Investigating Inquiry-based Learning Implementations for Enhancing Students’ Scientific Skills and their impact on TIMSS exams in Private Schools in UAE.

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A dissertation submitted in partial fulfillment of the requirements for the degree of MED in Science

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Abstract

Inquiry-based learning (IBL) is an important teaching instructional approach that is supported by educational reforms globally and in the United Arab Emirates as it enhances students’ scientific skills and supports their abilities to improve their scores in the TIMSS exams. Science education is best taught by IBL instruction that is investigated through three dimensions in this study: inquiry, cognitive, and content. The main purpose of this study is to explain teachers’ perceptions of IBL and their practices that enhance students’ scientific skills. Moreover, these skills are measured in their five types: acquisitive, organizational, creative, communicative and manipulative skills as essentially required by the TIMSS exams. The study has three groups of participants comprising 50 teachers, 75 grade twelve chemistry students and two academic supervisors from two private schools in the UAE. Multiple tools were utilized in a mixed methods design to collect adequate data. Teachers’ perceptions were gathered by a questionnaire with close and open-ended items, their practices were observed through class visits, students’ perceptions were collected by a quantitative questionnaire, and finally, students’ achievements were analyzed qualitatively from schools’ official TIMSS results.

The major results of the study indicated that teachers have good pedagogical knowledge about IBL, and have developed their practices but not at the same level of their knowledge. Results also indicated that students acquired adequate scientific skills but still may need more consistent practice to improve their scores in the TIMSS exam. Therefore, students showed interest in learning chemistry as a result of IBL activities. Interestingly, the study found that teachers who had attained master in education degrees as part of their professional development positively enhanced students’ skills.

Keywords: Inquiry-based learning, Scientific skills, TIMSS exams.
صغرة

وه فيجلبنا تنازل مبتززاً في (IBL) يورشيا بلغ ديبندرنا تاح إصلا تقع ثم جرفنا وهو سرعانداً ماه فيبرغنا جهن مهجر.وزان ينصح مهتارنا مختيرblocks لبلاطنا يد مبتززا تاراضياً زاني خلا حزيرباً شامراً حذفنا تاجيكو يداً مبتزاً صارداً هذه يف داعياً خلا للاح ثم حكي دهلماً ديرجنا بلغ مبتززا ماجعزا هجرمز مولهاً مردننا لفندنا سيسننا تاناحنا يعيبنا ماجعزا حريطم نع ديرحنا شاروض حش وه مسارداً هذه ثم يسيتراً ضريرناً.وّيرتجناً، ماجعزاً تقتحناً وهي وهو بلداً شامراً هذه سراق برم لذ بلغ موالح بلاطناً مبتززا تاراضياً زانحاً ألعيرطاً هذه تامسراممو فيزحنا بلغ يفروض لنكث بولطم وه امك بيرنانو لصوانتنا، معببدنا، ميسكيزا، شامراً ماجعزاً وهو عوفنا صرحنا بلا تقيش فابرنا يف عائبة بياتاً 0 و بولج ملمع 5 مهو مينكراً نا تم تاعوجم ملك صارداً هذه مضت.مسيب تازارنا يف ديرجاً يدحتمنا ندو.دحتمنا مبتززا تاراضنا حذف يد نيننحز نيسرامد يف نيبنرانا نينفشرنا نا تم نيننراً رشع بيلانا هاننا بلغ ووترنا.نيبناً تاروضاً ماجي.نانيما للذبنا.مطبنخ نلزهم ويبط للاح ثم دنناك تاناب عده.مدمج مادخشاً تابج فبر بلاطنا شاروضنا ام.مينيراً شمرونزا ضوع.للاح ثم مهتاراممو تظحول نزو، دهجناً يرخ او هزغم.

نينساردنا.سينيحة تارابينا،اي ميرالنا،جواننا فيد بلاطنا شازارنا لمح، متاريز او.يهدنا عوننا ثم نابنا.

مطبرطل حديق ميربر منبرعم مهيربا، نيبنرا نا تم صارنداً ميجيرزا جمانا ضراشاً اولامي ام (IBL).نيننرا اد او مهتاراممو تروطخ دقو نيفناو ميجا ميبرغنا شامراً اوستكا دقو بلاطنا نا ويلا، جيبنزا تراشاً امك.نيبرغنا يرويرنا وح.جفنا بلغ سيل مجي عامبنا ميربر ماغنا امامها ببلاطنا رطلة تاجيز.ميسكيزا رشابين يف ما شيء.حيزنا نيسنزا ماجعزا تامسرامميا تم ريبنزا نوجات.مطشننا (IBL).نيننرا نيبنرا نا صارنزا تجر دقو ينيهما مهروطن تم عرط ماجعزا يف ربرنا اوغ.ببلاطنا شامراً بباجا لكلب.وزغر.

فيسورلا تارابينا تاملكنوا: سميت (تارابينا - ديبندرنا تاحان)
Dedication

This dissertation has been one of the greatest challenges in my life. This achievement is lovingly dedicated to my parents who strongly encouraged me and my grandmother who believed in my abilities and launched me in the direction of success.

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Chapter 1: Introduction

Inquiry-based learning (IBL) is one of the most substantial key elements of many reform efforts in science education because of its impact on accelerating students’ acquisition of scientific skills within the spectrum of 21st century skills (Kazempour, Amirshokoohi & Harwood 2012) as well as enhancing students’ achievements through overcoming misconceptions, and acquiring the essential content knowledge (Kizilaslan, Sozbilir & Yasar 2012) which can be measured by standardized tests (TIMSS, 2011).

1.1 Scientific Inquiry

Inquiry is commonly defined as the process of understanding and doing science in the way scientists follow to discover the nature of life, while Science is a “unique mix of inquiry and argument” (Yore et al. 2004, p. 347). Three main concepts intensively used in science education were differentiated as Inquiry, Science Inquiry and Scientific Inquiry. The first term, Inquiry, refers to the process of seeking knowledge through posing a question. The second term which is Science-Inquiry is described as the implementation process where students can follow its procedures through learning activities and exploration by conducting experiments to solve specific questions (Llewellyn 2011). Finally, Scientific Inquiry is the learning process where science students can investigate the nature of the real world through diverse ways that rely on evidence-based explanation (Al-Naqbi 2010; NRC 1996a; Singer, Marx & Krajcik 2000). Additionally, it requires a combination of the content matter with general science process skills, critical thinking, creativity, and problem solving to successfully develop scientific knowledge (Lederman 2009).

Recently, a positive correlation has been found between understanding nature of science (NOS) and inquiry teaching skills (Forawi 2010). Although Lederman et al. (2014) mentioned that scientific inquiry is often used as a synonymous term of NOS, they have a difference which makes them independent. Basically, NOS embodies various aspects of science, including the general features that make it different from other disciplines, scientific inquiry characteristics that derive from acceptable scientific knowledge, social-cooperative group work and its significant impact (Clough 2006; Irzik & Nola 2011; Lederman et al. 2014; Wong & Hodson, 2009, 2010). Next Generation Science Standards also supported this contrast between these two terms (Achieve, Inc. 2013). Ultimately, science education reform explicitly emphasized the
importance of the development of understanding NOS (AAAS 1990; CMEC 1997; NRC 1996b) that requires two essential kinds of experiences consisting of learning the history of science and conducting scientific investigation consistently (Nott & Wellington 2000) which refer to implementing scientific inquiry. Previous research has revealed that inquiry learning is an effective instructional strategy that enhances students’ achievements (Bunterm et al. 2014; Deboer 1991; Flick & Dickinson 1997). Consequently, NOS is defined as a meaningful endeavor that is considered as a fundamental component of scientific literacy (Wan & Wong 2013) which recommended IBL as an effective classroom instruction (Khasnabis 2008). Furthermore, Forawi (2003) confirmed that inquiry oriented teaching strategy as an indirect teaching approach develops better conceptions of the nature of science.

1.2 Inquiry-based learning (IBL) in Science Education

There has been a sound definition of inquiry learning as an active process which is strongly related to scientific inquiry approach, while there are no boundaries or specific definitions of inquiry teaching (Anderson 2007, cited in Coban 2013). The popularity of the concept of inquiry has increased in supporting pedagogical science as well as its practices. Yager (2010) argues that though being familiar with this term, the majority of science teachers are unaware of the core meaning of inquiry and its actual implementations in their classes. The following diagram illustrates the continuum of teaching instruction (Llewellyn 2011).

![Teaching instruction diagram](image)

**Figure 1: Teaching instruction diagram.**

Different levels of inquiry were distinguished according to the amount of instruction that was given to the learners (Banchi & Bell 2008; Buck, Bretz, & Towns 2008; Colburn 2000; Herron 1971; Martin-Hansen, 2002). In addition, researchers classified inquiry as four major types according to whether each is the responsibility of the student or the teacher (Bell, Smetana & Binns 2005; Llewellyn 2011) as shown in the following table.
<table>
<thead>
<tr>
<th>Area of inquiry</th>
<th>Demonstrated inquiry</th>
<th>Structured inquiry</th>
<th>Teacher initiated inquiry</th>
<th>Self-directed inquiry (Open)</th>
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<tr>
<td></td>
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<td></td>
<td>Guided inquiry</td>
<td>Coupled inquiry</td>
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<tr>
<td>1. Posing a question</td>
<td>Teacher</td>
<td>Teacher</td>
<td>Teacher</td>
<td>Students select from</td>
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<td></td>
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<td>predetermined bank of</td>
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<td></td>
<td>questions</td>
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<tr>
<td>2. Planning procedures</td>
<td>Teacher</td>
<td>Teacher</td>
<td>Student</td>
<td>Student</td>
</tr>
<tr>
<td>3. Analyzing results</td>
<td>Teacher</td>
<td>Student</td>
<td>Student</td>
<td>Student</td>
</tr>
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<td>4. Drawing conclusion</td>
<td>Teacher</td>
<td>Student</td>
<td>Student</td>
<td>Student</td>
</tr>
</tbody>
</table>

Table 1: Types of inquiry-based learning strategy.

Although the essential features of inquiry practices vary according to both cultural and social conditions (Abd-El- Khalick et al. 2004), there is only one single way to conceptualize IBL, which is student-centered approach based on hands-on activities that effectively enhance the acquisition of critical-thinking skills as well as science content knowledge (Bunterm et al. 2014). In addition, not all hands-on activities given to students refer to inquiry learning, e.g. building an atom model, because it does not depend on a research question (Bell et al. 2005). The main focus in this study is the features of IBL found in the chemistry classroom and its impact on students’ learning skills and achievements.

Student-centered activities such as guided inquiry practices based on constructivist methodology require concrete learning experiences rather than abstract presentations (Orlich et al. 2013). In addition, Ronis (2008) refers to integrating inquiry practices in science classes as an equivalent approach to problem-based learning (PBL) which simultaneously operates three significant types of learning: cognitive learning, collaborative learning and content learning, which support the acquisition of high-order thinking skills, social constructivism skills and better use of knowledge gained respectively (Capraro, Capraro & Morgan 2013).

1.3 International-Standardized Tests and Science Education Reform
Thirty-two international comparative studies have been initiated in education by the International Association for the Evaluation of Educational Achievement (IEA) which are classroom-based
studies to address a wide range of academic subjects like mathematics, science and reading literacy, to assess the educational outcomes such as students’ achievements based on the context of teaching and learning process (Drent, Meelissen & Van der kleij 2013). There has been a growing concern among policy makers participating in these international reports and studies started by only 12 countries involved in the First International Math Study (FIMS 1963- 1967) and reached 69 countries from the different regions in the world (Rindermann 2007). The importance of these studies is not exclusive to ranking participating countries according to their average achievements’ scores, but they also provide an in-depth vision into the diverse aspects of educational systems all over the world. Moreover, countries participating in these studies for more than one cycle of TIMSS (every 4 years) or PISA (every 5 years) can analyze the provided information across assessment for educational development purposes such as elaboration of textbooks in order to enhance the successful acquisition of scientific habits of minds, learning skills and scientific knowledge (Dagher & BouJaoude 2011).

Recently, the ranking of Arab states, including Gulf countries in major international tests such as Trends in International Mathematics and Science Study (TIMSS), Progress in International Reading Literacy Study (PIRLS), and Program for International Student Assessment (PISA) are considered as the benchmark and the significant driving force for the current educational reforms in the UAE. Accordingly, Dubai tested all its public schools, and a wide range of private schools with a total of 5,571 grade eight students who sat for the TIMSS 2011 assessment, which means that this standardized test can be considered as a census of all Dubai eligible schools (KHDA, 2014). Consequently, the Knowledge and Human Development Authority (KHDA) (2014) inspectors announced that the UAE National Agenda was launched at the beginning of 2014 by H.H. Sheikh Mohammed Bin Rashid, and consists of a set of targets that map the next stage of the UAE’s educational development. These targets covered a variety of elements affecting both quality of education, and student achievement across different stages. Two major targets which are concerned with the UAE’s ranking in international assessments are as follows:

- “By 2021, the UAE will be among the 15 highest performing countries in TIMSS
- By 2021, the UAE will be among the 20 highest performing countries in PISA”

(KHDA 2014)
1.4 Background of the Research

In the past decades, many educators recognized the importance of students’ active role in learning such as Lane (1857-1925), Dewey (1870-1952) and Montessori (1870-1952) who refer to the nature of inquiry-based education. Their views were drawn from the earlier ideas of Rousseau (1712-1778), Pestalozzi (1746-1827), and Froebel (1782-1852) that represent the roots of an approach that seeks to stimulate students’ imagination and curiosity (cited in Harlen, 2013). In the 21st century, inquiry has been gradually adopted in science education, and its importance has been progressively emphasized in many educational aspects such as curriculum development, teaching and learning science (Al-Nabqi 2010; Bryant 2006; Lord & Orkwizzeski 2006; Marx et al. 2004).

