepts of chemical bonds are incorporated firstly into the UAE science curriculum at 8th Grade in the public schools. The chemical bonds and bonding are given as general information, whereas this topic is emphasised comprehensively in Tenth Grade as described in (Table 1).

It is important to carry out an investigation since science education is regarded as a cornerstone in the evolution of the society. In the present study, I hope that the findings will highlight the impact of teaching methods (guided inquiry approach), gender and students' reasoning and understanding ability and misconceptions regarding the concepts associated with chemical bonds.

3.3. Participants

This study was carried out with 140 students sampled out from 260 students drawn from two public secondary schools in the Dubai Educational Zone. Out of 140 participants, there were 68 male and72 female. The classes were selected randomly from Tenth Grade of two public secondary schools in Dubai Educational Zone. The schools involved were selected on the purpose of convenience, as the researcher is a teacher at one of these schools. The selected sample is considered homogeneous in terms of ability and age.

The majority of the participants were UAE citizens and some of them were other Arab nationalities (Egyptians, Jordanians, Palestinians, Sudanese, Syrians, etc.), whereas their ages ranged between 14-16 years, with various level of academic achievement (excellent to weak). Such various levels in the students' achievement are largely attributed to school records, policies and streaming. The number of students in each class was between 27and 30. The topic of chemical bonds is given briefly in the Eighth Grade science curriculum, whereas is broaden in the Tenth Grade curriculum.

3.4. Design

The study employed a mixed approach to collecting data. Both quasi-experimental quantitative designs as well as qualitative designs in the form of interviews and classroom observations were used in this study. By using both qualitative and quantitative approaches (mixed methods), the researcher tried to achieve the target of this research to arrive at valid and acceptable answers to the research questions. For the quantitative part, the researcher applied many tools.

Pre-post-test related to the topic of chemical bonds and the Lawson test for reasoning ability were used. By utilizing pre-tests, the researcher aimed to measure the students' point of reason and their prior knowledge related to the issue of chemical bonds. In respect to this, both control and experimental groups were at the same degree of performance as revealed by the data analysis chemical bonds test.

The post-test aimed at measuring the effectiveness of treatment method (student-centred and teacher-guided-inquiry) on the students' level of understanding of chemical bonds and level of associated alternative conceptions. On the other hand, Lawson's test was used to measure the students' level of reasoning ability, as well as to find whether there is any link between the level of students' reasoning ability and their achievement in science subject in general, and in chemistry, in particular.

The qualitative part is applied through the use of interviews with some students from different academic abilities and classroom observations. The researcher adopted the method of observation of the behaviour of students in the classroom work, laboratory work and classroom activities among different groups with different academic levels in both the experimental and control group to establish links between classroom practices related to guided-inquiry and student achievement in chemical bond concepts.

In this study, the researcher followed the sequential procedure starting with the quantitative method by dividing the Tenth Grade students into two groups (control and experimental groups); each group included 60 students (30 male and 30 female). The topic of chemical bonds was presented to the control group as scheduled in the curriculum by using traditional teaching method, which focused on a teacher-centred approach by using the board only, or sample models and work sheets. In this approach, the students were given limited opportunity to participate or get involved in any discussion or preparation of scientific materials or submission in the class.

The second group (experimental group) was based on the student-centred approach described by Welty (1989). In this approach, the students were actively involved in their learning and contributed significantly in terms of discussion, and investigating about activities under the guidance of their teachers. Students were divided into groups of different academic levels and the work was distributed under the guidance of their teacher, who acted as a motivator and supporter of the process of learning that allowed the students to build a deeper understanding of the topic. In addition to this, the students were given more responsibility to explain the lesson to their peers. They were also given more opportunity to ask questions and to discuss results with the teacher or to use the school library or internet for in-depth learning.

3.5. Instruments

The research employed three instruments to collect both quantitative and qualitative data, a chemical bonds assessment test, namely Lawson's test for logical reasoning, interviews and observational protocols.

3.5.1. Chemical Bonds Assessment Test

The chemical bond assessment test was prepared by the researcher specifically for the present study to cover the goals described in the chemistry curriculum for the Tenth Grade" chemical bonds”. The concept of chemical, covalent and ionic bonds was in chapter 6 in the chemistry curriculum of Tenth Grade in 4th edition textbook in the 2011/2012 academic year. The chapter includes three lessons i- Identify the chemical bond, ii- General characteristics of covalent bonding and molecular compounds, and iii- General characteristics of ionic bond and ionic compounds. The contents of the three lessons and intended learning goals are illustrated in (Table 1).

Contents	Instructional Objectives
First lesson (*Introduction of a chemical bond*)	1. Give the definition of the chemical bond. 2. Explain why the chemical bonds are formed. 3. Describe ionic and covalent bonds. 4. Determine the type of bond based on the Electro negativity
Second lesson (*General characteristics of covalent bonding and molecular compounds*)	1. Give a definition of the molecule and molecular formula. 2. Classify the relationship between the length of the chemical bond and energy. 3. Determine the type of covalent bond built during Louis structure.
Third Lesson (*General characteristics of ionic bond and ionic Compounds*)	1. Describe the arrangement of ions inside atoms. 2. Determine the general characteristics of ionic and covalent compounds. 3. Comparing the ionic compound and covalent compound.

Table 1: Shows the distribution of the content for each of the three lessons

The goal of the contents was to extend students' prior knowledge of the topic and introduce students to the concept associated with the chemical bonds at Tenth Grade. Mainly the contents aimed at achieving the following objectives:

1. Students had to learn the definition of chemical bonds and use the value of electro negativity to find the difference between ionic and covalent bonds.
2. Students were introduced to the general characteristics of the association of chemical bond such as bond length and strength.

3. Students used the Lewis structure for clarify the relationship between ionic and covalent compounds.
4. Students had to recognize the general properties of ionic compounds.
5. Students had to compare the general characteristics of ionic and covalent compounds, such as boiling and melting points and electric conductivity and hardness.

These objectives were achieved in association with the following previous concepts related to the understanding of the chemical bonds:

1. Boiling and melting point of different components.
2. Electronic distribution in atoms.
3. Location of chemical elements in the periodic table.
4. The electro negativity of the elements.
5. The difference between atoms and ions.
6. The Quantum numbers.

The first version of the test consisted of 30 questions related to the topic of chemical bonds derived from the contents of the chemistry curriculum and focused on achieving the above-mentioned objectives. The following steps were taken to improve the validity and the reliability of the test.

3.5.2. Validity

Validity of an instrument refers to the extent to which the instrument measures is supposed to measure. Research studies identified various forms of validity such content, construct, and face validity. In this research, the test validity was established by submitting the first version of the test, which was made up of 31 questions to be revised by the two Professors of chemistry education in College of Education at the United Arab Emirates University (UAEU).

The test was also reviewed by two chemistry supervisors and two chemistry teachers in the Dubai School District. The chemistry supervisors and the teachers have more than 15 years or experience in teaching chemistry. The test has also been submitted to the chemistry coordinator in one secondary school in Dubai who holds a master's degree in chemistry and has 20years of work experience as a teacher in model secondary school in Dubai. Comments and feedback received were used to improve the wording and the comprehensiveness of the test, and accordingly the first draft was modified. As a result, only 23 questions were chosen to be included in the final version of the test.

In order to make sure that answers to the questions are genuine and reflect the level of understanding of participating students, the test was developed in a multiple-choice format. Each question consisted of two parts: the first part consists of traditional multiple-choice format followed by a reason part in which students are required to justify their response to the first part. This format also allowed the researcher to assess the nature of the misconceptions among the students. The students' responses were regarded as correct if both parts were correctly chosen. Table 2 shows the distribution of the contents of the final version of the test.

Group (1): Formation of ionic and covalent bonds

Sr.	Question
1	Force of attraction
2	Formation of chemical bonds
3	Definition of equivalent bond
5	How chemical bonds are formed

Sr.	Question
7	Types of bond in identical atoms
13	Types of links in covalent compounds
17	Ways of atoms linked to form compounds
21	Covalent bonds formation

Group (2): Properties of ionic and covalent compounds

Sr.	Question
18	Properties of ionic compounds
19	Reason for metal shines as a physical property
20	Type of bonds between metals and non-metal
22	Conductivity in ionic compounds

Group (3): Prior concepts related to the chemical bonds

Sr.	Question
4	Type of bonds on the basis of electro negativity
6	The octet rule
8	The relationship between electro negativity and the types of bond
9	Definition of bond length
10	Lewis atomic structure
11	Recognition of molecular formula
12	Definition of noble gases
14	The definition of the chemical formula
15	NaCl as an example of molecular formula
16	The state of inner energy

Table 2: Distribution of content covered by the test

3.5.3 The Pilot Study

The final 23 test items were piloted using 61students from the Tenth Grade from 2 secondary schools in Dubai Educational Zone, 30 males and 31 females who were not included in the main study; about 23 items constituted the final test.

The pilot study consisted of a cover letter, which included the personal information about the students who participated in the study and definition of the purpose of the study followed by three set of questions. The first part asked about the definitions and the formation of ionic and covalent bonds. The second part focused on the properties of both ionic and covalent compounds and the third part asked about some concepts related to the same topic of the chemical bonds.

3.5.4. Reliability Test

In this study the researcher conducted a reliability analyses to measure the extent to which the test items clustered initially under the three identified area of content knowledge presented in the pilot study were consistent among themselves.

Analysis of the scores obtained from pilot study was used to establish the reliability of the test as well as to allow judging the amount of time needed by students to complete the test in the original study sample. The analysis of the scores collected from the 61 Tenth Grade students revealed that the reliability was found to be 0.79 (Table 3) which was regarded as reasonable and adequate for the purpose of this study and it was in line with the suggestions offered by Leedy and Ormrod (2010, p. 28-29).

Reliability Statistics

No. of Items	Alpha
23	0.79

Table 3: Final test reliability

3.5.5. Lawson Test for Reasoning Ability

The Lawson test for reasoning ability was used to measure the student's ability in the Tenth Grade on scientific reasoning. Previous research studies have pointed to the importance of developing students’ scientific reasoning ability (Lawson & Wesser, 1990).

Gillies, Nichols, Burgh, and Haynes (2014) defined scientific reasoning as a total of the mental processes that are used to assess the beliefs of the students and the linking of facts and knowledge, including data interpretation and logical access to the results. Other studies provided similar views (e.g., Lawson & Bealer, 1984). These studies have generally focused on maximizing student level of scientific reasoning such as linking cause with effect.