Inquiry practice is the main focus of science education reform, which allows students to construct their knowledge and accommodate these new experiences in a suitable way to their natural brain development (NRC 1996b). Furthermore, it supports the acquisition of modern learning skills such as critical thinking, and problem solving to be implemented in real-life situations which are considered as major benefits in applying the inquiry process in schools (Gupta 2012). In addition, many researchers found that guided inquiry as a student-centered active method is an effective approach in science generally, and in particular, chemistry, as it enhances students’ conceptual understanding (Hofstein 2004; Hofstein, Navon, Kipnis & Mamlok- Namaan 2005; Tobin 1990; Weaver 1998)

National Science educational standards NRC (1996b) interpreted three main angles of scientific inquiry. They are process skills, content, and strategies of teaching and learning science which refer to consistent practice of inquiry investigation, nature of this inquiry method based on standards, and instructions used to enhance students’ conceptual understanding respectively (Wang 2011). As such, implementing effective scientific inquiry activities in schools is one of the significant UAE goals in learning science where teachers are encouraged to practice and apply this approach in their classes in order to produce a new generation of students who are more scientifically literate (Ministry of Education 2001). Accordingly, implementing guided inquiry-based science education can efficiently achieve some of the essential objectives of the UAE’s Ministry of Education’s educational message, which were stated in the last five-year plan.
that consists of different developmental projects to support the educational mission and vision in the UAE:

- Address any weaknesses of students’ scientific skills.
- Creative and innovative teaching strategies should be implemented to facilitate constructivism classrooms.
- Scientific curriculum is designed to support the development of students’ critical and creative thinking skills, which contribute to the upgrading of educational methods as well as the efficiency of learning outcomes (Ministry of Education, 2009).

Hence, Education for All Strategy (EFA) aims to improve the quality of education. Its measurement of the educational progress of the participating schools relies on the Education for All development index (EDI) between 0.97 and 1 (UNESCO 2010). In spite of no country in the Middle East and North Africa (MENA) achieving this EFA goals, Dubai was close to this standard measurement (EDI between 0.95 and 0.96) (Bouhlila 2014). That is why it is important to investigate teaching instructional strategy in the UAE as a factor affecting the quality of science education.

Although many studies estimated that inquiry-based learning as a PBL design is the best strategy to teach science and support students’ future careers (Asghar et al. 2013; Mosier, Bradley-Levine & Perkins 2013; Venville, Rennie & Wallace 2004), there is inadequate information in measuring the degree to which IBL approach enhances learning scientific skills and affects students’ achievements in high grade chemistry classes in the UAE. The aim of this study is to emphasize the beneficial role of IBL instruction in improving the quality of science education in private schools in Dubai, the UAE, based on both teachers’ perceptions and practices as well as students’ perceptions and achievements in the TIMSS exams.

1.5 Statement of the Problem
Inquiry-based learning practices including PBL strategy address many of the challenges that generally face the learning process (McKinley 2012). In addition, it is seen as a tool to support science education reform through integrative methods that address all the students’ educational
levels and provide them with sufficient opportunities to solve a variety of authentic problems through implementing guided-inquiry instruction (Lehman, George, Buchanan & Rush 2006). Moreover, the consistent demand for advanced and innovative workplace skills has increased the importance of IBL at the workplace in terms of developing scientific literacy (NRC 1996 cited in Kizilaslan et al. 2012) which provides a rationale for investigating their relationship between IBL and scientific skills that improves the quality of science education. The aim of IBL is to shift the traditional learning paradigm into more constructivist instruction that relies on a social, and collaborative environment to support independent learning (Gupta 2012; Magee & Wingate 2014). In addition, Bunterm et al. (2014) concluded that guided and open inquiry activities are beneficial to students’ achievements. Students in the UAE achieved below the average score in TIMSS 2011 (KHDA 2012). Hence, teaching quality, students’ activities and their attitudes towards learning science are considered as main concerns that could have a direct influence on learners’ achievement (Lee & Luykx 2006). Investigating the main factors affecting students’ achievement such as their engagement in the learning process, instructional strategies and reasoning skills is warranted (KHDA 2013).

Generally, implementing IBL instruction is a new trend in the UAE. That is why, KHDA inspectors encourage all Dubai schools to prepare and support their science teachers to apply this active learning method in the classroom (Ministry of Education 2010). However, only 29% of the total number of Dubai schools sample were private schools that follow the US curriculum which participated in TIMSS 2011 to assess their students’ achievements (KHDA 2014) based on the type of inquiry they consistently implement. The rationale behind choosing the schools participating in the study is the implementation of IBL in their classes according to KHDA inspection report of school B which recorded that students’ attainment in science is good and added that in the high school, “students often developed hypotheses, conducted investigations, collected and recorded data, and evaluated findings” (KHDA 2014, p. 9). Additionally, KHDA report of school A noted that high school “students enthusiastically collaborated, participated fully and confidently presented and explained work” (KHDA 2014, p.10).
1.6 Purpose of the Study

The aim of the study is to understand and explain features of IBL that affect the quality of science education through enhancing students’ achievement in standardized tests and supporting their scientific skills that are categorized into five main types of skills: Acquisitive, organizational, Creative, Communicative and Manipulative skills (Bybee & Powell 2014). Furthermore, teachers’ and students’ perceptions will be taken into consideration as well as their practices and scores in TIMSS exams 2011 respectively.

The study is conducted to answer the following questions;

1. What are teachers’ perceptions and practices in developing students’ scientific skills through inquiry-based learning (IBL) strategy in science classes?
2. What are students’ perceptions and experiences towards IBL implementations in chemistry classes?
3. How does IBL instruction impact students’ achievement in TIMSS exams?

Previous studies have emphasized that IBL is an active learning approach that successfully engages learners in real investigation to enhance their cognitive skills such as critical thinking and problem solving (Etherington 2011; Harlen 2013; Mckinley 2012; Rust 2011). Another hypothesis found in the literature explains that teachers’ inquiry practices are affected by their beliefs about inquiry features which require them to act as facilitators who scaffold the students’ activities and support independent learning (Asghar et al. 2013). Furthermore, experts (Broussard & Garrison 2004; Lange & Adler 1997) contend that the consistent experience of inquiry-based activities can significantly motivate students in learning effectively to produce better achievement.
1.7 Scope of Work

In light of the above, educators encourage teachers to implement IBL strategy in their science classes to support students’ achievements through promoting their cognitive skills. The purpose of this study is to explore and explain teachers’ perceptions about inquiry features that promote these skills as well as their actual practices in high-grade chemistry classes. In addition, students’ experience in the light of their perceptions of inquiry activities will be investigated as a lens to extract the impact of inquiry implementation on their achievements in TIMSS exams. Mixed methods design embedded in a case study will be used to collect the data required to investigate three domains in the study. Firstly, the Inquiry domain, which is based on teaching strategy to support cognitive learning, questions used to support content learning, and students’ interaction to support collaborative learning. The second and third domains are the same domains used in the TIMSS structure. One is Content domain, which is based on teachers’ and students’ perceptions of IBL as well as students’ achievement in TIMSS 2011, and finally, cognitive domain, which is based on students’ scientific skills gained by inquiry implementation. Two main branches of a private school A and B that follow the American curriculum contributed to the study. The participants are all science teachers of these schools and grade twelve chemistry students who sat for the TIMSS 2011 exam. The following figure illustrates the main domains of the study.

**Figure 2: The three main dimensions of the study.**
1.8 Structure of Dissertation

This study is divided into five main chapters. This chapter has provided the definition of the key concepts, rationale, purpose and significance of the study to highlight the research questions and emphasize the scope of this work. Next, the literature review explains the results of what has been found and said about IBL, its types, and its impact on student outcomes including both achievements and learning skills that are mentioned in the introduction. The third chapter outlines the methodology used including the practical work of how two types of data are collected. In addition, instruments, sampling, reliability and validity are also described. Data analysis and results are presented in chapter 4. Finally, chapter 5 outlines the conclusion, discussion of the study findings and recommendations.
Chapter 2: Literature Review

The focus of the current study is to examine the indicators of IBL method in teachers’ instructional practices and their perceptions towards it, and to measure students’ scientific skills and their perceptions towards IBL implementations in chemistry classes that impact their achievements in TIMSS exams. This chapter delivers a review of the literature from several angles related to IBL instruction. Particular attention is paid to the historical and theoretical research backgrounds that shed light on IBL, followed by the nature of IBL and its effectiveness on education. Constructivism will then be compared to IBL as an active learning instruction. The relationship between IBL and students’ acquisition of scientific skills is also discussed. Factors affecting its implementation and IBL between theory and practice are briefly mentioned. Finally, the relationship between TIMSS and strategies of inquiry model is interpreted.

2.1 Conceptual Framework

In the light of the study objective, the conceptual framework is designed to illustrate the main theories that guide this research.

Figure 3: A conceptual framework demonstrates the incorporation of study theories.
2 Historical and Theoretical Background of IBL Instruction

John Dewey (1910) proclaimed that students could understand and experience the process of science more efficiently by giving more emphasis on attitudes of mind and thinking skills rather than being passive receivers when the main focus is only on scientific facts. Therefore, developing thinking and formulating habits of minds by engaging students in learning are articulated as the main objectives of inquiry instruction. Thus, being an active learner is the primary factor that motivates students to freely construct their knowledge in a supportive environment (Dewey 1938).

Accordingly, calling for reform in education was essential to meet the demands of the new century to produce students who are scientifically literate through developing methods of teaching science as enquiry (Schwab 1960) in order to enhance scientific skills such as observing, inferring, classifying and controlling variables (Barrow 2006; Martin 2010). In addition, science teachers were encouraged to use the school laboratory to help their students to be fully engaged in the process of scientific investigation which is considered as an invitation to enquiry learning, within which inquiry-based instruction was recommended (Schwab 1966) because of its potential to empower learners when they work as experts to clarify their own data (Tabak & Baumgartner 2004). Although, science teachers supported the inclusion of this new instruction in teaching science and opposed the didactic techniques, their actual teaching of science does not represent inquiry (Rutherford 1964).

National Science Educational Standards (NSES) advocated that IBL activities that accomplish scientific literacy benchmarks are pertinent for enhancing student achievements (NRC, 1996b). The American Association for the Advancement of Science claimed that science-literate students would be generated by 2061 when IBL is implemented consistently in science classes (AAAS 1993). Basically, successful IBL involves the development of students’ cognitive abilities when they act as scientists to answer specific question during investigation which help them to gain better scientific knowledge and enhance their inquiry abilities (Bybee 2000; NRC 2000).

NRC identified the main features of inquiry that should be the responsibility of students in science classes, which are posing problem-oriented questions, collecting evidence, developing explanation, evaluating justifications and communication (NRC 2000). Subsequently, a list of
statements were designed by NRC (1996b) to illustrate the emphasis shift that guide all science teachers in general to the essential elements of inquiry learning as shown in the following table.

<table>
<thead>
<tr>
<th>Changing Emphases to Promote Inquiry</th>
<th>Less emphasis on</th>
<th>More emphasis on</th>
</tr>
</thead>
<tbody>
<tr>
<td>Treating all students alike and responding to the group as a whole</td>
<td>Understanding and responding to individual students’ interests, strengths, experiences, and needs</td>
<td></td>
</tr>
<tr>
<td>Rigidly following curriculum</td>
<td>Selecting and adapting curriculum</td>
<td></td>
</tr>
<tr>
<td>Focusing on student acquisition of information</td>
<td>Focusing on student understanding and use of Scientific knowledge, ideas, and inquiry processes</td>
<td></td>
</tr>
<tr>
<td>Presenting scientific knowledge through lecture, text, and demonstration</td>
<td>Guiding students in active and extended scientific inquiry</td>
<td></td>
</tr>
<tr>
<td>Asking for recitation of acquired knowledge</td>
<td>Providing opportunities for scientific discussion and debate among students</td>
<td></td>
</tr>
<tr>
<td>Testing students for factual information at the end of the unit or chapter</td>
<td>Continuously assessing student understanding</td>
<td></td>
</tr>
<tr>
<td>Maintaining responsibility and authority</td>
<td>Sharing responsibility for learning with students</td>
<td></td>
</tr>
<tr>
<td>Supporting competition</td>
<td>Supporting a classroom community with cooperation, shared responsibility, and respect</td>
<td></td>
</tr>
<tr>
<td>Working alone</td>
<td>Working with other teachers to enhance the science program</td>
<td></td>
</tr>
</tbody>
</table>

Table 2: The main aspects that support implementing IBL instruction (NRC 1996b, p. 113).

The literature on IBL discusses several kinds of instruction based on significant qualifiers that emphasize its nature, scaffolding level, learning emphasis depending on either existing knowledge or constructing knowledge, and finally, the scale of inquiry which could be within the class or course, or represented in the whole course or degree (Spronken-Smith & Walker 2010). Hence, scaffolding process refers to the guidance and support provided to students at the beginning, and then gradually decreased until they can take the charge of their learning (Wood, Bruner & Ross 1976) as decreasing scaffolding level leads to increasing students’ independent learning abilities and enhancing their skills.

2.3 Nature of IBL Instruction & its Benefits (Theoretical View)

Inquiry instruction is a powerful method within the learning process that depends on student-center approach as it supports the inquisitiveness of learners (Blanchard,
Souterland & Granger 2008) who are expected to pose critical questions in a collaborative setting. Investigation is required to answer these questions through seeking evidence and discussing critical reasoning. National science education standards seek to promote IBL instruction that enables educators to build on students’ natural curiosity (NRC 2000) through understanding science discipline as human endeavor. In addition, it increases their motivation and stimulates their interest (Gibson & Chase 2002; Deboer 2002; NRC 2005) to pursue a scientific career when they show better acquisition of both essential scientific concepts (Gott & Duggan 2002; Minner, Levy & Century 2010) and experimental skills (Drayton & Falk 2001). The following figure illustrates the nature of inquiry learning as demonstrated by Etherington (2010).

Figure 4: Nature of scientific method of inquiry (Etherington 2011, p. 38).

Figure 4 shows that IBL model focuses on engaging students in conducting a research to answer a specific question through constructing their hypothesis and testing it, then analyzing the results to draw a logical conclusion (Banerjee 2010).

IBL instruction has been regarded in the international educational field as an effective learning strategy that strongly enhances science education (Mäeots & Pedaste 2014). A vast body of literature affirms that a wide range of educational goals are clearly affected by applying IBL practices such as students’ motivation and disposition towards learning science, understanding scientific concepts, and acquiring problem solving skills (Papacek 2010a, 2010b, cited in Cincera 2014; Wilke & Straits 2002).
Hence, inquiry learning is considered as a student-driven process. Understanding and investigating students’ perceptions and interests towards learning science by IBL instruction is a critical issue that affects the direction of the inquiry process (Magee & Wingate 2014). Students who reliably apply inquiry practices in their class usually acquire the habits of working as scientists faster. These habits enhance their inquiry learning skills rather than just reading from the given text (Latta, Buck, Leslie-Pelecky & Carpenter 2007).

2.4 IBL Instruction as Constructivist and Active Learning Strategy (Practical View)

The most appropriate teaching and learning approaches should facilitate students’ acquisition of 21-century skills and competencies through independent learning groups (DES 2003; NASRV 2008). Supporting this viewpoint, Airasan and Walsh (1997, cited in Orlich et al. 2013, p. 82) feel that “[C] onstructivism is a theoretical model about how learners come to know”. Moreover, it is a pedagogical concept that refers to discovery learning where students acquire new knowledge that builds on their prior information when they conduct their own experiences (Bal 2009; Mayer 2004). Additionally, Forawi (2014, p. 41) contends that “[C] onstructivism is the dominant paradigm of learning in science, and a large amount of science education research has been carried out from a constructivist perspective”.

Ronis (2008) argues that there is a close match between inquiry model and the theory of constructivism. Thus, IBL is an example of constructivist approach where learners should investigate the surrounding phenomena by evaluating the collected data to make a logical conclusion (Blanchard et al. 2010) rather than the teacher passing the information passively to them (McKinley 2012). Therefore, constructivist philosophy encourages self-directed learning strategies that allow students to have the active role of monitoring the learning process through planning procedures and evaluating evidences (Kang, Jordan & Porath 2009) which enhance their problem-solving abilities (Hmelo-Silver 2004).

There are several points of agreement that justify to what extent inquiry-oriented approach and constructivist approach are significantly connected (Richardson 2003). The following figure shows the commonalities between them.
Points of Agreement between IBL & constructivism

<table>
<thead>
<tr>
<th>Points of Agreement between</th>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>Student is the main focus</td>
<td></td>
</tr>
<tr>
<td>flexible pace of instruction</td>
<td></td>
</tr>
<tr>
<td>IBL &amp; constructivism</td>
<td></td>
</tr>
<tr>
<td>Students should search for implications, produce conclusions and evaluate their ways to solve real problems</td>
<td></td>
</tr>
<tr>
<td>Humans classify objects provided by nature</td>
<td></td>
</tr>
<tr>
<td>It is not a sole learning model</td>
<td></td>
</tr>
</tbody>
</table>

**Figure 5: Commonalities between IBL & constructivist approach** (Richardson 2003).

Previous studies have referred to any constructivist approach as an outstanding contribution that positively supports the quality of science education (Gruender & Tobin 1991; Moutmer 1995; Nezvalova 2008). IBL instruction refers to diverse ways that provide students with the opportunities to connect their content knowledge to real-life applications through organized thinking (Slavin 2012). Consequently, teachers are encouraged to apply IBL techniques consistently so as to fulfill the basic goals of literacy, and effectively maximize students’ understanding of a wide range of scientific concepts in order reduce their misconceptions (Holbrook & Rannikmae 2007, in Forawi 2011). Thus, shifting the paradigm from the didactic-traditional atmosphere into inquiry-constructivist learning becomes essential in science education. It is still impossible to do this shift without transforming the epistemology of both teachers and students to fully understand how knowledge should be constructed to provide them with a meaningful learning experience (Bell & Pearson 1992; Lamanauskas 2010). This is why professional development programs are required to improve teachers’ pedagogical knowledge about IBL and its implementations. Inquiry teaching needs sufficient time where teachers behave in the same energetic manner while playing a supportive role (Powell & Kalina 2009).

Within the context of the UAE, high school students’ low achievement is one of the significant problems that face science education in general, particularly, in chemistry. A previous study asserted that integrating cooperative learning with constructivist activities was more effective with chemistry students in the UAE than traditional teaching when taking into consideration
students’ abilities and gender as well (Balfakih 2003). As a result, there have been some crucial goals in the Vision 2020 plan produced by the Ministry of Education that emphasized the urgent need for applying IBL practices to enhance consequential thinking and meaningful learning by producing a generation of active learners who can effectively communicate to solve ill-structured problems (MOE, cited in Balfakih 2003). Thus, this study aims to shed light on the actual IBL implementation in the UAE based on both the theoretical and practical views previously mentioned.

2.5 IBL Pedagogical View

There has been a reasonable tendency to consider that teachers’ beliefs which represent espoused theory is the potential factor that direct teachers’ practices underlying theory of action (Kane, Sandretto, & Heath 2002). Basically, it is crucial to explore both perceptions and practices of teachers to determine the notion of two educational theories which Argyris and Schon (1974, cited in Jones 2009, p. 177) identify as “espoused theory and theory-in-use” that underpin the ongoing learning experience. Roehrig (2004) claims that in spite of the constant emphasis on the implementation of IBL instruction in science education reform, translating this reform vision from theory to actual practice is still difficult because teachers are affected by the way they were taught, which formed their beliefs (Roth et al. 2006) which may render them resistant to modification or change (Kagan 1992). Moreover, many studies asserted that science teachers frequently use appropriate new concepts or educational terms as a reform jargon to refer to existing teaching instructions or learning activities such as ‘hands-on’, ‘students build on their own knowledge’, and ‘teachers as facilitator’ even though those terms do not match their actual implementations (Bryan 2003; King, Shumow, & Lietz 2001; Yerrick, Parke & Nugent 1997) which has led to an urgent call for teachers’ professional development programs to help them feel more confident in IBL applications.

Although there is an obvious disconnection between the didactic ways of teaching observed in science classes and teachers’ perceptions and descriptions of their inquiry teaching instruction (King et al. 2001), a recent study concluded that “the challenge of bridging the theory-into-practice gap is not actually an eternity away” (Leaman & Flanagan 2013, p. 59), but it can be
directed to the reform path by avoiding or modifying any vulnerable tasks that negatively affect the learning process.

In Standard B of National Science Educational Standards (NSES), it is stated that “teachers of science guide and facilitate learning” (NRC 1996, p. 32) which means that teachers should not provide their students with the scientific knowledge as a straightforward answer present in their textbook. Instead students should be encouraged to debate collaboratively in order to develop more scientifically oriented questions (Smith 1996). Furthermore, the question under investigation is called the efficacy of IBL because its technique can be designed in a way that does not underpin the inquiry goals which provide students with meaningful learning experience (Klahr & Nigam 2004; Pine et al. 2006). Therefore, the stress on underlying scientific content should be decreased, while behavioral and skillful outcomes through IBL activities should be highlighted. Researchers’ observations of IBL classes found that teachers’ priorities were in getting students to enjoy doing experiments and using a variety of materials more than cognitively, thus engaging them to understand in-depth the required scientific concepts (Furtak & Alonzo 2009). Accordingly, prioritizing activity over developing cognitive abilities and understanding content-oriented objectives is considered as a misinterpretation of IBL goals and leads to an undesirable mismatch between science reform-oriented expectations and teachers’ priorities in their actual practices which certainly threaten the acceleration of the reform achievement and its success.

The essential capabilities that are expected from high school students have been identified by five science Threshold Learning Outcomes (TLOs) as a foundation to articulate the required scientific skills of a science graduate (Yates, Jones & Kelder 2011) which are demonstrating good understanding of science as inquiry, representing breadth and depth of the content knowledge, and communicating knowledge to real life (Yates et al. 2011). These skills were categorized by the Science Students Skills Inventory (SSSI) in six significant areas, which are team work, oral communication, scientific writing, scientific knowledge, quantitative skills and ethical thinking (Matthews & Hodgson 2012). Five of these skills are developed effectively by enhancing interactive learning activities in feasible classes that implement IBL instruction (Aurora 2010) especially in laboratory investigations. More recently, Hodgson, Varsavsky, & Matthews (2014) argued that traditional teaching instructions provide students with the required
content knowledge without developing any of their learning skills, while practical laboratory classes based on IBL activities utilize all the six nominated scientific skills as perceived by 93% of the students in their study.

Basically, learning science is a physical attempt to positively understand the natural phenomena in the surrounding environment through observation, questioning and investigation that requires acquiring some essential scientific skills (Papacek 2010a, cited in Cincera 2014). Learning the nature of science is a major part in learning science through implicit application of IBL instruction coupled with explicit teaching of NOS (Forawi 2014). Correspondingly, Bybee and Powell (2014) classified the science process skills that are the substantial outcomes of consistent IBL practices into five types. The first type is the acquisitive skills which refer to abilities of students to collect the required data. The second type is the organizational skills which indicate how students are able to put their data in systematic order to be available for analysis stage. The third type of skills is the creative skills which identify the abilities of students to develop new ways of approach to think more critically. Communicative skills are the fourth type that distinguishes the abilities of students to transfer and explain their information successfully to others. Finally, manipulative skills signify the abilities of students to handle the scientific tools, machines or any laboratory instruments that should be used during their investigation.

The consistent emphasis on theoretical scientific knowledge through traditional teaching techniques and neglecting hands-on activities integrated with technology applications are the main reasons behind the problems affecting the quality of science education in the Arab states, including the UAE (Dagher & BouJaoude 2011). That is why IBL as an experiential learning instruction has also been endorsed as a student-centered pedagogy (Hmelo-Silver 2004; Magnussen, Ishida & Itano 2000) which has the maximum benefits for students’ learning by enhancing both the development of their high-order thinking skills and their outcomes (Spronken-Smith & Walker 2010).

Harlen and Qualter (2009) suggested three main dimensions of students’ progression in scientific skills based on IBL strategies from simple to more elaborated skills, followed by the effective use of these skills in familiar and unfamiliar situations, and end up with consciously making reasonable predictions which imply development of skills into the more advanced stage of metacognition skills. Akinoğlu and Tandoğan (2007) advocated that employing the highest level
of IBL in science education which is the guided and open inquiry with problem-based active learning strategies will positively enhance students’ achievement in standardized tests that measure both learning content and skills. In addition, increasing the level of problems complexity leads to increasing the acquisition of skills that enrich students’ cognitive development (Capraro et al. 2013; Bauer & Bennett 2003; Celia 2005; Lopatto 2004; Russell, Hancock & McCullough 2007; Seymour, Hunter, Laursen & DeAntoni 2004; Zydney et al. 2002a; Zydney et al. 2002b). Ronis (2008) referred to IBL as a brain-compatible methodology that provides students with real opportunities in order to connect educational theories to effective practical experiences (Schwartz, Barnsford & Sear 2005) which enable them to positively interact with types of reasoning and achieve high levels of Bloom’s taxonomy within the cognitive process (Liu & Lin 2009). Thus, IBL activities promote students’ critical thinking and problem solving skills because this instruction utilizes questioning techniques that launch students in the direction of analyzing and evaluating their data to make proper decisions and find a conclusion to solve an authentic problem (Snyder & Snyder 2008), as well as increasing focus on practical opportunities enhances students’ intrinsic motivation and improves their metacognitive skills (Zimmerman 2007). Conclusively, IBL practices as a scientific methodology enhance students’ cognitive acceleration and develop their scientific reasoning skills (Hugerat, Najami, Abbasi, & Dkeidek 2014). Thus, investigating ill-structured problems stimulates students’ innovation and creativity through brainstorming to find alternatives that efficiently solve the required tasks (Gurses, Acikyildiz, Dogar & Sozbilir 2007).

The technique of IBL is interpreted based on complex and interrelated contextual influences (Pea 2012) such as teacher competence, learner autonomy, assessment and technology integration. Mostly, teachers’ competence is the most significant factor that underpins positive implementation of IBL instruction (Onwu & Stoffels 2005) because teachers are considered as central-decision makers who prepare and adapt IBL activities in their classroom (Colburn 2000). Accordingly, science teachers not only require a deep understanding of their subject matter to introduce correct scientific concepts to their students, but they should also be aware of the scientific process to effectively facilitate the learning development, and guide the students to formulate successful investigation (NRC 2005). Lack of the combination between content knowledge, theoretical knowledge and pedagogical knowledge would lead to unsatisfactory experience of learning science and low quality of education (Kim & Tan 2011). Consequently,
providing teachers with sufficient and authentic professional development opportunities has a positive relationship with the level of IBL practices that they apply in their classes (Rogan & Aldous 2005) because generally most of them have never experienced IBL instruction in their own education stage (Hahn & Glimer 2000, cited in Abd-El-Khalick et al. 2004). That is why investigating science teachers’ perceptions of applying IBL in their teaching method is advantageous to support their practice. Moreover, using the term inquiry investigations or practices is beneficial in the educational field to “stress that engaging in scientific inquiry requires coordination both of knowledge and skills simultaneously” (NRC 2012, p. 41).