Furthermore, these studies have examined the link between scientific reasoning with student age, teaching methods used and the level of previous studies. This means that the existence of factors such as age is associated with the development of reasoning skills in different academic level, where a variety of students acquires knowledge through years of study in different class and different subjects allow them to develop expertise in making a link between the information and concepts and the use of scientific evidence to connect learning in school and try to apply it in their daily life.

Based on the findings of previous studies it was envisioned that guided-inquiry might have an impact on the level of student reasoning ability. So, one of the aims of this study was to examine to what extent guided-inquiry influence students with different reasoning ability levels. It was hypothesized that students who have low level of reasoning ability suffer from difficulty and high level of misconceptions in their academic level in different Grade because they build their knowledge through memorizing information without using analytical skills that are usually associated with scientific reasoning.

On the other hand, students who have had an acceptable level of scientific reasoning might seek to reach acceptable level in their academic achievement because they have an acceptable level of basic skills that are more likely to be associated with inquiry teaching to solve problems they have when studying science. Previous studies have shown that guided-inquiry often positively influences students with high levels of a scientific reasoning (Vosniadou, 1994).

The current study used a scientific reasoning test developed by Lawson to characterize the reasoning ability of participants into low and high reasoning ability groups so that the impact of using a student-centred teaching approach and guided-inquiry could be addressed in relation to reasoning ability of the participants. The validity and the reliability of Lawson test have been addressed in previous research studies, (Lawson & Bealer, 1984).

The reasoning ability test was translated into Arabic and the validity of this Arabic version was established via a critical review of two science educators at a local university and two secondary school English teachers in the Dubai Educational Zone. The validity of the final version was achieved through the confirmation of data obtained by this version and comparing it with another version.

The final version of the test was administered to the sample of the study to characterize the sample as high, medium and low level of reasoning ability. Data analysis showed two groups of student's ability as show in the following table:

Reasoning ability level before treatment		
Group type	***Control group***	***Experimental group***
Low reasoning	42	45
High reasoning	28	25

Table 4: Students reasoning ability level

As shown in Table 4, the participants have equal number of students ate each level of reasoning before the experiment in both group (experimental and control groups). This categorization of student with different scientific reasoning ability will allow examining the respective impact of the intervention (student centred and guided-inquiry), and how students with different level of scientific reasoning respond to the teaching of chemistry using student centred and guided-inquiry approaches.

3.6. The Qualitative Approach

The qualitative approach was applied to support the quantitative part. In this study two qualitative approaches were used, interview and classroom observation and interaction.

3.6.1. Interview

In addition to the quantitative perspective (in the form of a performance test and reasoning ability test to establishing further authenticity to the quantitative data), interview protocols were carried out with 10 Tenth Grade female students of different academic abilities and two chemistry teachers (one male and one female) to support the results of quantitative data of this study used to answer the questions related to the possible reasons of the source of misconception related to the topic of chemical bonds and low level of achievement.

Accordingly, two types of interviews were conducted: face-to-face interview with female students and a telephonic interview with one male chemistry teacher. The researcher clearly explained the purpose of the study and illustrated that the aim of the interview was to give in-depth reasoning for the students' low level of achievement and high level of misconceptions related to the topic of chemical bonds which was illustrated in the quantitative part (pre-test , post-test and Lawson test for reasoning ability). The interview was conducted in Arabic language. They included both open-ended questions and closed questions. Both questions were asked in fixed order and it took about (15-20) minutes.

3.6.2. Classroom Observation and Interaction

The researcher used the classroom observation as an additional support to the data collected by the research instruments to illustrate the possible reasons behind the presence of misconceptions related to research topic and the level of understanding related to the concepts of chemical bonds.

The researcher took the role as a non-participant observer. She recorded events related to the student's interaction in the classroom or in the practical work such as hand raising, correct and wrong answer and the results in the practical work according to the properties of ionic and covalent compounds. One female class from both the experimental and control group was extensively observed for two weeks.

3.7. Procedures

To initiate the present study the researcher started by resolving the logistics needed to collect the information about students' level of understanding and misconceptions related to the topic of chemical bonds by obtaining the necessary permissions to access schools from Dubai Educational Zone so that required information could be explored.

Initially, students' Grade records of final examinations in science subjects (chemistry, biology, physics and mathematics) over previous three years 2009-2011 were reviewed to in order to evaluation accurately the real level of students' achievement, particularly in chemistry. According to the results in the final records, students showed remarkably varied levels of achievement in chemistry. Based on this step the researcher started preparing an appropriate design to conduct the present study on students' level of understanding and possible reasons for low levels of achievement related to the topic of chemical bonds.

The study was conducted during the second term of 2011-2012 academic year, when the topic of "Chemical bond" was being covered as part of the regular school curriculum. The instruction for the two study groups took place during the same weeks by the same teacher (the researcher) and lasted for a period of one month with eight class-hours (45 min each) each week.

3.7.1. The Experimental Group

Experimental group had their instruction in the laboratory. Since, guided inquiry may be regarded as a new practice for the students, before the treatment students in the experimental groups were trained about the usage of instructional tools related to teaching and learning in the laboratory so that they were aware of the teaching approach. They were allowed to work individually as well as in groups with guided instructions from the teacher who was also the researcher.

The activities that are related to the guided-inquiry practices were developed in advance and students in the experimental group spent more time involved in i- investigation, and ii- how they could independently carry out their respective planned activities with a minimum intervention from teachers. Often the teacher made brief introduction about the subject that was the focus of the lesson and simply presented the content. Then, the students were left to work alone, with minimal interference from the teacher who was present only to respond the questions raised by students. The major part of instruction time (70–80%) was devoted to students' engagement with experiments under the supervision of the teacher with minimum intervention from the teacher.

3.7.2. The Control group

The control group was given traditionally designed instruction, which is the dominant approach found in most of the UAE schools. In the control group, the teacher-directed strategy was used as traditional instruction. The teacher used lecture and discussion methods to teach the chemical bond concepts. The students were required to read the related topic of the lesson from the textbook before class.

In addition, the teacher described and defined the issues and afterwards, students were engaged in discussion through teacher-directed questions. The major part of instruction time (70–80%) was devoted to instruction and engaging in discussions stemming from the teacher's explanation and questions.

3.7.3. Stages of implementation

- ***First stage: Preparation of study tools***

Tools were identified to answer research questions. In this stage, the test of measuring the performance of Tenth Grade students related to the topic of chemical bonds was prepared. In addition, the test of measuring students' level of reasoning ability had been translated and prepared. The two instruments were then piloted, validated, and prepared in their final forms for actual implementation.

- ***Second stage: The pre-test***

In order to establish a baseline for student level of understanding before introducing the intervention, the participants were pretested using the test for assessing students' level of understanding related to the concept of chemical bonds.

- ***Third stage: The post-test***

After a month of intervention, the researcher post tested the participants using the same test for the second time to assess students' level of understanding of the chemical bond concepts on both the experimental and control groups in order to assess the effectiveness of the intervention (student centred approach and guided-inquiry).

3.7.4. Data Analysis

In the present study, both quantitative and qualitative data were analysed using descriptive and inferential statistics for quantitative data and thematic analyses for the qualitative data.

3.8. The Quantitative Part

In this study, data was analysed by using the Statistical Package for the Social Sciences (SPSS) programme for both achievement test (pre-test, post-test) and the Lawson test for reasoning ability. The results of the pre-test, post-test and Lawson test for reasoning ability were converted in to numbers and transferred into the SPSS programme to calculate descriptive and inferential statistics.

3.9. The Qualitative Part

In this study, the researcher listed some common student behaviours through classroom interaction and discussions related to the topic of chemical bonds to triangulate findings from the quantitative part.

The findings of both the observations and interviews assisted in explaining the reasons behind students' low levels of achievement, as well as high level of misconceptions. These findings might support the quantitative part and tried to answer the research questions and to find the possible solutions to increase students' achievement in science and chemistry subject.

3.10. Summary

The aim of this study is to assess student level of understanding and misconceptions related to the topic of chemical bonds because this topic is considered as one of the most important topic in Tenth Grade chemistry curriculum of the UAE, because it is linked with many other topics. To achieve research target, the researcher applied this study to (140) students in two public schools in Dubai.

The sample was selected randomly from Tenth Grade students from two convenient schools. The study employed a mixed methods approach to collect data quantitatively using pre-test and post-test design as well as another test namely the Lawson of logical reasoning to determine the reasoning ability level of students in order to assess its impact on student understanding of concepts related chemical bonds using student centred and guided-inquiry approach.

Qualitatively, the researcher used classroom observation and interview with both teachers and students from different academic achievements to try to explain and ascertain reasons behind low levels of achievement regarding these concepts associated with chemical bonds. To achieve the study targets, the data collected in this study has been analysed by using the SPSS programme in order to answer the research questions.

CHAPTER IV - FINDINGS AND DISCUSSION

4.1. Introduction

This chapter presents and discusses the result of data analysis of both the quantitative and qualitative part of this study. The quantitative analysis deals with presentation of findings related to the alternative conceptions of chemical bonds that are held by Tenth Grade students in public schools in the Dubai Educational Zone.

The analysis in this part focuses on the conceptions and the alternative conceptions shown by Tenth Grade students regarding chemical bonds concepts, the impact of the intervention, the guided-inquiry strategy on improving student conceptions of these concepts, the significant differences in student performance attributed to student gender in guided-inquiry and traditional contexts, and the relationship between students' reasoning ability and their performance in the topic of chemical bonds.

On the other hand, the data analysis of the qualitative part aims to find sources of the nature of the alternative conceptions held by Tenth Grade students and to describe the different reasons for the low level of achievement that students show in chemistry related to the topic of chemical bonds. All together, the results deal with the following questions:

1. What are the alternative conceptions of chemical bonds that are held by Tenth Grade students?
2. What is the nature of the alternative conceptions held by Tenth Grade students?
3. How did centred and guided-inquiry approach affect student performance?

4. Are there any significant difference in performance attributed to students' gender in student centred and guided-inquiry and traditional context?
5. What is the relationship between student reasoning ability and understanding of chemical bond concepts?

4.2. Level of Understanding of Students of Chemical Bond Concepts

An important step to improve the learning process of students is to find out what they already know so that prior knowledge can be established and learners can be taught accordingly. The first step taken in this research was to find out the participants' level of understanding of chemical bond concepts.

In order to answer the first research question on the level of understanding of the concepts of the chemical bonds topic and the association chemical concepts shown by Tenth Grade students, mean and standard deviations of both control and experimental groups before the start of the intervention were calculated and presented. Table 1 showed that before the start of the intervention both groups showed similar levels of understanding to the topic of chemical bond as seen by the approximately similar mean scores of 5.7 and 5.4, respectively.

The mean scores for both groups represent 24.9% and 22.3% respectively, indicating low understanding. Furthermore, in order to test for any significant differences between the means of both groups *t*- test was performed and the value of (*t*-test) was found to be insignificant ($t = 1.643$, $P \leq 0.05$) indicating that both groups had similar chemical bond knowledge.

	Group type	N	Mean	Std. Deviation	Std. Error Mean	*t*-Value	Sig,
Pre-test for achievement	experimental	70	5.7	2.5	0.454		
	control	70	5.46	1.9	0.446	1.643	0.103 1

Table 5: **Pre-test scores for experimental and control groups**

(Table 5) clearly shows that the two groups of students responded almost in similar way suggesting that they have a similar background and knowledge of concepts related to chemical bonds, and thus, no significant differences can be recorded. In order to pinpoint the alternative conceptions at this stage, answers to the first research question (*What are the alternative conceptions of chemical bonds that are held by Tenth Grade students*?) were further investigated by analysing data before and after implementing the guided-inquiry approach as an intervention strategy. Each section of the test was analysed individually.

The results were based on calculating the percentages and frequencies of each question before and after the intervention. Every student answered the question and chose the possible scientific reason for each question and each correct answer or correct reason coded as one point mark. Both the questions and *t* results are illustrated in the following tables for the experiment and the control groups before and after the treatment:

Question		(A)		(B)		(C)		(D)	
		Frequency	**%**	**Frequency**	**%**	**Frequency**	**%**	**Frequency**	**%**
1	Experimental	41	58.5	14	20.0	4	5.7	11	15.7
	Control	38	54.2	17	24.2	5	7.1	10	14.2
2	Experimental	29	41.4	16	22.8	7	10.0	17	24.3
	Control	31	44.2	17	24.2	7	10.0	15	21.4
3	Experimental	20	28.5	32	45.7	5	07.1	13	18.5
	Control	18	25.7	35	50.0	12	17.1	14	20.0
5	Experimental	16	22.8	12	17.1	18	25.7	24	34.2
	Control	19	27.1	9	12.8	16	22.8	26	37.1
7	Experimental	11	15.7	15	21.4	6	08.5	38	54.2
	Control	6	08.5	11	15.7	12	17.1	41	58.5
13	Experimental	13	18.5	22	31.4	15	21.4	20	28.5
	Control	9	12.8	24	34.2	12	17.1	25	35.7
17	Experimental	6	08.5	10	14.2	14	20.0	40	57.1
	Control	4	05.7	16	22.8	11	15.7	39	55.7
21	Experimental	11	15.7	9	12.8	10	14.2	40	57.1
	Control	8	11.4	10	14.2	13	18.5	39	55.7
Average	Experimental	**18.0**	**25.7**	**16.0**	**22.8**	**10.0**	**14.2**	**25.0**	**35.7**
	Control	**16.0**	**22.8**	**17.0**	**24.2**	**11.0**	**15.7**	**26.0**	**37.1**

Table 6: Pre-test result of Subtest-1

(**A**= Correct answer & correct reason; **B**= Correct answer & wrong reason;

C= Correct reason & wrong answer; **D**= Wrong answer & wrong reason)

(Table 6) presents the pre-test result of Subtest 1 (*Definition /Formation of Ionic and Covalent Bonds*) for the experimental and control groups. The responses for each group are divided into four categories to reflect levels of performances as follows:

1. If a student provided correct answer and correct reason to the question the student was be awarded mark and his/her response was regarded as correct conception of the tested concept.

2. If a student provided correct answer and wrong reason to support his answer the students is classified as partial understanding, was awarded half the marks.

3. If student provided a wrong answer and a scientifically correct reason, the student shall also be classified as not having a sound understanding, was awarded half marks.

4. If a student provided wrong answers and wrongs reasons to support these answers the student was judged to lack any understanding of the tested concepts.

(Table 2) also shows as well the students in both group performed poorly. Only 25.7% and 22.8% of the experimental and control groups succeeded to answer the entire questions of this sub-test correctly by providing a correct responses to support scientifically acceptable reasons.

The same Table showed that students in both groups performed poorly (less than 20%) on topics such as types of bond in identical atoms (15.7% for experimental group and 8.5% for control group), types of links in covalent compounds (18.5% for experimental group and 12,8% for control group), ways of atoms linked to form compounds (8.5% for experimental group and 5.7% for control group) and covalent bonds formation (15.7% for experimental group and 11.4% for control group). It can be hypothesized that such low responses might have resulted from the lack of meaningful understanding and the lack of meaningful instruction that lead to meaningful understanding (Fullan, 2005).

	Question	**(A)**		**(B)**		**(C)**		**(D)**	
		Frequency	**%**	**Frequency**	**%**	**Frequency**	**%**	**Frequency**	**%**
18	Experimental	13	18.5	14	20.0	12	17.1	31	44.2
	Control	9	12.8	11	15.7	15	21.4	35	50.0
19	Experimental	15	21.4	11	15.7	11	15.7	33	47.1
	Control	17	24.2	15	21.4	10	14.2	28	40.0
20	Experimental	9	12.8	11	15.7	16	22.8	34	48.5
	Control	7	10.0	13	18.5	16	22.8	34	48.5
22	Experimental	12	17.1	10	14.2	13	18.5	35	50.0
	Control	14	20.0	11	15.7	15	21.4	30	42.8
Average	Experimental	**12.0**	**17.1**	**12.0**	**17.1**	**13.0**	**18.5**	**33.0**	**47.1**
	Control	**12.0**	**17.1**	**13.0**	**18.5**	**14.0**	**20.0**	**32.0**	**45.7**

Table 7: Pre-test result of Subtest 2

(**A**= Correct answer & correct reason; **B**= Correct answer & wrong reason;
C= Correct reason & wrong answer; **D**= Wrong answer & wrong reason)

In a similar way, Table.7 shows that only 17.1% in both experimental and control group correctly responded to the questions of this sub-test of "*Properties of ionic and covalent compounds*". Students in both groups performed poorly on topics such as properties of ionic compounds (18.5% for experimental group and 12.8% for control group) and conductivity in ionic compounds (17.1% for experimental group and 20.0%

for control group), leaving a large percentage of students who failed to correctly answer the questions at both the answer and the reason levels.

Finally, Table.8 shows the students' responses to sub-test 3, which is concerned with prior concepts related to the chemical bonds. Students also responded poorly in this sub-test. On average, only 21.4% of students in the experimental group and 17.1 in the control group managed to provide correct responses to questions in this section. Students on both groups performed poorly on topics such as the relationship between electro negativity and the types of bond (14.2% for both experimental and control group), definition of bond length (14.2% for experimental group and 10.0% for control group), definition of noble gases (8.5% for experimental group and 7.1% for control group) and the definition of the chemical formula (15.7% for both experimental and control group).

Question		**(A)**		**(B)**		**(C)**		**(D)**	
		Frequer	**%**	**Frequen**	**%**	**Frequen**	**%**	**Frequenc**	**%**
4	Experiment	17	24.2	16	22.8	15	21.4	22	31.4
	Control	12	17.1	19	27.1	11	15.7	28	40.0
6	Experiment	23	32.8	8	11.4	12	17.1	27	38.5
	Control	19	27.1	11	15.7	7	10.0	33	47.1
8	Experiment	14	20.0	12	17.1	16	22.8	28	40.0
	Control	10	14.2	14	20.0	12	17.1	34	48.5
9	Experiment	10	14.2	14	20.0	10	14.2	36	51.4
	Control	7	10.0	10	14.2	12	17.1	41	58.5
10	Experiment	16	22.8	15	21.4	7	10.0	32	45.7
	Control	11	15.7	17	24.2	10	14.2	32	45.7
11	Experiment	21	30.0	24	34.2	10	14.2	15	21.4
	Control	18	25.7	24	34.2	12	17.1	16	22.8
12	Experiment	6	8.5	15	21.4	7	10.0	42	60.0
	Control	5	7.1	14	20.0	9	12.8	42	60.0

	Experiment	15	21.4	8	11.4	3	4.2	44	62.8
14	Control	11	15.7	11	15.7	1	1.4	47	67.1
	Experiment	11	15.7	20	28.5	13	18.5	26	37.1
15	Control	9	12.8	17	24.2	17	24.2	27	38.5
	Experiment	12	17.1	12	17.1	17	24.2	29	41.4
16	Control	14	20.0	10	14.2	13	18.5	33	47.1
Average	Experiment	**15.0**	**21.4**	**14.0**	**20.0**	**11.0**	**15.7**	**30.0**	**42.8**
	Control	**12.0**	**17.1**	**15.0**	**21.4**	**10.0**	**14.2**	**33.0**	**47.1**

Table 8: Pretest result of Subtest 3

(**A**= Correct answer & correct reason; **B**= Correct answer & wrong reason;
C= Correct reason & wrong answer; **D**= Wrong answer & wrong reason)

4.3. Analysis of Student Performance in Chemical Bonds Concepts

Examining the findings presented in Tables 6, 7, and 8, the students showed an acceptable level of performance in some of questions that focus on the ability of remembering simple concepts in chemistry such as Force of attraction in question No.1 (58.6% for experimental group and 54.2% for control group), the definition of valence electrons in question No.3 (Electrons participating in the formation of chemical bonds called valence electron), 28.2% for experimental group and 25.7% for control group). The octet rule (32.8% for experimental group and 27.1% for control group) and recognition of molecular formula in question No. 11 (Which of the following examples is not an example of a molecular formula, 30 % for experimental group 25.7% for control group).

For questions that needed mental skills and inquiry (e.g., Questions No. 7, 8, 9, 12, 14, 17 18, 19, 20 and 21) most of the study sample showed low level of performance. The percentage of students who failed to answer these questions ranged between (47.1% for experimental group and 40.0% for the control group in question 19 to 60% for both groups in question 12). For example for Question No.7, which deals with the type of bonds in identical atoms, the number of students who able to give correct answers and correct reasons for their answers ranged between 8.5% to 15.7% of the study sample in both experimental and control group. Similarly, Question No.14 that focuses on the type of links associated with the covalent compounds, approximately 15.7 to 21.4% of the students were able to answer the questions correctly and in a scientific way in both groups while 62.8% to 67.1% failed to answer the questions correctly.