Learner autonomy has been flagged as one of the dynamic principles that reinforce expressive activities in IBL environment where students’ practical work and self directed learning drive the vehicle of the educational situation in the classroom with less control from teachers and more learning responsibility from students (Anderson 2007, cited in Coban, 2013). Furthermore, high stakes of standardized assessments, including summative examinations play a practical role in improving inquiry-based practices in science classes (Blanchard et al. 2010; Saka, Southerland & Brooks 2009). Moreover, there has been an argument that there is an intrinsic link between acquiring scientific process skills and enhancing students’ content knowledge (Bybee 1997; Chiappetta & Adams 2004).

NRC (2005) encourages teachers to integrate technology as a valuable tool in the scientific inquiry process which strongly contributes to the enhancement of constructivist, student-centered practices (Seimears, Graves, Schroyer & Staver 2012), and enriches teachers’ pedagogical knowledge (Hechter & Vermette 2013). Recently, the integration of technological skills into science education has become an extensively popular trend (Tsai & Chai 2012). According to the literature of science-based technologies, this integration facilitates the learning process and helps students to understand more key scientific concepts in short time as well as engage them in real scenarios for further investigations (Abbit & Klett 2007; Anderson & Maninger 2007; Bauer & Kenton 2005; Capraro et al. 2013; Gulbahar 2007; Judson 2006; Kotrlik & Redmann 2005; Totter, Stutz & Grote 2006; Wood & Ashfield 2008; Zhao 2007).

Previous studies emphasized that technology integration into scientific academic content is another key element (Almekhlafi 2006a, 2006b) required to solve problems by operating IBL to develop students’ metacognitive skills (Sherry, Bilig, Jesse & Acosta 2001) as a result of its
progressive impact in both teaching and learning practices (Almekhlafi & Almekdadi 2010; Manzo 2001). In this regard, Science education reform identifies the inclusion of technical applications in learning science as a primary goal (Seimears et al. 2012) that directly enhance students’ motivation to gain more knowledge (Ottenbreit-Leftwich, Glazewski, Newby & Ertmer 2010).

2.6 The Relationship between TIMSS & Strategies of Inquiry Model.

A current research categorized scientific content knowledge into six main kinds which are “canonical, procedural and experimental, nature of science, real-life issues, classroom safety, and meta-cognitive” (Furtak & Alonzo 2010, p. 427). Given the prominence of IBL in science education reform to all grade levels, researchers have been inspired to consider the relation between knowledge categories and features of the inquiry model. The strategies and relevant skills of the inquiry model are illustrated in Figure 6. However, IBL is a nonlinear process. It has a recursive, highly individual and flexible nature (Oberg 2013).

![Figure 6: Inquiry Model](image-url)
Hence, inquiry is defined by NRC (2001) as “consisting of the activities and thinking processes of scientists, as well as knowledge of what scientists do and what science is, embedded within a foundation of deep conceptual understanding” (in Furtak & Alonzo 2009, p. 428). Based on this definition and considering all the six categories of knowledge that are measured by TIMSS, they have parallel representations with fundamental inquiry goals which aim to produce independent learners who acquire not only scientific skills, but also the disposition to employ those abilities along with deep understanding of self-assessment strategies and their own responsibilities towards learning in order to thrive in a digital environment full of complex information (Alberta, 2004). In addition, the progressive inquiry principles were designed (Scardamalia, 2002; Song & Looi 2012; Yeo & Tan 2010) to explicate the dynamics of scientific inquiry process, and adapted to represent inquiry strategies (Kong & Song, 2014).

Based on the previous literature, the following table is designed in light of this present study’s objectives to highlight the link between knowledge categories and inquiry principles in relation to the essential scientific skills that can be achieved.

<table>
<thead>
<tr>
<th>(TIMSS) Knowledge categories</th>
<th>meaning</th>
<th>Strategies of Inquiry model related</th>
<th>Instructional principles of IBL</th>
</tr>
</thead>
<tbody>
<tr>
<td>Canonical knowledge</td>
<td>propositional information found in a textbook such as facts, laws, theories and explanations</td>
<td>Retrieving: gain background &amp; connect to self prior information to pose a question e.g: (Forawi 2014)</td>
<td>Building on what students’ already know</td>
</tr>
<tr>
<td>Procedural &amp; experimental knowledge</td>
<td>steps of scientific practices and choose materials to execute scientific procedures</td>
<td>Planning: identify the topic area and sources of collecting data for inquiry investigation e.g: (Song &amp; Looi 2012)</td>
<td>Using authoritative sources constructively in a sequence of stages</td>
</tr>
<tr>
<td>Nature of science knowledge</td>
<td>what scientists do conduct investigation to discover natural phenomena which represent the value of science</td>
<td>Processing: choose pertinent information to make connection and inferences</td>
<td>Encouraging diverse ideas at critical point relies on evidence-based assessment</td>
</tr>
<tr>
<td>Real-life issues</td>
<td>Connection between content learning and life situations such as social or personal</td>
<td>Evaluating: transfer learning to new situations with critical analysis &amp; logical decision e.g: (Mäeots 2014)</td>
<td>Working in authentic problems</td>
</tr>
<tr>
<td>-----------------</td>
<td>--------------------------------------------------------------------------------</td>
<td>-------------------------------------------------------------------------------------------------</td>
<td>----------------------------------</td>
</tr>
<tr>
<td>Metacognitive knowledge</td>
<td>Strategies for learning to skillfully develop new thinking</td>
<td>Creating: organize &amp; edit the information to establish new product</td>
<td>Engaging actively and reflecting on that experience. e.g: (Oberg 2013)</td>
</tr>
<tr>
<td>Classroom safety knowledge</td>
<td>Handling classroom science materials safely in group work</td>
<td>Communicating: Share and present to audience</td>
<td>Providing collaborative opportunities in social interaction</td>
</tr>
</tbody>
</table>

Table 3: The relationship between inquiry strategies and categories of knowledge measured by TIMSS.

The assessment of students’ performance in science is scaled to 500 as an international average, and standard deviation of 100. These achievements are based on four criteria which are called international benchmarks that explain each level of students’ understanding and knowledge. The following table explains how each science international benchmark in TIMSS refers to inquiry types:

<table>
<thead>
<tr>
<th>International Benchmark</th>
<th>Description</th>
<th>Type of IBL required</th>
</tr>
</thead>
<tbody>
<tr>
<td>Advanced 625</td>
<td>- understand and apply basic elements of investigation to draw conclusions and solve real life problems - communicate &amp; explain knowledge in a written report</td>
<td>Open inquiry</td>
</tr>
<tr>
<td>High 550</td>
<td>- Some scientific skills are demonstrated - Interpreting data in graphs, diagrams …etc - Writing conclusion in short intensive response</td>
<td>Guided inquiry</td>
</tr>
<tr>
<td>Intermediate 475</td>
<td>- Interpreting information from graphs to draw conclusion - Brief explanation</td>
<td>Structured inquiry</td>
</tr>
<tr>
<td>Low 400</td>
<td>- Interpreting simple graphs - Applying basic knowledge to similar situation</td>
<td>Demonstrated inquiry</td>
</tr>
</tbody>
</table>

Table 4: The relationship between science international benchmark and inquiry types.
2.7 The Results of Previous Studies

Many studies have highlighted the effectiveness of IBL applications (Anderson 2002; Ketpichainarong, Panijpan & Ruenwonga 2010) as increasing students’ behavioral, intellectual engagement and providing them with lifelong learning skills (Harris 2006; Richardson & Liang 2008; Mo 2008). These latter qualities are seen as vital in developing students’ scientific conceptual understanding and supporting logical ways of creating this scientific knowledge and its nature. As a result, a new generation of successful decision makers to their future investigations will be produced (Harlen 2013; Royal Society 2006, 2010) that achieve the major goals of scientific literacy (Holbrook & Rannikmae 2007, cited in Forawi 2011) through enhancing their cognitive skills such as problem-solving and critical thinking (Gupta 2012; Hammerman 2005; Wu & Hsieh 2006).

Ramnarain (2014) argued that science teachers believe that IBL practices provide students with more enjoyable science classes and develop their skills in the experimental process during consistent inquiry investigations to construct new knowledge based on their prior information. Researchers emphasized that teachers play a critical role to encourage their students to understand the nature of scientific process that is constantly changing and dynamic (Khishfe & Abd-El-Khalick 2002) through IBL techniques, which means that teacher training and development programs should frequently include more teachers’ practices of inquiry-based laboratory which increase their attitude towards learning science, and develop their scientific process skills that are essential to professionally lead their students to apply IBL activities to support their creative skills (Yakar & Baykara 2013).

Although, students are working in cooperative groups to implement IBL activities in the UAE, it is difficult to effectively develop their practicing inquiry abilities because insufficient opportunities are given to them to work independently, and all their investigations are under intensive support from their science teachers (Al-Naqbi 2010). Thus, other obstacles such as inadequate class time, limitations of students’ skills and prior knowledge, teachers’ frequent intervention, and shortage of scientific tools act as the main barriers towards implementing successful IBL experiences (Anderson 1996; Cheung 2007; Wallace & Kang 2004). Based on these theories, the next chapter will present the methodology of the present study.
Chapter 3: Methodology.

The previous chapter has shown that there are limited studies in IBL that have investigated features of inquiry instruction and its implementation in the UAE, and no studies refer to its impact on students’ achievements in TIMSS exams. This study was carried out over a period of three months in two private schools (A and B) in Dubai, where science teachers are trained to apply IBL activities in their science classes. The main foci of the study are features of IBL instruction that are actually implemented in grade 12 chemistry classes as well as students’ development of scientific skills that might impact their achievements in TIMSS exams. Therefore, a variety of instruments were applied to overcome the difficulty in measuring types of scientific skills such as cognitive and collaborative skills as they are interrelated (Lai & Viering 2012).

3.1 Research Design

In this present study, a case study is embedded in a mixed methods research paradigm (Luck, Jackson & Usher 2006; Yin 2009) on pragmatic grounds (Creswell 2012) to achieve the purpose of the study by explaining and investigating elements of IBL and its applications to develop students’ scientific skills and its impact on their achievement in TIMSS exams. A case study is defined as “an approach that involves an in-depth exploration of a single case, or example, of the phenomenon under study” (Mertens 2010, p. 233). The type used in this study is called “instrumental case study” (Creswell 2013, p. 99) that focuses on a specific concern which is IBL, and then selects a bounded case to illustrate it. Accordingly, the case in the present study is based on two private schools in Dubai that are branches of the same school organization. While the mixed methods approach is used to answer the questions of the study and to fulfill its purposes. This design is defined as “an approach to inquiry that combines or associates both qualitative and quantitative forms” (Creswell 2009, p.4).

Thus, the rationale behind implementing a mixed methods design lies in its philosophical assumptions, which indicate an overall strength that can successfully overcome the limitation of each solitary method, and gain the maximum benefits from both qualitative and quantitative advantages for more depth and breadth through understanding and collaboration (Johnson,
Onwuegbuzie & Turner 2007), in order to increase the validity and reliability of the findings (Creswell 2009). Therefore, the interpretive framework of this research depends on the philosophy of pragmatism that is concerned with applications that solve problems, and focuses on the outcomes rather than other antecedent conditions (Creswell 2014). This study requires implementing many approaches to collect adequate information to best address the research problem, and deeply understand all its aspects (Creswell 2013; Fraenkel & Wallen 2012). Moreover, integrating multiple measures in collecting data is recommended to fully answer the study questions (Creswell 2008). Thus, collecting qualitative and quantitative data are beneficial to measure teachers’ perceptions and students’ skills.

The qualitative and quantitative data are collected through a concurrent embedded strategy of mixed methods in order to determine if there is any convergence or combination when the two databases are compared. (Creswell 2009). This comparison is essential in the “concurrent triangulation approach” (Creswell 2009, p. 213) for corroboration, confirmation or cross-validation purposes (Steckler et al. 1992). More recently, this design is called “convergent parallel mixed methods design” (Creswell 2014, p. 219) which is conducted to compare different perspectives drawn from both quantitative and qualitative information.

At the first stage, quantitative data will be collected from science teachers’ perceptions and practices at the beginning of the academic year, followed by qualitative data during the implementation of inquiry learning by classroom observation to answer the first question in the study: ‘What are teachers’ perceptions and practices in developing students’ scientific skills through IBL strategy in science classes?’

More quantitative and qualitative data are collected simultaneously at the second stage to fulfill the second question ‘What are students’ perceptions and experiences towards IBL implementations in chemistry classes?’ where a questionnaire will be administered to grade 12 students as well as one-to-one interviews with the schools’ academic supervisors at the end of the first academic term to obtain adequate data to fully answer the third question ‘How does IBL instruction impact students’ achievement in TIMSS exams in the UAE?’.

The quantitative statistics are considered as the primary data that guides the study. Thus, the qualitative data supplements the procedures as required (Creswell 2009). Accordingly, weight is
given to the quantitative data as a predominant factor to address the expected outcomes, while the qualitative data is embedded within it to explore the inquiry learning process implemented in the school. The integration of different types of data can benefit the researchers to gain perspectives to provide an overall composite evaluation of the study problem (Johnson & Christensen 2012). Stages of all data collection are illustrated in the following figure.

![Figure 7: The research design of the study.](image)

### 3.2 Study Population and Sampling

The population of the study is defined as a complete set of elements that have similar characteristics regarding the criteria of sampling (Mertens 2010). The present study has “accessible population” (Fraenkel & Wallen 2012, p. 97) which is a subset of the whole target population, and the research has reasonable access to it (Mertens 2010). Two groups represent the accessible population of interest in this study meaning all science teachers and all grade 12 chemistry students in private schools in Dubai. Non-probability with disproportional stratified sampling has been applied to choose the participants in the study to efficiently represent the study population, and to provide adequate information (Kalton 1983). Hence, a sample is defined as any group on which the required data is obtained (Fraenkel & Wallen 2012), The sample of the study is selected purposefully (Lodico, Spaulding & Voegtle 2010) from both science
teachers (N1 = 50), and grade 12 chemistry students (N2 = 75) who participated in TIMSS 2011 in two private schools in Dubai which apply IBL instruction in their science classes.

3.3 Instrumentation

Instrumentation is defined as “the whole process of preparing to collect data, it involves not only the selection or design of the instruments but also the procedures and the conditions under which the instruments will be administrated” (Fraenkel & Wallen 2012, p. 118). Multiple instruments are utilized in the present study to collect the required data. The first tool is the science teachers’ questionnaire, followed by classroom observation for grade 12 in chemistry sessions. At the end of the term, students’ questionnaire is used for the same students. Finally, the interview is planned with the academic supervisors. All data is analysed and discussed in light of the TIMSS 2011 report to give insights into the quality of science education provided in Dubai.

3.3.1 Science Teacher Questionnaire

A questionnaire is one of the “Written-response instructions” (Fraenkel & Wallen 2012, p. 122) that is defined as “a self-report data-collection instrument that each research participant fills out as part of a research study” (Johnson & Christensen 2012, p. 162). Objectives of the questionnaire are defined based on the research problem to provide the information desired. Utilizing a questionnaire is beneficial because it has uniform procedures, and is easy to score. Moreover, it can be anonymous (McMillan & Schumacher 2010).

The study questionnaire designed (Appendix 3) for all science teachers in the participating schools is modified from the teacher questionnaire in TIMSS 2011 according to the study framework. This questionnaire aims to collect quantitative data about teachers’ perceptions of applying IBL instruction that develop students’ scientific skills during chemistry classes. Some open-ended questions were also posed to concurrently collect qualitative data for more explanation and validation.
The questionnaire has four sections that appropriately match the main dimensions of the current study which are Inquiry and cognitive dimensions. The first section consisted of “Closed-form items” (McMillan & Schumacher 2010, p. 197) to collect teachers’ demographic information so that they can be easily categorized according to school, gender, nationality, teaching experience, grade level taught, academic qualifications, and any professional development training. The second section measured the teachers’ perceptions of the essential elements of IBL based on “Summated rating scale” (Johnson & Christensen 2012, p. 178) or Likert scale to indicate a rank order of agreement or disagreement (Bell 2005). This scale of potential responses is designed to provide great flexibility that best reflects teachers’ perceptions (McMillan & Schumacher 2010). Basically, these elements are classified into three parts according to the main sections of the inquiry-scientific method, which are question, procedures and results. The frequencies of applying five categories of scientific skills are measured in the third section under a multi-barreled question by rating scale, which are acquisitive, organizational, creative, communicative and manipulative skills. Ultimately, open-ended questions in the last section are added to allow more freedom in teachers’ responses, which can clarify ambiguous aspects that are difficult to be quantified. This mixed questionnaire is favorable through providing the participants with more space for further exploration to express and clarify their views more fully (Johnson & Christensen 2012), which increases the validity of the quantitative data provided (Fraenkel & Wallen 2012). The following table demonstrates the structure of the mixed questionnaire.

<table>
<thead>
<tr>
<th>Section 1</th>
<th>Section 2</th>
<th>Section 3</th>
<th>Section 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Objective</td>
<td>Demographic information</td>
<td>teachers’ perceptions of IBL features</td>
<td>teachers’ explanation</td>
</tr>
<tr>
<td>Responses</td>
<td>by selected-response</td>
<td>by likert scale</td>
<td>by rating scale</td>
</tr>
<tr>
<td>Data collected</td>
<td>Quantitative</td>
<td>Quantitative</td>
<td>Quantitative</td>
</tr>
</tbody>
</table>

Table 5: Construction of the study questionnaire.

The teachers’ questionnaire was conducted at the first month of the academic year when teachers usually are registered in the school workshops as an internal professional development program. The questionnaire was sent to them by email through Jotform website to collect both quantitative and qualitative data about their knowledge and practices of IBL elements. Teachers were given
two weeks to complete the questionnaire and some reminder emails were sent to the participants during these weeks to maximize the response rate.

3.3.2 Classroom Observation

The second tool was a “structured observation” (Bell 2005, p. 188) using an observation schedule in the form of a checklist. This “naturalistic observation” (Creswell 2012, p. 207) for IBL features in grade 12 chemistry classes served as a “purposeful sampling” (Lodico et al. 2010, p. 34) to discover the practical elements that might be unconsciously missed in the questionnaire, and to enable the researcher to collect more data in the programme setting (Cohen, Manion & Morrison 2000). This observation of teachers in grade 12 chemistry classes required about 7-10 weeks to collect more data about the teachers’ practices of IBL implementations. Only teachers who volunteered were observed.

Individuals’ behavior as well as their attitude is not usually congruent, as a result, observing these behavioral patterns that might happen within the classroom context is critical in collecting qualitative data (Johnson & Christensen 2008). Therefore, extensive field notes were maintained to precisely investigate all the available characteristics that affect the relevant phenomena (Creswell 2008; Johnson & Christensen 2008). Moreover, being a complete observer is advantageous to naturally explore unfamiliar issues of ongoing behavior supplemented by appropriate notes to discern its salient features (Cohen et al. 2000), and to get the complete picture of the students’ learning practices (Fraenkel & Wallen 2012). In addition, it reduces the reactivity effect or the change in participants’ behavior to the minimum (Cohen et al. 2000). As grade 12 students are above 14 years old, they have the basic skills of the formal operational stage according to Piagetian theory of cognitive development that allow them to positively analyze hypothetical situations (Slavin 2012).

Chemistry is one of the four content domains that were considered in TIMSS 2011 in the middle school, where its science assessment is based on an inclusive framework that is collaboratively established with participating countries (TIMSS 2012). The observation report of the present study was designed specifically to cast light on the same three areas of cognitive domain (knowing, applying and reasoning) that assessed grade eight students in TIMSS 2011. It was
used to describe the sets of thinking process in three main aspects in the class comprising instructional strategy, questioning and students’ interaction which are represented in the type of inquiry applied, the new levels of Bloon Taxonomy, and inquiry activities or scientific investigations implemented in the chemistry class respectively.

![Cognitive process](image)

**Figure 8: Aspects observed of the cognitive process in chemistry classes.**

The classroom observation tool (Appendix 5) is divided into two main sections. The first section is the lesson effectiveness including teachers’ and students’ interaction as well as teaching instructions and learning activities in order to determine the type of IBL experienced in the class. Second section is questioning strategies which focus on time given, students’ role and level of questions asked that affect students’ thinking skills based on Bloon Taxonomy.

Six class observations took place randomly to warrant greater detail in grade 12 chemistry classes to explore and investigate naturally the type of inquiry learning, and its features that facilitate the cognitive process.

**3.3.3 Students’ Questionnaire**

Cohen et al. (2000) mentioned that methodological triangulation of collecting data is an efficient technique when a case study is conducted in educational research through using multiple instruments for better data acquisition. In addition, this triangulation of instruments in the traditional mixed method strategy is recommended as a valid “technique of physical
measurement” (Cohen et al. 2000, p. 112) to provide more substantial information and validate findings (Creswell 2009). Consequently, the questionnaire for grade 12 chemistry students is a third tool in the study (Appendix 4), and modified from two reliable sources comprising the Student questionnaire in TIMSS 2011, and a survey used by Enger and Yager (2009, p. 67) in their study. It was delivered to students at the end of first term in the academic year 2014. Mainly, it is divided into three quantitative sections using the Likert scale, with only one qualitative question at the end of each section for further clarification. The first two sections are equivalent to their counterparts in the teacher questionnaire in order to investigate the same dimensions with the participating students. Section one aims to explore students’ perceptions about IBL features, while section two investigates the scientific skills acquired by inquiry practices in chemistry classes. To suit this present study, section three is added to discover and explain the effect of IBL implementation on students’ desire towards learning chemistry, and impact on their future careers. According to Fraenkel and Wallen (2012) this type is called a Cross-sectional survey, where information is collected over the course of the questionnaire from a particular sample that is selected from a predetermined population at approximately the same time. All the quantitative data is saved in Microsoft EXCEL file to be statistically analyzed using the Statistical Package for Social Science (SPSS) software. Reliability of this questionnaire was checked by piloting it and the results are attached (Appendix 5).

3.3.4 Interview

Semi-structured interviews (Appendix 6) were conducted with the academic supervisors in the schools according to the need of the study as face-to-face interviews (Creswell 2009) with open-ended questions at the end of the study. This social interaction tool is effective in collecting more qualitative data that is impossible to be observed such as school intention and behavior of participants at some previous point of time as well as their thoughts and feelings towards the phenomenon under investigation (Fraenkel & Wallen 2012). Thus, the academic supervisors’ interviews were done to clarify the intentions of the school administrations, and the procedures taken to improve the quality of science education in their schools. Successful interviewing relies on efficient probing and sequence of questions (Cohen et al. 2000). The guideline for the interview protocol is started by demographic information required, followed by statements of the
purpose and focus of the study, and ending with qualitative questions from general to more specific controversial questions to collect “perceptions-based data” (Louis 2000, p. 305). Notes were taken during the discussion to record any useful non-verbal communication to facilitate data analysis (McMillan & Schumacher 2010).

3.3.5 TIMSS Report

The TIMSS 2011 online-report was used as a guide in tandem with the TIMSS 2011 results provided by the participating schools and simultaneously interpreted with both qualitative and quantitative data collected from the previous tools to evaluate the holistic picture of the quality of science education provided in those private schools in Dubai. According to McMillan & Schumacher (2010), this document is considered as an external communication that provides an official perspective to enrich the findings of the study.

3.4 Pilot Study

Hence, the questionnaire wording is of paramount importance, so the pre-testing process by piloting is crucial to eliminate ambiguities in phrasing, and increase the practicability, validity and reliability of a more efficient study questionnaire (Cohen et al. 2000). Accordingly, administering students’ questionnaire to twelve students from grade 11 was beneficial to test its reliability. Several modifications were made to this pilot questionnaire. Few words were revised and changed to avoid clustering items in different scales, and to prevent possible misconceptions (McMillan & Schumacher 2010). The reliability level of student questionnaire was measured by SPSS software, and resulted in Cronbach’s-Alpha = 0.996 which signifies a high level of internal consistency for this questionnaire with a total of 33 quantitative questions (Appendix 7). The following table illustrates the reliability scale of the questionnaire.

<table>
<thead>
<tr>
<th>Cronbach's Alpha</th>
<th>N of Items</th>
</tr>
</thead>
<tbody>
<tr>
<td>.996</td>
<td>33</td>
</tr>
</tbody>
</table>

Table 6: Reliability Statistics of students’ questionnaire.

Validity and reliability are addressed by different ways in the recent study. Thus, the high degree of mixing both approaches through the triangulation of methods and data collected maximizes the validity and minimizes the weaknesses, subsequently, enhancing its internal validity. In
addition, designing several instruments to collect the required data was useful to increase the credibility of the study findings (Johnson & Onwuegbuzie 2004). Furthermore, external validity is considered through both Idiographic causation which is represented in teachers’ perceptions and students’ attitudes towards IBL, and Nomothetic causation which is represented in the standard view to IBL in science education (Johnson & Christensen 2012).

The present study reflected the ecological validity that refers to generalization across settings where the classes visited for observation purposes were chosen randomly to investigate teachers’ practices of IBL. As long as the process of collecting the data can effectively combine and switch between both quantitative and qualitative perceptions in teachers’ and students’ questionnaires, it allows another validity which is called “Commensurability mixing validity” (Johnson & Christensen 2012, p. 274).

Consistent with the framework of the study and its purpose, the teachers’ questionnaire was modified from the science teacher questionnaire in TIMSS 2011, the qualitative observation reports, and students’ questionnaire adapted from Enger and Yanger (2009) increased the reliability of the study. Furthermore, all the forms of the study instruments were reviewed by a professional instructor to ensure validity.

Hence, employed teachers have a good advantage to establish strong rapport with many of the concerned participants as sharing documents with members of the administration and colleagues enhances the accessibility to official documents required in the study. Generally, feasibility of the research design is based on the scholastic information and the competence of the inquirer to perfectly employ the two different methods in one single study (Creswell 2008).