It may be speculated that students are unable to link the concepts of similar atoms and internal energy of the atoms during association of the bonds type through the chemical reaction. Moreover, the students may not be able to imagine how the atoms integrated during the reaction. The level of performance can also be seen in question number 8 when the question asks about the relationship between electro negativity and the type of bond. Only 14.2% to 20% in both groups can answer this question correctly and scientifically, whilst 40.0% to 48.5% in the groups respectively failed to reach to the correct answers or scientific reasons.

On the other hand, bond length tested in Question No.9 is considered a barrier for most of the study sample; only 10% to 14.2 % of students in both groups answered this question correctly, while 51.4% to 58.5% were unable to display correct answers or responses in both groups. This low level of performance was similar in Question No.19, which focused on "the ability of metal to shine" as a physical characteristic of the elements in the first and the second group of the periodic table, which includes the alkali metals in this question. Only 21% to 24.2% of the students showed acceptable understanding in both groups, while 40% to 47.1% answered the question incorrectly.

Furthermore, students were unable to make links between some concepts such as Question No.17 (ways atoms are linked to form compounds), and the relationship between these concepts and other similar concepts mentioned in other questions such as in Questions No.20 (Type of bonds between metals and non-metal). For example, Question No.17 focuses again on the reason behind the formation of chemical bonds and the role of electro negativity and related concepts such as the stability of the octet rule and the tendency of metals to lose electrons and non-metals to gain electrons from the external level as a way to form bond. In such questions, students should make a link between more concepts to display the correct answer.

The general performance of students has also decreased in questions No. 20 and 21. Question No. 20 asks about the type of links between metals and non-metals based on the location of the elements in the periodic table. The percentage of correct answers ranged between 10% and 12.8% of the total number of students who participated in this study in both the experimental and control groups.

On the other hand, about 48.5% of the students gave the incorrect answer. Students showed the similar performance in Question No.21, which focuses on the type of bond formation between non-metal compounds where the percentage of correct answers obtained was 11.4% in control group and 15.7% in experimental group. The percentage of wrong answer reached 55.7% to 57.1% in both groups.

Questions No.18 deals with the ability to identify and separate the properties of ionic compounds and covalent compounds based on the physical properties such as fusion and boiling point and electrical conductivity. The percentage of correct answers ranged between 12.8% and 18.5% of the total number of students participating in the study, while the percentage of wrong answers in both the selection of the correct answer, or the correct scientific explanation was 44.2% to 50% of total number of study samples. These findings suggest that students were unable to perform as expected from them and as stated in the curriculum document.

A conclusion could be drawn on student performance on concepts related to the chemical bonds, and can be summarized that students showed high levels of misconceptions related to the following points:

1. Formation of chemical bonds
2. Type of bonds on the basis of electro negativity
3. Recognition of molecular formula
4. Mechanism of chemical formula
5. Electric conductivity in ionic compounds
6. Lewis atomic structure

4.4. How did Guided-inquiry Influence Student Performance?

The results that were generated from recent developments in cognitive learning theory and classroom research have suggested that the students generally experience improved learning when they are actively engaged in the classroom to enable construction of new knowledge within the course of the learning cycle. Farrell, Moog, and Spencer (1999) described an implementation of these ideas in the instruction of a first-year course in general chemistry for secondary students.

Findings from the first research questions clearly call for intervention to raise student performance in the chemical bonding concepts. Previous research studies suggested that inquiry teaching and a student-centred approach significantly impact student learning (Jones, 2007; Turner & Patrick, 2004; Welty, 1989), particularly when coupled with teacher intervention and guidance (Chin & Brown, 2000; Turner & Patrick, 2004).

Analysis of the question related to whether or not the guided-inquiry strategy might affect student performance was based on comparing student performance before and after the implementation the guided-inquiry approach as an intervention strategy. Students in both experimental and control groups were tested after the intervention. Results are presented in the following Table:

Group type	N	Mean	SD	Std. Error	*t*-value	sig
Experimental group	70	15.0	2.6	0.3135		
Control group	70	12.0	2.5	0.2927	7.026	0.000

Table 9: Comparison of experimental and control group on post-test scores

As it can be seen in (Table 9), the intervention (guided-inquiry strategy) has significantly influenced the performance of students in the experimental group. Although the students' performance has increased from an average of 5.7429 and 5.1286 for students in experimental and control groups to 14.9857 and 11.9714 respectively there was also a significant increase in mean score of the experimental group (t = 7.026, ($p < 0.000$). This means that the guided-inquiry strategy has positively influenced the performance of students who were taught using this strategy. It seems that using guided-inquiry, as a teaching method would give students more opportunity to participate in the classroom and lead them to develop self-confidence and hence self-learning. Guided inquiry seems to have helped students to achieve high level of understanding with minimum level of misconceptions. Previous research studies had similar findings (Bowell & Eison, 1991; Kuhn, 2010).

Furthermore, Kuhn (2010) recommended using a guided-inquiry approach because it is a dynamic process, which gives students opportunity to be involved in learning positively and build a strong and correct understanding of scientific subjects. This is particularly true for all students in different level of ability because guided-inquiry approach would give them attentions that are more individual in the classroom and thus, they can explore learning meaningfully. Pazicni & Bauer (2014) supported the same findings of Kuhn, as they believed that guided-inquiry is a powerful approach of learning experience in introductory chemistry students.

In order to assess the impact of guided-inquiry on individual concepts tested by the questions, responses of students to individual test items were carefully examined for each sub-test. Tables No. 6-8 display the percentage and frequencies of the students who answered post-test questions in both experimental and control groups in the three different subsets and compared them with the students' performance in the pre-test. This analysis will assist in identifying how the guided-inquiry and the intervention would influence student performance.

Table 10 (definition/formation ionic and covalent bonds) compares the performance of students in both experimental and control groups regarding before and after the intervention. These results showed clearly that the understanding level of the experimental group increased significantly higher than that of the control group did. According to findings, it appears that guided-inquiry influenced student achievements significantly better than the traditional strategies used with the control group.

Question		(A) Post-test		(B Pre-test		
		Frequency	Percent	Frequency	Percent	Increase in %
1	Experimental	58	82.8	41	58.5	24.3
	Control	38	54.2	38	54.2	0.00
2	Experimental	53	75.7	29	41.4	43.3
	Control	46	65.7	31	44.2	21.5
3	Experimental	43	61.4	20	28.5	32.9
	Control	38	54.2	18	25.7	28.5
5	Experimental	57	81.4	16	22.8	58.6
	Control	53	75.7	19	27.1	48.6
7	Experimental	47	67.1	11	15.7	51.4
	Control	29	41.4	6	08.5	32.9
13	Experimental	51	72.8	13	18.5	54.3
	Control	29	41.4	9	12.8	28.6
17	Experimental	19	27.1	6	08.5	18.6
	Control	17	24.2	4	05.7	18.5
21	Experimental	35	50.0	11	15.7	34.3
	Control	16	22.8	8	11.4	11.4
Average	Experimental	**45.0**	**64.7**	**18.0**	**25.7**	**39.7**
	Control	**33**	**47.3**	**16.0**	**22.8**	**23.7**

Table 10: Post result of Subtest-1 for experimental/control group

(**A**= Correct answer and correct reason; **B**= Correct answer and correct reason)

McDonnell (2013) investigated the use of guided-inquiry approach in the chemistry classroom. The study revealed that the students demonstrated increased engagement during class activities. Both the students and the teacher also experienced an increase in motivation as a result of the guided- inquiry intervention. This study recommends the increased use of guided inquiry in all units of chemistry and the rewriting of existing laboratory activities to promote more higher-order thinking and student-directed learning.

Therefore, teaching chemistry through guided inquiry might help the students to reconstruct knowledge in their mind through active participation in the classroom, as well as to encourage the students to develop concepts in theoretical and experimental procedures. Although there is a considerable body of literature on the benefit of inquiry teaching, few chemistry teachers appear to have implemented it in their chemistry class, which could help students to think out of the box and give critical and creative solutions to different situation (Cheung, 2009). Table 11 (properties of both ionic and covalent compounds) shows how the student responded to the questions related to properties of both ionic and covalent compounds and how guided theory influenced their answers.

The Table also shows that in general positive responses were observed. Compared with the increase in the student percentages in the control group, the student percentages in the experimental group who correctly answered the questions has increased for all questions. This is an indication of the positive impact of the intervention strategy used with the experimental group.

Question		**(A)**			**(B)**	
		Post-test		**Pre-test**		Increase
		Frequency	%	Frequency	%	in %
18	Experimental	41	58.5	13	18.5	40
	Control	18	25.7	9	12.8	12.9
19	Experimental	48	68.5	15	21.4	47.1
	Control	24	34.2	17	24.2	10.0
20	Experimental	46	56.7	9	12.8	43.9
	Control	29	41.4	7	10.0	31.4
22	Experimental	13	18.5	12	17.1	01.4
	Control	11	20.0	14	15.7.0	05.5
Average	Experimental	**37**	**50.5**	**12.0**	**17.1**	**33.1**
	Control	**21**	**29.2**	**12.0**	**17.1**	**14.9**

Table 11: Post-test result of Subtest 2 for experimental and control group

(**A**= Correct answer and correct reason; **B**= Correct answer and correct reason)

With the exception of Question No.22, all questions show remarkable increases in the percentages of students who correctly answered these questions after being exposed to the guided-inquiry strategy. This means that when students are given opportunity to inquire and apply investigative behaviours during learning they are more likely to develop analytical skills needed to reason and solve chemical problems similar to those shown in this performance test. These findings are in line with the study of Black and William (1998) who found that if teachers give students more opportunities (using guided-inquiry) to explore and self-learning through using experiments, lab work, research and media this will encourage them to analyse, classify, compare scientific information and find links between different subjects such as the differences between the properties of ionic and covalent compounds.

In similar way, Schroeder and Zarinnia (2001) found similar results; using guided-inquiry help students to have a life-learning experience always accrue through integrating the curriculum and enabling students to learn meaningfully from diverse information sources. In short, in guided-inquiry environment students will able to build the bigger picture of learning (Bonwell & Eison, 1991). An interesting observation is the response from the control group in which the right response after using the guided theory only increased by 14.9% on average compared to 33.1% in the experimental group. A further look into possible reasons is required because the difference in the responses is almost double. Also looking at the results from the Table we can clearly see that when using traditional approach only 29.2 % of students (21 out of 70) were able to provide right answers in the area of "*properties of both ionic and covalent compounds*" compared with the guided-inquiry approach.

The students in the control group performed poorly in this section, which can be explained by the fact that the nature of the topic “properties of ionic and covalent bonds” can only be understood by engaging students in hands-on activities and experimental experiences, which are missing from the traditional approach to teaching experienced by these students. Table 12 (*Prior concepts related to the chemical bonds*) shows that the results of the questions about prior concepts are related to the same topic of the chemical bonds, and reflects concepts of students from both groups.

Eleven questions were asked and the average results showed that the student percentage in the experimental group compared to that of the control group has increased from 21.4% to 39.5%% after the intervention. This high percentage in this area of the chemical subjects is the highest among the three areas tested which strongly prove the worthiness of the intervention as a viable teaching approach.

Question		**(A)**		**(B)**		
		Post-test		**Pre-test**		
		Frequency	%	Frequency	%	Increase in %
	Experimental	41	58.5	17	24.2	34.3
4	Control	19	27.1	12	17.1	10.0
	Experimental	52	74.2	23	32.8	41.4
6	Control	51	72.8	19	27.1	45.7
	Experimental	41	58.5	14	20.0	38.5
8	Control	21	30.0	10	14.2	15.8
	Experimental	50	71.4	10	14.2	57.2
9	Control	26	37.1	7	10.0	27.1
	Experimental	48	68.5	16	22.8	45.7
10	Control	32	45.7	11	15.7	30.0
	Experimental	35	50.0	21	30.0	20.0
11	Control	38	54.2	18	25.7	28.7
	Experimental	43	61.4	6	5.0	52.9

	Control	14	20.0	5	07.1	12.9
12						
	Experimental	34	61.4	15	21.4	40.0
14	Control	35	50.0	11	15.7	34.3
	Experimental	37	52.8	11	15.7	37.1
15	Control	28	40.0	9	12.8	27.2
	Experimental	32	45.7	12	17.1	28.6
16	control					
		17	24.2	14	20.0	2.0
Average	Experimental	**42**	**59.2**	**15.0**	**21.4**	**39.5**
	Control	**28**	**40.1**	**12.0**	**17.1**	**23.3**

Table 12: Post-test result of Subtest 3 for experimental and control group
(**A**= Correct answer and correct reason; **B**= Correct answer and correct reason)

The findings presented in Table 8 seem to support many findings from previous studies of Nahum, Mamlok-Naaman, Hofstein, and Krajcik (2007), and Dhindsa and Anderson (2004); they concluded that using traditional approaches in teaching science will lead students toward more misconceptions in science subject because teacher focus on getting structure to memorize the information by giving them direct questions and using limited resources. Dhindsa and Anderson (2004) reported similar findings from their research; they recommended that if teachers do not give the students more opportunities for self and independent learning by exploring the world of knowledge they cannot build a strong experience from what they learn.

Researchers recommended the use of the guided-inquiry strategy to help students reach a high level of understanding because of its ability to help students become involved and actively engaged in classroom activities, which will lead to self-learning and personal knowledge construction (Welty, 1989). In guided-inquiry context, students do not depend on their teachers all the time; they only wait for instructions, advice or words of approval (Jones, 2007). In such circumstances, the teacher may engage in planning lessons, the activities related to student culture, and environment, whereas leave the actual engagement, and learning to students, so most of these become the centre of learning processes (Chin & Brown, 2000).

The findings also point to the fact that guided-inquiry strategy may be considered as an appropriate strategy to implement for questions that need critical thinking and/or meaningful understanding such as those presented in sub-tests 2 and 3. Students can explore different relationships and get the understanding needed to comprehend issues such as formation of bonds and electronegativity or metallic a non-metallic elements (Barr & Tagg, 1995).

4.5. Relationship between Students' Gender and Performance

To answer the question related to gender differences because of the intervention, pre-test and post-test scores were compared and possible interaction between the gender and the experiments were examined. (Table 13) and (Table 14) show the comparisons of the scores before and after the intervention. The results presented in Table.13 shows no significant differences finding between male and female before the experiment.

Student gender		N	Mean	Std. Deviation	Std. Error Mean	F	sig
Control	male	33	5.6	1.4	0.23546		
	female	37	5.8	1.5	0.24950		
Experimental	male	35	6.0	2.7	0.614	2.662	0.112
	female	35	5.6	2.4	0.40791		

Table 13: Student performance in the pre-test of the chemical bonds

Whereas results presented in (Table 14) show that, there were significant differences between the groups in favour of the male students. Male students obtained a mean score of 15.5 compared to female students who obtained a mean score of 14.6. Both of the groups (male and female students) have significantly raised their performance after the experiment indicating that the student centred and guided-inquiry approach helped them to improve their performance. Previous research studies showing differences in performance regarding student performance related to their gender are similar to these findings.

Student gender		N	Mean	Std. Deviation	Std. Error M	F	sig
Control	male	33	12.5	2.2	0.29275		
	female	37	11.5	2.62	0.42909		
Experimental	male	35	15.5	3.02	0.50936		
	female	35	14.52	2.12	0.35585	49.368	0.000

Table 14: Student performance in the post-test of the chemical bonds

Two points of discussion can be drawn from (Table 10) that the intervention used in this study matches to a large extent the learning perspectives of both male and female students, and as such, it has contributed to their performance in improving from the initial performance shown in the pre-test. The second point is that the male students (and as expected) showed a better performance than the female students, although the difference is not high but in this case the difference is higher compared to the difference from the pre-treatment results.

It could be concluded that male students showed a better performance when using the guided-inquiry compared to female students. When looking to the Arabic culture within the UAE context, the gender difference could be justified by the tendency of male students to be more independent from instructions and often like have more space when learning. In this way, one may conclude that the student centred and guided-inquiry approach matches male students more than the female students in terms of the freedom of expression and the space provided through active involvement and participatory mode of the approach.

The contextual and the cultural circumstances shown in this study, confirm that it is possible to create a new learning culture to help students to enjoy the learning process, especially with male students (Wilson, Taylor, Kowalski, & Carlson, 2010). The findings of this study are similar to the results of other studies about the same topic (Shymansky, Hedges, & Woodworth, 1990). The success of guided-inquiry such the approach used in this study in enhancing student performance was emphasized more in the literature (Aho, Huopio, & Huttunen, 1993).

In this study, the guided-inquiry helped in developing the achievement level of the students. The findings presented in this study showed that the student centred and guided-inquiry approach seem to be better approaches for teachers who are not experienced in conducting open inquiry approaches as is the case for most of the UAE science teachers. Thus, within this context, the findings of this study may be used as a precursor for further professional development for the UAE science teachers who are not familiar with the guided-inquiry approaches.

4.6. Qualitative Findings

To supplement findings of the quantitative analysis regarding the nature of student understanding of chemical bonds concepts, the researcher used classroom observations and interviews with selected individual students from both experimental and control groups. The results of these observations and interviews were classified and grouped to come up with descriptive themes. The process of grouping yielded meaningful themes that reflect some of the problems that contributed to the low level understanding of students as can be seen in (Table 15).

The findings presented qualitatively in the above table are in line with the findings of previous studies that the negative images of science and chemistry in particular and the perception possessed by students towards chemistry contribute negatively to understanding. Furthermore, it was found that teaching methods used, curriculum and prior knowledge could also be regarded as determinant factors (Driver & Easley, 1978).

It becomes apparent from the interview that many students were unable to make a link between the abstract concepts and the chemical knowledge in real life situations. They believed that chemistry was very difficult in nature because of the existence of the abstract concepts such as electronegativity, molecules and atoms and they could not see how these concepts relate to everyday life situations.

Theme	***Interpretative meaning***
Perceived difficulty of chemistry as a subject among students	Chemistry was perceived as a subject that is difficult by nature. Students do not think that they are good enough to understand and do well in chemistry.
	The existence of many abstract concepts that cannot be easily understood in depth because they do not see those concepts with their naked eye and cannot deal with them directly in the laboratory or daily life, such as the atom, Electro negativity and Lewis structure.

Role of prior knowledge	Most students think that they lack the conceptual level needed to comprehend concepts associated with the topic of chemical bonds.
	Curriculum length and frequency of the homework that do not allow enough time to review the information.
Time spent on task and laboratory work	Laboratory work is something to be done to complete tasks. The perceived importance of laboratory work has not been integrated and understood by students. Laboratory work doesn't provide much information to understand the theory of chemical bonds
Teaching methods and classroom interactions	Teaching methods used in the classroom focus on the amount of information provided to the students and not on how the information is presented. Teaching methods focus on preparing the students for the examination only and not to learn and develop their skills.
	Teachers do not take into account individual differences among students in the preparation of the examination or worksheets and classroom activities.
	Existence of teaching behaviors that do not encourage students to perform well in the subject.
Quality of textbooks	Textbooks do not provide the needed information to aid understanding.
	Textbooks lack illustrative examples for some concepts in the science curriculum.

Table 15: Responses to perceived challenges to chemical bonds understanding

Previous research findings such as those of Haidar and Abraham (1991 suggest that student can greatly impact achievement. These findings, along with the emerged findings of the qualitative analysis of this study clearly suggest a need to modify science curriculum teaching methods used and the need to give students more opportunity to realize the connection between and the role of prior knowledge in the development of meaningful understanding and conceptual map of chemical knowledge.

On the other hand, time spent on task and laboratory work have direct effects on students' level of understanding. The findings of the present study suggest that students did not really conceptualize the role of laboratory work in aiding understanding. The perceived role of laboratory work seems to be as something that is required by the curriculum developers rather than opportunities to realize the practical aspects of chemistry and how theories are developed. Studies such as those of Al-Naqbi and Tairab (2005) have shown that laboratory work is an integral part of learning science and therefore it should be implemented meaningfully and provide students with the necessary tools to bring a positive attitude to and perception of the role of practical work.

Teaching methods and classroom interactions are considered as one of the most important factors that impact student understanding in science subjects (Turner & Patrick, 2004). Students interviewed and observed in this study commented on classroom interactions. Participants believed that student participation is among the best way to lead toward deep learning and motivation. The perceptions among participants reflect the dissociation between the teaching and meaningful learning.

The focus seems to be on completing the prescribed curriculum rather than to develop student meaningful understanding. Development of 21st century skills as advocated by the educators of the country necessitates that teachers should provide students with more opportunities to participate in the classroom through different activities and help them to realize connections between theory and practice rather than teaching science for passing examinations (Chin & Brown, 2000).