### 3.5 Ethical Considerations

Punch (2005) refers to the importance of anticipating any ethical dilemmas that might arise in the study to be actively addressed in advance. Creswell (2009, p. 87) identifies five ethical principles derived from the Ethical Principle of Psychologists and Code of Conduct (2002) which include Beneficence and Nonmaleficence, Fidelity and Responsibility, Integrity, Justice and Respect for People's Rights and Dignity. Correspondingly, all possible ethical approvals are taken into consideration. The purpose of the study and its benefits were elucidated and discussed with the schools’ administrations to obtain consent. In addition, the process of collecting data was
clarified and approved. Thus, the informed research consent form was signed by the study participants who were assured of their confidentiality and anonymity. Finally, a report of the exploratory findings that are interpreted from different perceptions in the light of the schools’ results in TIMSS 2011 will be shared with the respective schools management so they can use it in their self-evaluation report. The following chapter will present the combination of both qualitative and quantitative findings in light of the study purpose and its questions.
Chapter 4: Results and Data Analysis

The aim of the current study is to determine the degree to which applying IBL instruction enhances students’ scientific skills and promotes their achievements in TIMSS exams. This chapter presents the results gathered from qualitative and quantitative data to explore and investigate teachers’ perceptions of IBL elements and their implementation in classrooms, and students’ perceptions of IBL instruction. Finally, students’ achievement in chemistry in TIMSS 2011 as an official benchmark showing the level of students in both content and cognitive domains in standardized tests was analyzed.

4.1 Demographic Information

Table 7 below shows the results from the demographic section of the teachers’ questionnaire.

<table>
<thead>
<tr>
<th>Gender</th>
<th>Male</th>
<th>18%</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Female</td>
<td>82%</td>
</tr>
<tr>
<td>Academic qualification</td>
<td>Master</td>
<td>12%</td>
</tr>
<tr>
<td></td>
<td>Post-graduated diploma</td>
<td>16%</td>
</tr>
<tr>
<td></td>
<td>Bachelor</td>
<td>66%</td>
</tr>
<tr>
<td>Teaching experience</td>
<td>1-4y</td>
<td>30%</td>
</tr>
<tr>
<td></td>
<td>5-10y</td>
<td>42%</td>
</tr>
<tr>
<td></td>
<td>&lt; 10Y</td>
<td>28%</td>
</tr>
</tbody>
</table>

Table 7: Percentage of teachers’ demographic information.

4.2 Teachers’ Perceptions of IBL Elements

The aim of this questionnaire is to reveal the perceptions of all the science teachers in the schools A and B (N=50) about the main elements of IBL instruction and to explore their practices of the essential scientific skills with their students. Results are presented in the following six sections: demographic information, overall responses of teachers, elements of IBL, scientific skills practices, teachers’ perceptions based on both gender and academic qualifications and responses to open ended questions.
4.2.1 Teachers’ Perceptions of Overall IBL Sub Elements

The teachers’ questionnaire examined their perceptions about elements of IBL and the rate of practicing scientific skills in their classes.

![Bar graph showing overall percentage of teachers' responses.](image)

**Figure 9: Overall positive responses of teachers by percentage.**

The above bar graph shows that the majority of science teachers (90%) precisely identify the main elements that distinguish IBL instruction. Participating teachers’ perceptions of their practices were fairly equal for three types of scientific skills: Acquisitive skills (79%), communicative skills (78%) and organizational skills (77%). On the other hand, fewer teachers practice creative skills (69%) and manipulative skills (66%) with their students.

4.2.2 Elements of IBL Instruction

This is the first section of the questionnaire that aims to explore teachers’ perceptions of the main features of IBL that they apply with science students. The highest three means is for observing natural phenomena (4.46), analyzing data (4.44) and testing hypotheses (4.42) while the lowest means (3.84) is for doing background research.
<table>
<thead>
<tr>
<th>Elements of IBL</th>
<th>Mean</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Students observe natural phenomena and describe what they see.</td>
<td>4.46</td>
<td>0.613</td>
</tr>
<tr>
<td>2. Students pose their own questions</td>
<td>4.30</td>
<td>0.543</td>
</tr>
<tr>
<td>3. Students’ prior knowledge is assessed about this phenomenon</td>
<td>4.18</td>
<td>0.628</td>
</tr>
<tr>
<td>4. Students do background research.</td>
<td>3.84</td>
<td>0.865</td>
</tr>
<tr>
<td>5. Students construct their hypothesis to answer their questions.</td>
<td>4.24</td>
<td>0.686</td>
</tr>
<tr>
<td>6. Students test their hypothesis by doing an experiment or lab activity.</td>
<td>4.42</td>
<td>0.574</td>
</tr>
<tr>
<td>7. Students decide what data needed to be collected.</td>
<td>4.24</td>
<td>0.476</td>
</tr>
<tr>
<td>8. Students analyze their data and draw conclusion.</td>
<td>4.44</td>
<td>0.540</td>
</tr>
<tr>
<td>9. Students are able to communicate their results.</td>
<td>4.34</td>
<td>0.592</td>
</tr>
</tbody>
</table>

Table 8: Teachers’ responses to elements of IBL instruction.

4.2.3 Teachers’ Responses on Practicing Scientific Skills

This is the second section of the questionnaire results which is divided into five clusters that represent types of science process skills: acquisitive, organizational, creative, communicative and manipulative skills that should be developed by applying IBL technique. The following tables show their mean and standard deviations.

4.2.3.1 Acquisitive Skills

Listening and observing skills have the highest means (4.78, 4.58 respectively). The lowest mean is for gathering data (3.60).

<table>
<thead>
<tr>
<th>Acquisitive skills</th>
<th>Mean</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Listening—being attentive.</td>
<td>4.78</td>
<td>0.418</td>
</tr>
<tr>
<td>2. Observing—being alert</td>
<td>4.58</td>
<td>0.498</td>
</tr>
<tr>
<td>3. Searching—locating sources, ability to use computer search programs</td>
<td>3.64</td>
<td>0.827</td>
</tr>
<tr>
<td>4. Inquiring—asking, interviewing, corresponding</td>
<td>3.66</td>
<td>0.960</td>
</tr>
<tr>
<td>5. Investigating—formulating question</td>
<td>3.94</td>
<td>0.739</td>
</tr>
<tr>
<td>6. Gathering data—organizing, classifying</td>
<td>3.60</td>
<td>0.857</td>
</tr>
<tr>
<td>7. Tabulating data</td>
<td>3.76</td>
<td>0.938</td>
</tr>
<tr>
<td>8. Researching—locating a problem, setting up investigations</td>
<td>3.48</td>
<td>0.677</td>
</tr>
</tbody>
</table>

Table 9: Teachers’ responses on acquisitive skills practices.

4.2.3.2 Organizational Skills

The mean of both reviewing (4.16) and evaluating (4.00) skills are higher than all other organizational skills.
### Organizational skills

<table>
<thead>
<tr>
<th>Activity</th>
<th>Mean</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Recording—charting, working systematically</td>
<td>3.70</td>
<td>0.788</td>
</tr>
<tr>
<td>2. Comparing—looking for similarities</td>
<td>3.94</td>
<td>0.619</td>
</tr>
<tr>
<td>3. Contrasting—looking for dissimilarities, noticing unlike features</td>
<td>3.80</td>
<td>0.670</td>
</tr>
<tr>
<td>4. Classifying—identifying categories, deciding between alternatives</td>
<td>3.76</td>
<td>0.656</td>
</tr>
<tr>
<td>5. Organizing—putting items in order, establishing a system, arranging</td>
<td>3.96</td>
<td>0.754</td>
</tr>
<tr>
<td>6. Outlining—employing major headings using sequential organization</td>
<td>3.50</td>
<td>0.839</td>
</tr>
<tr>
<td>7. Reviewing—identifying important items</td>
<td>4.16</td>
<td>0.710</td>
</tr>
<tr>
<td>8. Evaluating—recognizing good/bad features, knowing how to improve grades</td>
<td>4.00</td>
<td>0.925</td>
</tr>
</tbody>
</table>

**Table 10: Teachers’ responses on organizational skills practices.**

### Creative Skills

The highest mean is for planning ahead (3.74) and the lowest is for inventing (3.14).

<table>
<thead>
<tr>
<th>Activity</th>
<th>Mean</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Planning ahead—seeing possible results, setting up hypotheses</td>
<td>3.74</td>
<td>0.777</td>
</tr>
<tr>
<td>2. Designing—identifying new problems</td>
<td>3.48</td>
<td>0.814</td>
</tr>
<tr>
<td>3. Inventing—creating a method, device, or technique</td>
<td>3.14</td>
<td>0.903</td>
</tr>
<tr>
<td>4. Synthesizing—putting familiar things together in a new arrangement</td>
<td>3.38</td>
<td>0.854</td>
</tr>
</tbody>
</table>

**Table 11: Teachers’ responses on Creative skills practices.**

### Communicative Skills

The highest means came for discussing (4.78), explaining (4.60) and asking questions (4.56) while graphing had the lowest mean (3.08).

<table>
<thead>
<tr>
<th>Activity</th>
<th>Mean</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Asking questions—learning to formulate good questions</td>
<td>4.56</td>
<td>0.643</td>
</tr>
<tr>
<td>2. Discussing—learning to contribute ideas, listening to ideas of others</td>
<td>4.78</td>
<td>0.464</td>
</tr>
<tr>
<td>3. Explaining—describing to someone else clearly, clarifying major points</td>
<td>4.60</td>
<td>0.571</td>
</tr>
<tr>
<td>4. Presenting—orally reporting to a class or teacher using media effect.</td>
<td>3.68</td>
<td>0.890</td>
</tr>
<tr>
<td>5. Writing—a report of an experiment or demonstration; describing a problem</td>
<td>3.28</td>
<td>0.701</td>
</tr>
<tr>
<td>6. Criticizing—constructively criticizing or evaluating a piece of work</td>
<td>3.24</td>
<td>1.041</td>
</tr>
<tr>
<td>7. Graphing—putting results in graphical form/ interpreting them to others</td>
<td>3.08</td>
<td>0.944</td>
</tr>
</tbody>
</table>

**Table 12: Teachers’ responses on communicative skills practices.**

### Manipulative Skills

The highest mean is for using technology in science class (4.72) and the lowest mean is for constructing a simple equipment (2.20).
### Table 13: Teachers’ responses on manipulative skills practices.

<table>
<thead>
<tr>
<th>Manipulative skills</th>
<th>Mean</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Using an instrument—knowing the instrument’s parts, how it works, adjusts</td>
<td>3.48</td>
<td>0.614</td>
</tr>
<tr>
<td>2. Caring for an instrument—knowing how to store it, using proper settings</td>
<td>2.92</td>
<td>0.876</td>
</tr>
<tr>
<td>3. Demonstrating—setting up apparatus, describing parts and functions</td>
<td>3.20</td>
<td>0.782</td>
</tr>
<tr>
<td>4. Using technology- Internet, videos, websites</td>
<td>4.72</td>
<td>0.453</td>
</tr>
<tr>
<td>5. Experimenting—recognizing a question, planning a procedure, collecting data,</td>
<td>3.56</td>
<td>0.674</td>
</tr>
<tr>
<td>drawing conclusions</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6. Constructing—making simple equipment</td>
<td>2.20</td>
<td>0.989</td>
</tr>
<tr>
<td>7. Calibrating—a thermometer, balance, timer, or other instrument</td>
<td>3.04</td>
<td>0.968</td>
</tr>
</tbody>
</table>

#### 4.2.4 Teachers’ Perceptions based on Gender

The following table 14 illustrates the mean and standard deviations for the required sections based on gender responses. Accordingly, the t-test’s statistical significance was measured in order to indicate any substantial difference in the study population from which its groups were sampled. Moreover, the t-value is converted to p-value so as to reflect the probability of this difference in this data, where p is significant at p <0.05. The table shows that t-value was not statistically significant in the sample in all sections of the questionnaire according to the variable (gender).

<table>
<thead>
<tr>
<th>Variables</th>
<th>MALE</th>
<th></th>
<th>FEMALE</th>
<th></th>
<th>t-value</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean</td>
<td>Standard Deviation</td>
<td>Mean</td>
<td>Standard Deviation</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Elements of IBL</td>
<td>38.333</td>
<td>2.69258</td>
<td>38.4878</td>
<td>3.64775</td>
<td>0.120</td>
<td>&lt;0.05</td>
</tr>
<tr>
<td>Acquisitive skills</td>
<td>32.111</td>
<td>2.84800</td>
<td>31.2927</td>
<td>3.71648</td>
<td>0.620</td>
<td>&lt;0.05</td>
</tr>
<tr>
<td>Organizational skills</td>
<td>35.333</td>
<td>3.67423</td>
<td>34.4878</td>
<td>4.59414</td>
<td>0.516</td>
<td>&lt;0.05</td>
</tr>
<tr>
<td>Creative skills</td>
<td>15.333</td>
<td>2.34521</td>
<td>13.3902</td>
<td>2.68215</td>
<td>2.008</td>
<td>&lt;0.05</td>
</tr>
<tr>
<td>Communicative skills</td>
<td>28.000</td>
<td>1.41421</td>
<td>27.0488</td>
<td>3.19336</td>
<td>0.870</td>
<td>&lt;0.05</td>
</tr>
<tr>
<td>Manipulative skills</td>
<td>24.111</td>
<td>2.93447</td>
<td>22.9024</td>
<td>3.52707</td>
<td>0.956</td>
<td>&lt;0.05</td>
</tr>
</tbody>
</table>

#### Table 14: Differences between gender’s responses to the sections of the questionnaire.

#### 4.2.5 Teachers’ Perceptions of IBL based on their Academic Qualifications

Table 15 presents teachers’ perceptions of IBL in correspondence with their academic qualifications.
Table 15: Teachers’ responses according to their academic qualifications.