The final theme developed from the qualitative analysis was the quality of textbooks and how participants see the role of textbooks. Most of the students interviewed and observed believed that the chemistry textbook in Tenth Grade did not aid understanding and independent learning. The issue of the abstract nature of the presented information, as well as the way concepts presented have negatively been perceived. Students think that textbooks did not have enough examples relate to the topic of chemical bond and related concepts such as electronegativity and the Lewis structure. These observations were in line with previous findings of Haidar and Abraham (1991).

4.7. Summary

This study focuses on specific questions related to the understanding level of concepts of chemical bonds and bonding in order to gain insights into the causes of the misconception. Furthermore, the study investigated the impact of incorporating "guided-inquiry" as an alternative teaching approach in chemistry in secondary schools, for improving the concepts of the students about the chemical bonds and bonding.

The quantitative findings presented in this chapter revealed that a number of alternative conceptions of chemical bonds were held by Tenth Grade students. The findings also pointed to the effectiveness of using guided inquiry as an alternative approach to the teaching of chemistry at Tenth Grade, particularly with male students.

The qualitative findings pointed to 5 distinct themes related to the perceived difficulty of chemistry as a subject among students; the role of prior knowledge, time spent on task and laboratory work, teaching methods and classroom interactions, and the quality of textbooks used in Tenth Grade as possible contributory factors to student understanding of chemical bonds concepts.

CHAPTER V - SUMMARY AND RECOMMENDATIONS

5.1. Introduction

This chapter presents summary and concise descriptions of the content of this thesis. It further stipulates recommendations derived from the findings as well as suggests future areas of research to complement these findings. In recent years, there has been much focus on student understanding of scientific concepts. This focus has been demonstrated by the large volume of research studies dealing with various levels of understanding of scientific concepts in all scientific disciplines. This study has been developed along the same line of focus to provide a knowledge base to a specific context.

In the UAE, educators have realized the disturbing trends in the continuous decrease of understanding in science subjects and the remarkable increase in the level of misconceptions possessed by students. Topics such as chemical bonds and its associated concepts were found to be of particular interest to researchers around the world. Many efforts have been carried out to lead students toward meaningful learning by integrated prior knowledge, experience, linking new concepts with relevant knowledge, and trying to find the possible sources of misconceptions that significantly might influence the promotion of meaningful learning among students.

Many past research studies have also shown that students' misconceptions are often highly resistant to change by traditional teaching methods. Traditional methods often focus on the teacher as the centre of learning rather than students, and thereby there is an urgent need to employ new trends in the teaching that focus on the student as a centre of learning, give them more opportunity to learn how to learn, and provide them with opportunities to participate in the learning process to integrate both knowledge and skills in their efforts to learn science and chemical concepts in particular. Hence, the current study was conceived in response to these calls.

5.2. Statement of the Problem

This study is concerned with examining the level of understanding of Tenth Grade students in respect to the concept of chemical bonds, because widespread perception amongst researchers and teachers that many students find chemistry one of the most difficult subjects in science section in secondary Grade, and in the university (Treagust, 1988). The reason suggested is that chemistry is a complex subject possessing many abstract, frequently counter-intuitive concepts.

With the difficulties suggested by previous research, the current study was specifically aimed at exploring levels of understanding of Tenth Grade students in relation to selected chemical bonds concepts. In particular, the study tried to find answers to the following questions:

1. What are the alternative conceptions of chemical bonds that are held by Tenth Grade students?
2. What is the nature of the alternative conceptions held by Tenth Grade students?
3. How did guided inquiry influence student achievement?
4. Are there any significant differences in achievement attributed to student gender in guided inquiry and traditional contexts?
5. How does student reasoning ability affect their achievement?

5.3. Survey Sample

This study employed a sample of 140 students in two of secondary schools in Dubai Education Zone (68 male and 72 female), randomly selected and were considered homogenous in the term of age and ability. The period extends for one month only to adjust the effective of teaching methods used in experimental group (guided-inquiry).

5.4. Methodology and Data Collection

The study employed a mixed research method in collecting data. Both quasi-experimental, mixed method including interviews and classroom observations. Quantitative data were collected using two instruments, namely the chemical bonds test, and the Lawson test for logical reasoning ability; Qualitative data were collected through interviews and classroom observations.

5.5. Data Analysis and Findings

The data analysis generates the findings that are referred to the following questions:

a) Q.1: *What are the alternative conceptions of chemical bonds that are held by Tenth Grade students*?

The study focused on measuring student level of understanding related to the research topic (chemical bonds) to find what they already know before the start of the implementation. The pre-test analysis showed that students in experimental and control group are of the same level of background related to the study topic the mean equal (o.454 sig = 0.103). The students in both group performed poorly suggesting that student have very little background information about concepts related to chemical bonds.

Among the questions that showed the higher level of misconceptions are:

- In the first part of the test, which deals with the definition and the formation of chemical bonds, only 25.7% of experimental and 22.8% in the control groups got the correct answer in the pre-test. This level of achievement was decreased.
- In the second part, which deal with the properties of ionic and covalent compound only 17.1% of the students in both experimental and control group could answer this part correctly. Moreover, the students showed the same level of performance in the last part of the test, which deal with the prior concepts related to the chemical bonds. Only 15.0% on the students in the experimental and 12.0% in control group could answer this part correctly.

b) Q.2: *What is the nature of the alternative conceptions held by Tenth Grade students*?

Further analyses of the data suggested a number of alternative conceptions of chemical bond that were held by Tenth Grade students. Among the most frequent misconceptions identified in the present study are the following:

- Formation of chemical bonds (the student were unable to explain the reason behind the formation of chemical bonds based on the position of the element in the periodical table and the different between ionic and covalent bonds)
- Type of bonds based on electro negativity (the students were unable to classify the kind of chemical bonds formed between different element based on the number of valence electron and electronegativity).

- Mechanism of chemical formula (the students were unable to classify the cases in which elements seek to lose or gain electron in the reaction).
- Electric conductivity in ionic compounds (the student unable to connect between the kinds of chemical bond formation and the electro conductivity between the elements in the chemical reaction).
- Lewis atomic structure (the student unable to imagine the ability of atom to form the chemical bonds based on the number of valence electrons).

c) Q.3: *How did guided inquiry impact student achievement*?

To answer the question related to the impact of the treatment (the effect of an guided inquiry) on student understanding of the concepts related to the chemical bonds, a post test data were analysed and compared for both experimental and control group.

The analyses showed that the students in the experimental group performed significantly better and showed a higher level of performance more than the students did in the control group, which used the traditional teaching method (teacher centre). Student performance increased from 5.7 and 5.1 in experimental and control group to 14.9 and 11.9 respectively, suggesting that guided inquiry helped students to perform and to understand better the concepts associated with chemical bond because guided inquiry give a student some of freedom inside the classroom so they can work and explain their ideas and share them with the teacher to reach the correct scientific reason through self-learning.

Most student can work and learn independently; moreover, using an inquiry approach can help the student to use the world as assures of knowledge by exploring, using data analysis and the concept map to connect scientific concepts together. These things may help students to decrease level of misconception.

d) **Q.4**: *Are there any significant differences in achievement attributed to student gender in guided inquiry and traditional contexts*?

Many studies around the world showed and reported few differences between genders in achievement at different Grade levels, with frequent differences in favour of male students when it comes to achievement. This study has gone along the same line. Data analyses showed that using guided inquiry as a teaching method had a positive impact on male students more than female students (the mean score for male = 15.4 and for female = 14.5) . These results could be due to cultural reasons in the Arab countries, male students need more freedom in learning process they will reach to high level of learning when they are giving an opportunity to explain their own idea and explore the world by themselves (student centre learning)

e) **Q.5**: *How does student reasoning ability affect their achievement*?

The reasoning ability is considered as a very important factor, which may affect students' achievement, to answer this question. The researcher applied the Lawson test for reasoning ability on both control and experimental group before and after the treatment. The data analysis showed that students who had high level of reasoning ability reached high level of performance, especially when the teacher used guided inquiry as a teaching method more than the students who used traditional teaching method in control group.

5.6. Recommendations

This study aims is to provide evidence for policy makers and educators to improve the teaching and learning of chemistry at secondary schools, which might lead to assisting in modifying and developing meaningful goals for the educational process such as teaching methods used, classroom and school environment, school administration, curriculum and students' performance especially in science subjects.

The findings reported in this study have implications for the educational policy-makers, the departments that are concerned with curriculum development at government and educational councils, school administration, science teachers, researchers, and students. It is worth giving more attention to introducing innovative approaches in teaching chemistry. Guided-inquiry can help in developing a better understanding about the abstract concepts on chemical topics, as bonds within atomic and molecular structure. The findings reported in the present study have implications for educators and policy makers. The study suggests the following:

1. ***Educational Policy-makers***: should take in to account new trends curriculum development and design curriculum that take in to account student need and ability. This can be done by making textbook and teaching methods user friendly and interesting to reduce level of misconception among students.

2. ***Curriculum Departments***: Increasing the effectiveness of the chemistry curriculum for the secondary schools can be carried out by enriching the course-books with models, illustrations, examples of laboratory experiments

and work. However, the curriculum should incorporate chemistry-related knowledge extracted the daily-life problems, such as gas pollution. As a part of inquiry teaching, the curriculum should include questions and quizzes to develop students’ critical thinking.

3. ***School Administration***: The Administration should pay more attention towards promoting the development and improving quality of the teaching methods, teacher-student classroom interaction, and students’ achievement. In addition, the Administration should place a special emphasis on the students who are experiencing learning difficulties in science subjects, as well as for the talented students so as to develop special teaching programmes for the two groups.

4. ***Science Teachers***: Chemistry teachers, particularly in the secondary schools should focus on using teaching methods that promote learning with understanding rather than merely focusing on completing the prescribed curriculum. The teachers should provide the students with more opportunities to participate in different activities and should also develop the belief that the role of the teacher is to support and guide the students towards meaningful learning rather than a rote one.

5. ***Educational Researchers***: As education becomes a hallmark of the progress of a modern society, the quality of education should be a core issue. In addition, the advent of information technology in the learning process has exerted an urgent necessity for improving curriculum contents and course delivery. Therefore, educational researchers are urged to develop innovative

teaching approaches to benefit both teachers and students in the digital era. It is recommended that future studies should be undertaken on a larger scale to provide comprehensive data to understand the reasons behind the low-level understanding of students' achievement in chemistry. Furthermore, studies related to teaching methods should also be introduced at different contexts to identify relevant approaches and strategies to help students at different academic levels to develop their level of understanding, self-confidence, self-learning and to reconstruct the knowledge to attain a meaningful learning.