<table>
<thead>
<tr>
<th>Variables</th>
<th>Sum of Squares</th>
<th>df</th>
<th>Mean Square</th>
<th>F</th>
<th>Sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Elements of IBL</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Between Groups</td>
<td>12,962</td>
<td>2</td>
<td>6.481</td>
<td>.527</td>
<td>&lt;0.05</td>
</tr>
<tr>
<td>Within Groups</td>
<td>577,458</td>
<td>47</td>
<td>12.286</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>590,420</td>
<td>49</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>1. Acquisitive skills</strong></td>
<td></td>
<td></td>
<td></td>
<td>1.820</td>
<td>&lt;0.05</td>
</tr>
<tr>
<td>Between Groups</td>
<td>44,723</td>
<td>2</td>
<td>22.361</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Within Groups</td>
<td>577,597</td>
<td>47</td>
<td>12.289</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>622,320</td>
<td>49</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>2. Organizational skills</strong></td>
<td></td>
<td></td>
<td></td>
<td>2.596</td>
<td>&lt;0.05</td>
</tr>
<tr>
<td>Between Groups</td>
<td>95,256</td>
<td>2</td>
<td>47.628</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Within Groups</td>
<td>862,264</td>
<td>47</td>
<td>18.346</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>957,520</td>
<td>49</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>3. Creative skills</strong></td>
<td></td>
<td></td>
<td></td>
<td>2.207</td>
<td>&lt;0.05</td>
</tr>
<tr>
<td>Between Groups</td>
<td>30,870</td>
<td>2</td>
<td>15.435</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Within Groups</td>
<td>328,750</td>
<td>47</td>
<td>6.995</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>359,620</td>
<td>49</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>4. Communicative skills</strong></td>
<td></td>
<td></td>
<td></td>
<td>2.895</td>
<td>&lt;0.05</td>
</tr>
<tr>
<td>Between Groups</td>
<td>47,233</td>
<td>2</td>
<td>23.616</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Within Groups</td>
<td>383,347</td>
<td>47</td>
<td>8.156</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>430,580</td>
<td>49</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>5. Manipulative skills</strong></td>
<td></td>
<td></td>
<td></td>
<td>5.708</td>
<td>&gt; 0.05</td>
</tr>
<tr>
<td>Between Groups</td>
<td>112,808</td>
<td>2</td>
<td>56.404</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Within Groups</td>
<td>464,472</td>
<td>47</td>
<td>9.882</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>577,280</td>
<td>49</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 15 above highlights the statistical information based on teachers’ academic qualifications by ANOVA which reveals that although F value was insignificant among almost all sections of the questionnaire including elements of IBL and each type of scientific skills, it was statistically significant only at section 5 (Manipulative skills) F=5.708. Sig >0.05. Accordingly, an L.S.D test was used to identify the differences of teachers’ responses according to their academic qualifications as presented below in Table 16.

**4.2.5.1 Teachers’ Responses to Manipulative Skills based on their Academic Qualifications**

Table 16 below shows the significant difference in teachers’ responses to manipulative skills based on their academic qualifications.

<table>
<thead>
<tr>
<th>Dependent Variable</th>
<th>Mean</th>
<th>Post graduate diploma</th>
<th>Mean Difference (I-J)</th>
</tr>
</thead>
<tbody>
<tr>
<td>5. Manipulative</td>
<td>Bachelor</td>
<td>Master</td>
<td>-1.69444</td>
</tr>
<tr>
<td></td>
<td>22.3056</td>
<td>Master</td>
<td>-4.52778(*)</td>
</tr>
<tr>
<td></td>
<td>24.0000</td>
<td>Bachelor</td>
<td>1.69444</td>
</tr>
<tr>
<td></td>
<td>26.8333</td>
<td>Master</td>
<td>-2.83333</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Bachelor</td>
<td>4.52778(*)</td>
</tr>
</tbody>
</table>
The mean difference is significant at the .05 level.

Table 16: Teachers’ responses to manipulative skills based on their academic qualifications.

Interestingly, table 16 reveals that teachers who have masters degrees practice the manipulative skills in IBL classes more than others who have lower degrees of academic qualifications. The following graph 10 shows the percentage of teachers’ responses regarding their practices in developing students’ manipulative skills based on their academic qualifications.

![Figure 10: Teachers’ responses (%) of their practices of manipulative skills based on their academic qualifications.](image)

Majority of the participating teachers who consistently practice manipulative skills with their students (54%) were teachers who have achieved a master degree. Teachers who obtained a postgraduate diploma contributed 48% which demonstrates their perceptions of developing manipulative skills in their science classes. The lesser proportion (45%) of teachers practicing manipulative skills had lower academic qualifications (Bachelor degree).

4.2.6 Participants’ Responses to the Qualitative Questions

The teachers’ questionnaire also included four open-ended questions to collect some qualitative data to support the previous quantitative data and further explain major constructs of the study. Additionally, these results were discussed with the schools’ academic supervisors in a face-to-face interview to verify authenticity.
• Definition of inquiry-based learning instruction

The majority of science teachers stated a clear and comprehensive definition of IBL as a student-centered method that is required in modern teaching and learning processes.

Example:

• ‘It is the method that seek for knowledge based on scientific investigation to answer a certain question by flexible procedures to collect the required data and analyzing them’
• ‘It is a significant way of teaching and learning based on students' plans to achieve a basic goal which is finding a clear answer to their questions with an evidence to support their conclusion.

• The extent of the effect of IBL strategy in science classes

As expected, all science teachers recorded their undoubted beliefs about the effective impact of implementing IBL strategy and its activities consistently in their classes.

Example:

• ‘it is highly effective and recommended by KHDA because of its impact on students' outcomes as well as supporting their scientific skills such as critical thinking and problem solving which are necessary to their careers’
• ‘the potential of this technique to enhance students’ intellectual engagement which in order foster their deep understanding to science concepts through interesting inquiry activities that encourage both hands-on and minds-on, then successfully they can solve real life scenarios’
• ‘IBL is strongly effective in motivating their students toward learning science topics and stimulate their interest towards scientific careers’

• The effect of IBL implementation on students’ academic achievement in TIMSS exam.

All science teachers agreed that applying IBL activities in their classes is beneficial to their students.
Example:

- ‘IBL helps students to develop and master more scientific skills during their investigations. These abilities are needed to score high in TIMSS exam, which assess their skills as well as knowledge’
- IBL instruction help students to acquire new thinking techniques that would allow them to efficiently think further and greatly expand their knowledge through constructivist approach, which is highly required to achieve high scores in standardized tests’
- It enhances students’ scientific skills such as observe, classify, create a question, collect data, analyze results and make conclusions. These acquired skills improve students’ cognitive abilities to solve different life problems’

The academic supervisor asserted that TIMSS questions mainly rely on the students’ reasoning skills, scientific knowledge and how to understand science in order to connect it to real life context. Hence, the school administration believes that all these aspects can be achieved through the IBL implementation. The previous TIMSS results were analyzed to reinforce strengths and address the weaknesses in TIMSS 2015.

- **Assessment of students’ scientific skills.**

All science teachers in the schools agreed that they have recently applied an ongoing skills-based assessment system that allow them to observe and record students’ performance in tandem with their responses to laboratory exams, formative and summative assessments. This system focused on the IBL elements that enhance the five types of scientific skills.

Example:

- ‘We use ongoing skill-based assessment system that we have recently applied in the school and also lab exams where students are working in the science lab individually to assess their scientific skills’
- ‘Our modern assessment report provides us with the opportunity to measure students’ scientific skills and the extend of their progress’

The schools’ academic supervisors in the interview confirmed that this assessment system is developed according to KHDA recommendations and based on TIMSS assessment criteria to evaluate students’ achievement as well as to improve their learning incomes. Thus, a report card
is generated for each student which shows the level of scientific content knowledge as well as scientific skills where the percentage attained for each skill is recorded.

### 4.3 Classroom Observations for IBL Practices

Six class observations were conducted randomly in both laboratory and classes of participating teachers to understand the actual IBL practices that are implemented in chemistry classes of grade 12 students who attended TIMSS 2011 exams. The observed classes were taught by three chemistry teachers who have different academic qualifications (master in education, post-graduate diploma and bachelor degree). The following table illustrates the results of these observations that shed light on the type of IBL instruction, questions and the interaction in each chemistry class.

Table 17 below shows a summary of all IBL aspects that were observed in chemistry classes.

<table>
<thead>
<tr>
<th>Examples from Chemistry Lab</th>
<th>Instruction</th>
<th>Questions</th>
<th>Interaction</th>
</tr>
</thead>
<tbody>
<tr>
<td>- Questions were posed by the teacher to be investigated in students-centered approach as a dominant instruction.</td>
<td>- Factual, Convergent, divergent &amp; evaluative questions were asked to enhance students’ cognitive thinking abilities and to keep them on track.</td>
<td>- Students were fully engaged in cooperative learning through group processing techniques to investigate which type of oil is the best to foam soap.</td>
<td></td>
</tr>
<tr>
<td>- Group Discussion was initiated to represent their predictions, hypothesis, results, conclusion and errors.</td>
<td>- EX: What is the relation between PH of the soap and its quality?</td>
<td>- Positive interdependence cooperative group work was established based on students’ choices and levels to collect the data.</td>
<td></td>
</tr>
<tr>
<td>- Interdisciplinary science, math and Technology integration was applied by using internet as a source of information and displaying videos or animations.</td>
<td>- Which method is more appropriate to separate this chemical substance? Why?</td>
<td>- Debate between groups was conducted to show and criticize their results.</td>
<td></td>
</tr>
<tr>
<td>- Students chose their questions to be investigated from question bank.</td>
<td></td>
<td>- Teacher &amp; Students reflected on the tasks and connected them to lesson objectives.</td>
<td></td>
</tr>
</tbody>
</table>
Example from chemistry class:

- Jigsaw method was applied to empower students to take charge of their learning.
- Teacher was scaffolding each group to recall their bank of conceptualization and connect their learning to unfamiliar problems.
- Guided practice was used to support students to plan their procedures of investigation.
- Differentiation was taken into consideration during formative & summative assessments.
- Scientific-inductive approach was conducted and supported by evaluative questions to maximize students’ cognitive skills.

**EX:**
- To what extend do you think that identification of elements’ properties is essential to do chemistry?
- Which groups of elements can react only under sever conditions?
- What is the type of bond in each compound?

Students were working in heterogeneous groups to hypothesize and share ideas (Promotive, face to face interaction).

-- Teacher & Students were working actively and choose a partner randomly in the classroom to answer a question given in cards.
- Peer discussion to share their observations related to the provided visual ads.
- Each group created a question to assess another group understanding and discuss the correct answer.

Table 17: Summary of IBL aspects that were observed in chemistry sessions.

### 4.4 Students Achievement in TIMSS 2011

The following table 18 illustrates the level of grade 8 students achievement in the schools under investigation compared to their peers in Dubai in TIMSS 2011 (TIMSS & PIRLS 2011). Although school B has the highest average score (472) in comparison to other schools that teach US curriculum (464) the overall average score of students’ achievement in chemistry in both schools is lower than the TIMSS centrepoint of 500.

<table>
<thead>
<tr>
<th>Compared to</th>
<th>Average score</th>
<th>Rank</th>
</tr>
</thead>
<tbody>
<tr>
<td>School A</td>
<td>437</td>
<td></td>
</tr>
<tr>
<td>School B</td>
<td>472</td>
<td>Lower than TIMSS centrepoint (500)</td>
</tr>
<tr>
<td>All participating schools in Dubai</td>
<td>485</td>
<td></td>
</tr>
<tr>
<td>Other American curriculum schools</td>
<td>464</td>
<td></td>
</tr>
</tbody>
</table>

Table 18: Grade 8 science students achievement in the schools.

Table 19 shows that students’ average score of content as well as cognitive domains in chemistry is lower than TIMSS centre-point 500. The highest achievement is for applying domain with a score of 456, while scores of reasoning and knowing domains came fairly equally with slight increase of the former than the latter. Generally, students’ scores in the cognitive domain of knowing, applying and reasoning are lower than the overall average of Dubai (TIMSS 2013).
<table>
<thead>
<tr>
<th>Average score</th>
<th>Chemistry content domain</th>
<th>Cognitive domain</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Knowing</td>
</tr>
<tr>
<td>School A</td>
<td>439</td>
<td>430</td>
</tr>
<tr>
<td>School B</td>
<td>476</td>
<td>469</td>
</tr>
<tr>
<td>Average of both</td>
<td>458</td>
<td>450</td>
</tr>
<tr>
<td>Overall Dubai average</td>
<td>487</td>
<td>492</td>
</tr>
</tbody>
</table>

**Table 19: Grade 8 students achievement in chemistry in TIMSS 2011.**

Moreover, the following graph 11 indicates that school B achieved better chemistry scores compared to international benchmarks than school A.

![Graph showing students achievement in chemistry content domain against TIMSS benchmarks.](image)

**Figure 11: Students achievement in chemistry content domain against TIMSS benchmarks.**

4.5 Students’ Perceptions

Students’ perceptions were measured through a questionnaire provided to all grade 12 chemistry students (N=75) with 44% boys and 56% girls who attended TIMSS 2011 exams during grade 8. Thus, this questionnaire aimed to explore their perceptions of IBL elements, determine their experiences of basic scientific skills that might be acquired through IBL activities and investigate their disposition to science-based careers after their experience with IBL instruction.
4.5.1 Students’ Overall Responses of the Questionnaire

Figure 11 below shows grade-12 chemistry students’ responses to all aspects of the questionnaire.

![Graph: Overall Grade 12-Chemistry students' responses of IBL instruction]

Figure 12: Overall responses of grade-12 chemistry students perceptions of IBL.

Figure 12 indicates that the highest percentage (91%) is for practicing manipulative skills by chemistry students. Both acquisitive and creative skills came in second place with the same exact percentage (85%) in chemistry classes. The percentage of practicing organizational skills (84%) came fairly equally with communicative skills (83%). Finally, it is obviously seen that chemistry students practice all stages of IBL in chemistry classes with the same percentage (84%). Unsurprisingly, 82% of them explicitly show their interest to learn chemistry and work using its applications in the future.