6. ***Students***: Students nowadays are the digital generation using effectively the electronic devices (e.g., mobiles, tabs, web, etc.). Therefore, information technology could be used as a successful approach to increase the classroom activities for students. Thus, the students could switch to using non-traditional ways, such as conceptual or knowledge map (K-map), laboratory manuals, and discovery of the web to acquire scientific knowledge.

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APPENDIX ONE

Measuring Basic Skills for the Grade-10 Student to Conception of Chemical Bonds

UAEU College of Education

جامعة الإمارات العربية المتحدة
United Arab Emirates University

Department of Curriculum and Instruction

Master in Education Programme

Student Name:________________________ **School**:___________________**Class**:________

Measuring Basic Skills for the Grade-10 Student to Conception of Chemical Bonds

Dear Student,

This test aims at measuring the basic skills of the Grade-10 student related to the topic of chemical bonds. This test is only for the purpose of scientific research. Kindly, please answer all the questions, with the knowledge that every question consists of two parts; first part is the selection of the correct answer, and the second part is the selection of scientific reason.

1- Electrical attraction between the nucleus and the valence electrons between the different atoms is called as :

The Answer	The Scientific Reason
a) Bipolar powers. **b)** Lewis structure. **c)** Chemical bond. **d)** London dispersion forces.	**1)** Nucleus positively is charged **2)** Different atoms contain a negative proton and Positive electron. **3)** The nucleus of an atom is electrically neutral **4)** No single atoms, but are held together by chemical bonds

2- Most of the atoms tend to form chemical bonds due to the:

The Answer	The Scientific Reason
1) Attraction happens between the positive nucleus and negative electron **2)** Access to electronic stability **3)** The links change the atomic radius. **4)** Most of the atoms chemically inert	**1)** To achieve the octet rule. **2)** Links configuration make inert elements **3)** Nucleus have a different charge **4)** Only identical atoms make a link

3- Electrons participating in the formation of chemical bonds are called:

The Answer	The Scientific Reason
a) Valence electrons	**1)** Bond formation is due to loss of protons.
b) The inner layer electrons	**2)** Bond formation is due to gain electrons from the outer layer
c) Maine level Electrons	**3)** Bond formation is due to gain electrons from the internal energy levels.
d) Louis electrons	**4)** There is no loss or gain of electrons when there is bond formation

4- The greater difference in electro negativity between two atoms leads to association of:

The Answer	The Scientific Reason
a) Ionic bond.	**1)** High electro negativity increases the ability of atom to attract electrons from another atom to association of bond.
b) Covalent bond.	**2)** High electro negativity increase the ability of atom to share electrons with another atom to association of bond
c) Metallic bond.	**3)** There is no relationship between high electro negativity and type of bond association.
d) Hydrogen bond	**4)** Because metals tend to gain electrons through a bond association.

5- A chemical bond produces as a result of attractive forces between:

The Answer	The Scientific Reason
a) Atomic nuclear and electrons in the internal layer	**1)** Grater mass of the nuclear affects bond formation.
b) Electron in the external layer and neutrons.	**2)** The links should consist of neutron and proton inside the atom itself
c) Proton and electron	**3)** Valence electrons in the external layer are lost and gained through bond formation
d) Neutron and proton inside the atom	**4)** There is no need to have a bond between atoms

6- When the chemical bond associate, the number of electrons in the external layer should be:

The Answer	The Scientific Reason
a) 2 **b)** 7 **c)** 8	**1)** Each orbit should contain two electrons only. **2)** Because of Hond application. **3)** Because of octet role application. **4)** The external orbit can contain unlimited number of electrons.

7- If identical atom are linking together, the bond formation is known as:

The Answer	The Scientific Reason
a) Hydrogen bond **b)** Ionic bond **c)** Van Derfal bond **d)** Covalent bond	**1)** Identical atoms cannot link together **2)** Identical atom formed a strong bond **3)** There are no differences in electro-negativity between identical atoms **4)** Hydrogen gas is very important.

8- If you know that the electro negativity for the bromine atom = 2.8, what was the bond formed when two bromine atoms are linked together:

The Answer	The Scientific Reason
a) Ionic bond. **b)** Covalent bond. **c)** No bonds can be formed between bromine atoms. **d)** Ionic and covalent bonds together	**1)** Depending on the difference of electro negativity between the two atoms. **2)** There is no way to predict the type of bond between identical atoms. **3)** Since the atoms are identical, they will linked with double bonds **4)** there are no relation between electro negativity and type of bonds formed between the atoms

9- Bond length is the distance between two atoms when:

The Answer		The Scientific Reason	
a)	Less internal energy between atoms	**1)**	There is no relationship between the bond length and the distance between linking atoms
b)	The highest internal energy between atoms	**2)**	Bonding between atoms need high energy to be formed.
c)	Higher kinetic energy of molecules.	**3)**	Atoms tend to form links with less internal energy.
d)	Atomic radius is reduced when the bonds dissociate.	**4)**	Atoms tend to form links with more internal energy.

10- To draw the Lewis structure it is not necessary to know:

The Answer		The Scientific Reason	
a)	The type of atoms	**1)**	Lewis structure gives the geometry of the molecule and not the amount of energy.
b)	The internal Energy.	**2)**	Because there are no relation between the valence electrons and the type of bond formed
c)	Number of atoms that link together	**3)**	Because the atoms cannot be linked
d)	Number of valence electrons		
		4)	When the number of valence electrons increase, fewer bonds will be formed in the Lewis structure.

11- Which of the following examples is not an example of a molecular formula:

The Answer		The Scientific Reason	
a)	H_2O	**1)**	Because the molecular formula focus on the types and number of atoms linked together to form the compound.
b)	NH_3	**2)**	There is no relationship between the number of atoms and molecular formula.
c)	O_2	**3)**	Because some compounds are chemically inert
d)	B	**4)**	Because the internal energy of individual atoms is zero

12- What additional number of electrons are needed for nitrogen atom to achieve the octet rule if you know that Electronic distribution of energy levels are as follows ($1S^2 2S^2 2P^3$):

The Answer		The Scientific Reason	
a)	5	**1)**	Because the last level in the nitrogen atom contains three electrons.
b)	3	**2)**	Because the last level in the nitrogen atom contains seven electrons.
c)	1	**3)**	Because the last level in the nitrogen atom contains five electrons.
d)	8	**4)**	Nitrogen atom is stable without the addition of electrons

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

The Answer		The Scientific Reason	
a)	Alkali metals.	**1)**	Because it is located in the group of eighteen in the periodic table.
b)	Halogens.	**2)**	Because the external level contains eight electrons.
c)	Noble gases.		
d)	Lanthanide group.	**3)**	Because they tend to share electrons.
		4)	Because it is chemically active

14- How many double bonds are there in the Lewis structure of hydrogen fluoride (HF):

The Answer	The Scientific Reason
a) 0	**1)** Hydrogen fluoride is associated with mono covalent bonds.
b) 1	**2)** Hydrogen fluoride is associated with double covalent bonds.
c) 2	**3)** Hydrogen fluoride is associated with triple covalent bonds
d) 3	**4)** Hydrogen fluoride is not formed any links

15- Elements symbols and the number of atoms which form chemical compound are called:

The Answer	The Scientific Reason
a) Lewis structure.	**1)** Depends on the electrons of the last level
b) Chemical formula.	**2)** Depends on the electrons of the internal level
c) Noble gases	**3)** It describes the simplest formula of the chemical compound.
d) Ionic bond	**4)** Because all atoms are linked to reach octet rule

16- The formula of sodium chloride (NaCl) is an example of:

The Answer	The Scientific Reason
a) Noble gases.	**1)** Depends on the valence electrons
b) Lewis structure.	**2)** Represents the number of ions in each molecule.
c) Molecular formula.	**3)** It describes the simplest ratio of atoms, which link together.
d) Identical atoms	**4)** links to reach the stability of octet rule

17- The attractive forces between molecules in a covalent compound:

The Answer	The Scientific Reason
a) Stronger than the forces of attraction in ionic compounds	**1)** Ionic bonds are weaker than covalent bonds
b) Weaker than the attractive forces in ionic compounds.	**2)** Ionic bonds are stronger than covalent bonds
c) Equal to the attractive forces in ionic compounds.	**3)** Ionic bonds equal to the covalent Association in force.
d) Equal to zero	**4)** Difference in electro negativity between ionic and covalent compound equals zero

18- When the atoms are connected with each other:

The Answer	The Scientific Reason
a) Potential energy decreased and formed more stable compounds.	**1)** Sometimes the potential energy decreased and sometimes it increased.
b) Potential energy increased and formed more stable compounds.	**2)** When atoms are linking together, it reduced their potential energy.
c) Potential energy decreased and formed less stable compounds.	**3)** When atoms are linking together it increased their potential energy
d) Potential energy increased and formed less stable compounds.	**4)** Energy level remains constant during the links

19- Which of the following is not one of the properties of ionic compounds:

The Answer	The Scientific Reason
a) Toughness	**1)** Bonding strength between ionic compounds raises the boiling point.
b) High melting point.	**2)** Bonding strength between ionic compounds reduces the boiling point.
c) Low boiling point.	**3)** Ionic compounds do not have fixed properties
d) Good conductors of electricity	**4)** The ionic and covalent compounds have the same characteristics

20- The reason for Excellence metals lustre to its ability is to:

The Answer		The Scientific Reason	
a)	Absorb light and convert it to heat	**1)**	When the light begins collision with metal surface electrons absorb light and reflect it.
b)	Formation of crystals.	**2)**	Because the metals are used in jewellery, it should be shiny.
c)	Stored light inside.	**3)**	The metals in nature are pure so it reflect light
d)	Absorption and emission of light with multiple wavelengths	**4)**	Inability of metals to rust keeps them always shiny

21- The bond expected when a metallic element linking with another non-metallic is often:

The Answer		The Scientific Reason	
a)	Ionic bond.	**1)**	Because hydrogen gas is available in the air, it helps to form a bond.
b)	Covalent bond.	**2)**	There are differences in electro negativity between metals and non-metals help to form the bond.
c)	Metallic bond.	**3)**	Because the metals are good conductors of heat and electricity.
d)	Hydrogen bond.	**4)**	No linking can form between the metal and the metal.

22- The mono covalent bonds consist of:

The Answer		The Scientific Reason	
a)	One electron shared between two atoms.	**1)**	Each atom is shared with two electrons to form the bond.
b)	A shared of pair electrons between two atoms.	**2)**	Each atom is shared with one electron to form the bond.
c)	Gravitation between different Ionians.	**3)**	The nucleus share with one neutron to form the bond.
d)	A shared pair of electron and proton inside the atom.	**4)**	There is no a mono covalent bond between atoms.

23- Ionic compounds solutions that characterized with Electric current:	
The Answer	**The Scientific Reason**
a) Non conducting	**1)** The absence of ions in solution.
b) Conductive.	**2)** The presence of ions in solution.
c) Semiconducting.	**3)** The presence of neutrons in the solution.
d) Cannot expect the conductivity of the resulting solution.	**4)** The presence of protons in the solution.

APPENDIX TWO

The Lawson Classroom Test of Scientific Reasoning

UAEU College of Education

جامعة الإمارات العربية المتحدة
United Arab Emirates University

Department of Curriculum and Instruction

Master in Education Programme

Student Name:________________________ **School**:________________**Class**:_______

Lawson Classroom Test of Scientific Reasoning

Dear Student,

This test aims at measuring the basic skills of the Grade-10 student related to the topic of chemical bonds. This test is only for the purpose of scientific research. Kindly, please answer all the questions, with the knowledge that every question consists of two parts; first part is the selection of the correct answer, and the second part is the selection of scientific reason.

Q.1- Figure A shows two cylinders filled to the same level with water. They cylinders are identical in size and shape; also in Figure A are two marbles, one glass and one steel. The marbles are the same size but the steel one is much heavier than the glass one, when the glass marble is put into cylinder 1 it sinks to the bottom and the water level rises to the sixth mark.

If we put the steel marble into cylinder 2, the water will rise:

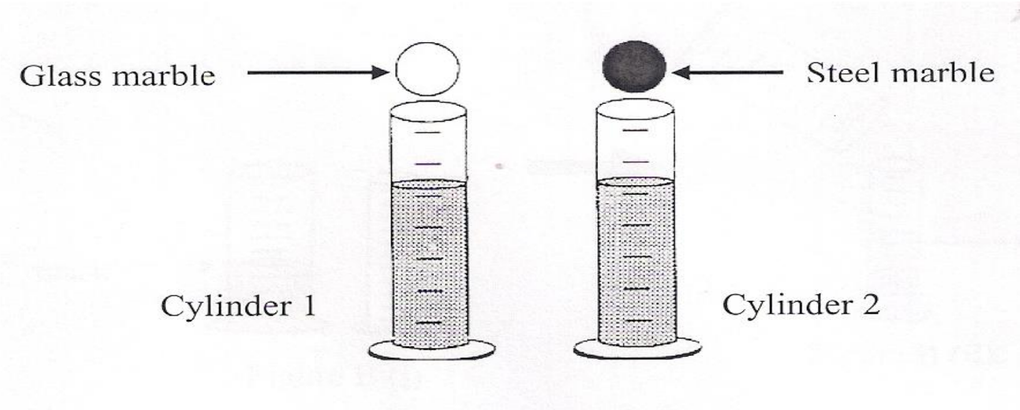

Figure A

The Answer	The Scientific Reason
a) To about 8	**1)** The answer cannot be determined with the information given
b) To about 9	**2)** It went up 2 more before, so it will go up 2 more again
c) To about 10	**3)** It goes up 3 in the narrow for every 2 in the wide
d) To about 12	**4)** The second cylinder is narrow
e) None of these answers is correct	**5)** One must actually pour the water and observe to find out

Figure B-1 shows a wide and a narrow cylinder. The cylinders have equally paced marks on them. Water is poured into the wide cylinder up to the Fourth mark (Figure B-1). This water rises to the Sixth mark when poured into the narrow cylinder as shown in *Figure B-II*. Both cylinders are emptied and water is poured into the wide cylinder up to the Sixth mark.

Q.2- How high would this water rise if it poured into empty narrow cylinder.

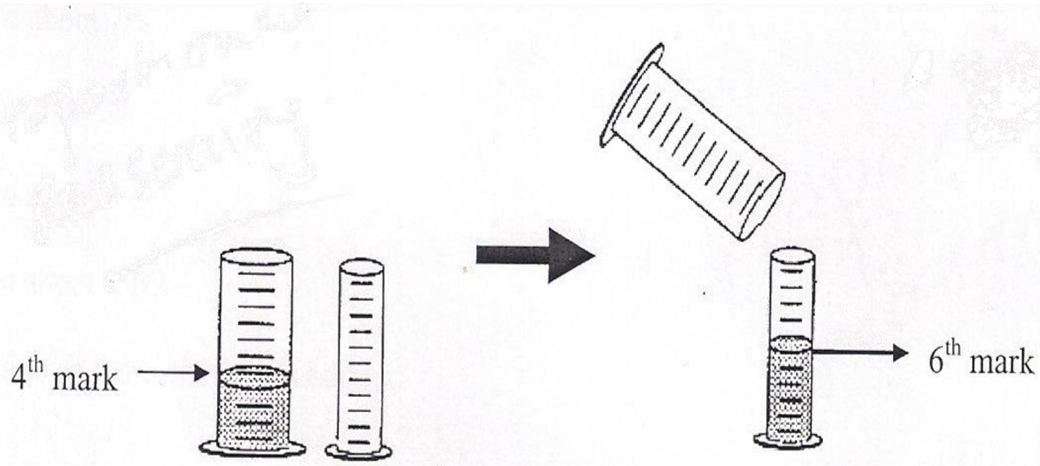

Figure B (i) Figure **B (ii)**

The Answer	The Scientific Reason
a) To about 8	**1)** The answer cannot be determined with the information given
b) To about 9	**2)** It went up 2 more before, so it will go up 2 more again
c) To about 10	**3)** It goes up 3 in the narrow for every 2 in the wide
d) To about 12	**4)** The second cylinder is narrow
e) None of these answers is correct	**5)** One must actually pour the water and observe to find out

Water is now poured into the narrow cylinder (as described in **Q.2** above) up to 11th mark. **Q.3- How high would this water rise if it were poured into the empty wide cylinder**.

The Answer	The Scientific Reason
a) To about 7 1/2	**1)** The ratio must stay the same
b) To about 9	**2)** One must actually pour the water and observe to find out
c) To about 8	**3)** The answer cannot be determined with the information given
d) To about 7 1/3	**4)** It was 2 less before so it will be 2 less again
e) None of these answer is correct	**5)** You subtract 2 from the wide for every 3 from the narrow

Figure C shows three strings hanging from a bar. The three strings have metal weights attached to their ends. String #1 and string #3 are the same length. String 2 is shorter. A 10-unit weigh is attached to the end of string #1. A 10-unit weight is also attached to the end of string #2. A 5-unit weight is attached to the end of string #3. The String (and attached weights) can be swung back and forth and the time it takes to make a swing can be timed.

Q.4- Suppose you want to find out whether the length of the string has an effect on the time it takes to swing back and forth. Which sting would you use to find out?

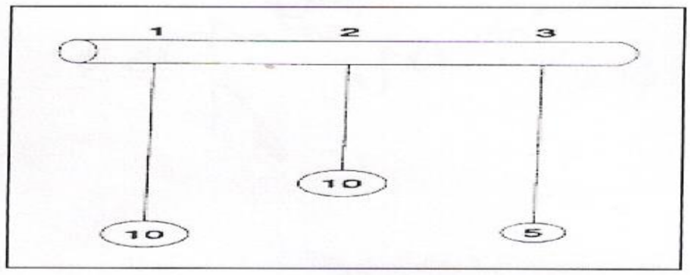

Figure C

The Answer	The Scientific Reason
a) Only one string	1) You must use the longest strings
b) All three string	2) You must compare strings with both light and heavy weights
c) 2 and 3	3) Only the lengths differ
d) 1 and 3	4) To make all possible comparisons
e) 1 and 2	5) The weights differ

Six square pieces of wood are put into a cloth bag and mixed about. The six pieces are identical in size and shape; however, three pieces are red (labelled R) and three are yellow (labelled Y) as shown in Figure D.

Q.5- Suppose someone reaches into the bag (without looking) and pulls out one piece. What are the chances that the piece is red?

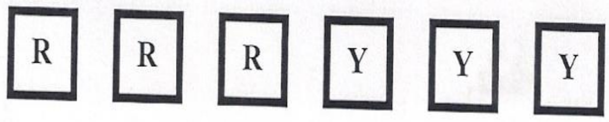

Figure D

The Answer	The Scientific Reason
a) 1 chance out of 6	**1)** 3 out of 6 pieces are red.
b) 1 chance out of 3	**2)** There is no way to tell which piece will be picked.
c) 1 chance out of 2	**3)** Only 1 piece of the 6 in the bag is picked.
d) 1 chance out of 1	**4)** All 6 pieces are identical in size and shape.
e) Cannot be determined	**5)** Only 1 red piece can be picked out of the 3 red pieces.

In the second experiment, 3-red square pieces of wood, 4-yellow square pieces, and 5 blue square pieces are put into a cloth bag. 4-red round pieces, two yellow round pieces and three blue round pieces are also put into the bag. All the pieces are then mixed about.

Q.6- Suppose someone reaches into the bag (without looking and without feeling for a particular shape piece) and pulls out one piece (Figure E). What are the chances that the piece is red round or blue round piece?

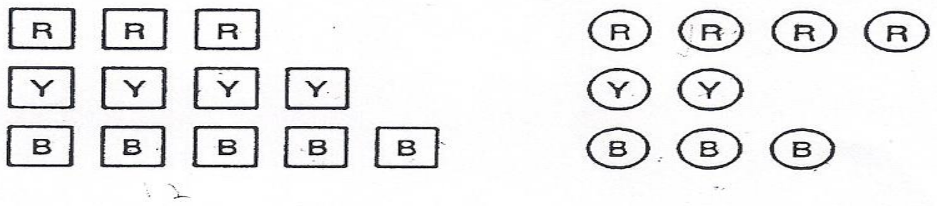

Figure E

The Answer		The Scientific Reason	
1)	Cannot be determined	**1)**	1 of the 2 shapes is round
2)	1 chance out of 3	**2)**	15 of the 21 pieces are red or blue
3)	1 chance out of 21	**3)**	There is no way to tell which piece will be picked
4)	15 chance out of 21	**4)**	Only 1 of the 21 pieces is picked out of the bag
5)	1 chance out of 2	**5)**	1 of every 3 pieces is a red or blue round piece