4.5.2 Chemistry Students’ Experiences of IBL Elements

As can be seen in table 19, the majority of students (92%) is engaged in IBL activities and experiments and regularly reports their observations from experiments. Less than half percentage of the total number of the students is able to ask their own questions for investigation.

<table>
<thead>
<tr>
<th>Students' experiences of IBL</th>
<th>Always practice</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ask my own question</td>
<td>49%</td>
</tr>
<tr>
<td>Engage in exploration of a phenomena</td>
<td>77%</td>
</tr>
<tr>
<td>Decided data &amp; material required</td>
<td>87%</td>
</tr>
<tr>
<td>Collect &amp; record data</td>
<td>81%</td>
</tr>
<tr>
<td>Engage in experiments and activities</td>
<td>92%</td>
</tr>
<tr>
<td>Report observations in notebook/ journal</td>
<td>92%</td>
</tr>
</tbody>
</table>
4.5.3 Students’ Disposition in Learning Chemistry

The highest two results are for participating students who find chemistry topics to be interesting (93%), and enjoy learning exercises (91%). The lowest two percentages are for students who are able to solve difficult problems in chemistry (64%), and for those who expressed their desire to pursue a future career involving chemistry applications (61%).

<table>
<thead>
<tr>
<th>Students' Disposition to chemistry</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Enjoy learning chemistry</td>
<td>91%</td>
</tr>
<tr>
<td>Learn many interesting things in chemistry</td>
<td>93%</td>
</tr>
<tr>
<td>Know what my teacher expects me to do</td>
<td>87%</td>
</tr>
<tr>
<td>Chemistry is one of my strengths</td>
<td>73%</td>
</tr>
<tr>
<td>Good at working out difficult chemistry problems</td>
<td>64%</td>
</tr>
<tr>
<td>Learning chemistry will help me in my daily life</td>
<td>81%</td>
</tr>
<tr>
<td>Like a job that involves using chemistry</td>
<td>61%</td>
</tr>
</tbody>
</table>

Table 21: Chemistry students’ disposition in learning chemistry

4.5.4 Chemistry Students’ Responses based on Gender

Table 22 below presents the mean and standard deviation of both male and female chemistry students for the key areas mentioned in the questionnaire. t-test for means of independent samples (Fraenkel & Wallen 2012) is used to identify any statistical significant value of their average that reflects the differences of their perceptions about IBL. The probability of any differences is measured by p-value which is significant only at p <0.05.

<table>
<thead>
<tr>
<th>IBL instruction</th>
<th>MALE</th>
<th>FEMALE</th>
<th>t value</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean</td>
<td>Standard Deviation</td>
<td>Mean</td>
<td>Standard Deviation</td>
</tr>
<tr>
<td>Stage of IBL</td>
<td>39.3939</td>
<td>2.12043</td>
<td>36.6667</td>
<td>4.09444</td>
</tr>
<tr>
<td>Acquisitive skills</td>
<td>13.6667</td>
<td>.85391</td>
<td>11.9762</td>
<td>1.96913</td>
</tr>
<tr>
<td>Organizational skills</td>
<td>21.8788</td>
<td>1.49494</td>
<td>20.3810</td>
<td>3.84424</td>
</tr>
<tr>
<td>Creative Skills</td>
<td>13.3939</td>
<td>.99810</td>
<td>12.1429</td>
<td>2.63718</td>
</tr>
</tbody>
</table>
As can be noted in table 22 the t-value was statistically significant among all areas of the questionnaire where p-value is > 0.05 except for manipulative skills which has insignificant p-value of <0.05 and t-value (t= -.402). These results reflect that male students have better interaction to IBL instruction (t= 3.474) as well as more practice to four types of science process skills namely, acquisitive, communicative, creative and organizational and their significant t-values are t= 4.599, t= 3.929, t= 2.581 and t= 2.114 respectively. Subsequently, male chemistry students have more positive disposition towards learning science and applying it in their future careers (M= 30.4848, SD= 1.78748) than female students (M= 27.3571, SD= 5.55602) which is indicated statistically by the significantly high t-value (t = 3.106). The next chapter will discuss these findings within the context of relevant literature.

<table>
<thead>
<tr>
<th></th>
<th>Communicative Skills</th>
<th>Manipulative Skills</th>
<th>Disposition in chemistry</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>17.9091</td>
<td>9.0000</td>
<td>30.4848</td>
</tr>
<tr>
<td></td>
<td>1.33144</td>
<td>.86603</td>
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</tr>
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<td>9.0952</td>
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<tr>
<td></td>
<td>&gt; 0.05</td>
<td>&lt; 0.05</td>
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Table 22: Differences in gender’s perceptions to all aspects of IBL instruction
Chapter 5: Discussion and Conclusions

Science education is best taught by IBL instruction as it promotes students’ conceptualization and develops their scientific skills. Discussion on the findings, final conclusion, recommendations for additional investigations in IBL area and study limitations are presented in this chapter.

5.1 Discussion

This study aims to identify teachers’ perceptions of IBL elements and their practices to develop students’ scientific skills and enhance students achievement in TIMSS exams. Multiple instruments were used to overcome the difficulty of measuring skills (Lai & Viering 2012). The study focused on three main dimensions to achieve its goal which are inquiry dimension, cognitive dimension and content dimension.

5.1.1 Inquiry Dimension

This domain is represented in the teachers’ perceptions of IBL elements and their practices to develop students’ scientific skills in all science classes at the schools.

5.1.1.1 Teachers’ Perceptions and Practices

Teachers’ perceptions and practices of IBL elements were perceived through the results of their questionnaire to answer the first study question. Their responses reflected that they are impressively aware of the features of IBL and many of them practice different types of scientific skills in their science class. However, their rate of practicing scientific skills does not match their perceptions of IBL (Bryan 2003).

The academic supervisor who works for school B for the last five years confirmed the successful improvement of science teachers’ IBL implementation which is developed through providing them with annual professional development workshops to enrich their knowledge and support their techniques. These programs focus on cognitive skills, critical thinking, teaching strategies, 21st century skills, differentiation and flipped classrooms to facilitate IBL applications. Besides, teachers’ inquiry practices are usually followed up and inspected during regular classroom observations to overcome any weaknesses found. These outcomes are evident in the research
experience and prove that these professional development programs introduced at the beginning of the academic year are crucial to strongly increase teachers’ pedagogical knowledge (Kalina 2009; Roth et al. 2006), enhance their performance and professionalism (Goe & Stickler 2008; Rockoff 2004) and significantly rises teachers’ confidence (Furtado 2010). However, this cannot grantee the most successful implementation unless it becomes more intensive and has enough demo classes that focus on IBL rehearsals to contribute efficiently to teachers’ instructional practices (Al-Shannag, Tairab, Dodeen & Abdel-Fattah 2013). Additionally, this can prevent the difficulties of transferring theory into practice (Roehrig 2004) through modifying some challenging tasks (Leaman & Flanagan 2013) that might consume the class time. These results are similar to the extensive review of studies on IBL implementations that raise teachers’ awareness on the positive effect of doing IBL on developing students’ skills through consistent experimentation and investigations (Drayton & Falk 2001; Ramnarain 2014; Yakar & Baykara 2013). Moreover, teachers’ perceptions were fairly equal for both male and female teachers with only a slight difference in the male perception, which means that both genders have almost the same perceptions about IBL elements and types of scientific skills that should be practiced at their classes during IBL implementations.

As discussed earlier, literature has classified scientific skills into five categories which are also referred to as Science process skills (Bybee & Powell, 2014; Trowbridge, Bybee & Powell 2000). In each category, skills are ranked in order of their increasing difficulty. Basically, scientific skills that require unaided senses only to develop are simpler than other skills that require higher order mental abilities to handle specific instruments (Appendix 8).

Statistics of the current study revealed that the highest percentages of scientific skills practices are for the simplest and middle level of skills in each category such as listening, observing, planning ahead, designing and using instruments, demonstrating and questioning, and discussing and explaining) except in organizational skills where teachers have more practice with high level skills such as reviewing and evaluating skills. Temiz and Tan (2003) found that teachers should give more opportunities to advanced levels of scientific skills in the educational process, as they require adequate time through the academic year to be successfully developed.
Park, Ae Jang, and Kim (2009) argued that science teachers often design activities using predetermined paths which can be successfully achieved within a relatively short time. Obstacles of teaching scientific skills by conducting IBL are mentioned in the literature such as limited class time, lack of materials, and intensive content knowledge (Cheung 2007; Wallace & Kang 2004). A recent study found that lack of collegiality is one of the basic impediments to the development of students’ scientific skills following implementing of innovative teaching approaches (Ambrossa, Meiring & Blignaut 2014). Therefore, this study found that creative and manipulative skills have the least emphasis in teachers’ daily practices.

An interesting result from this study is that there is an apparent significant statistical difference in practicing manipulative skills based on teachers’ academic qualifications. Teachers with Masters degrees showed higher tendency in implementing IBL skills and more awareness of the importance of applying IBL and its skills. This finding is supported by Pea (2012) who argues that teachers’ competence and qualifications are essential factors that affect their implementation. Additionally, Scantlebury (2008) also suggests that masters programs promote chemistry teachers to improve their content knowledge and practices.

Although, professional development programs are effective in enhancing pedagogy of teaching, not all teachers show interest in them. Thus, they do not gain much benefit. Therefore, the qualitative results show that science teachers stated clear definitions of IBL and its main axes as question, procedures and results and referred to teachers’ and students’ role in each of them. On the other hand, class observations revealed some successful features of IBL in teachers’ practices but not at the same level as their knowledge. Many students were able to observe, use their prior knowledge, construct hypotheses, analyze simple data, discuss the results and reflect on their learning experience in two guided inquiry classes. However, only one of the observed classes illustrated a clear evidence of open inquiry learning where students were able to ask an investigable question (Ambrossa et al. 2014). These differences between teachers’ perceptions of IBL and their practices would basically affect students’ acquisition of scientific skills. The literature of IBL proved that students who are more exposed to many features of open and guided inquiry show greater progress on their science process skills and better content knowledge (Bunterm et al. 2014; Sadeh & Zion 2009).
5.1.2 Cognitive Dimension

This dimension is represented in students’ perceptions of IBL features and their experiences to practice science process skills in chemistry classes.

5.1.2.1 Students’ Perceptions and Experiences

Chemistry students’ perceptions in grade-12 and their experiences in IBL elements were perceived through the results of their questionnaire to answer the second study question. Students’ responses indicated that majority of chemistry students at high schools consistently practice many features of IBL. Although, they are usually engaged in experimental activities in IBL classes, few of them pose and investigate their own questions. These findings are consistent with their teachers’ responses. During observations, most students were able to handle instruments, use technological applications, observe, choose materials and discuss their hypotheses. Many of them were also able to plan for experiments, analyze data, and reflect on their experience. Few of them were able to test hypotheses, think critically, solve problems and draw logical conclusions. Thus, science process skills of students are in the middle level (Temiz & Tan 2003). Hence, it is not expected to find students who are able to excel at advanced skills which they do not practice consistently (Chebii 2012). Students show better skills in terms of knowing and applying than reasoning skills that require more time and practice to be developed and help them to get better scores in TIMSS chemistry exams. More open and guided IBL implementation leads to better acquisition of high-order thinking skills.

According to the statistics of the study, overall, boys tend to practice scientific skills more consistently than girls. This result is contrary to a previous study that determined students’ achievements level of science process skills by using SPST and found no significant difference in students’ scientific skills’ level (Öztürk et al. 2010). However, there is no significant difference in terms of gender in manipulative skills only. Thus, all students practice manipulative skills intensively because all grade 12 chemistry classes are taught by two teachers who both have gained masters degrees, and who responded positively to practicing this type of skills.

Despite the high percentage of students who agreed that chemistry topics are interesting and they enjoy learning science, not all of them are able to solve difficult chemistry problems or like to have a scientific career. Studies have suggested that IBL instruction is a direct way to positively
enhance students’ interest in science (Bennet & Hogarth 2009; Palmer 2009) nevertheless; it is totally insufficient to engage students in just hands-on science activities. Instead, teachers should plan for IBL activities that emphasize authentic applications to motivate students and increase their interest (Jocz, Junqing & Ling 2014). This would definitely produce more qualified students for successful scientific careers.

5.1.3 Content Dimension

This domain is represented in the qualitative data collected from both teachers and academic supervisors as well as from analyzing grade eight students’ results in TIMSS 2011 chemistry exam to answer the third study question.

5.1.3.1 Students’ Achievements in TIMSS

One of the most significant priorities of the UAE is improving the quality of science education. Educational planning is crucial in stressing on evidence-based approaches within its modern and developing frameworks. That is why, participation of Dubai schools in all major international assessments such as TIMSS has been an essential requirement for KHDA in order to measure the performance of educational systems and students’ achievements at an international comparable scale (KHDA 2012).

Generally, the TIMSS 2011 report of the schools highlights the insignificant difference of grade 8 science scores based on gender; favoring girls by only one point. Interestingly, the chemistry result in school B has the highest score among science subjects while in school A, chemistry scores were the second highest. In both schools, students’ scores in chemistry were lower than TIMSS average benchmarks.

Nevertheless, all teachers agreed that IBL practices enhance students’ conceptualization and they observed that as long as students are engaged in IBL activities, they show improvement in their understanding to science content knowledge (Chiappetta & Adams 2004). Furthermore, IBL enhances students’ skills that are measured in TIMSS exams. However, Ramnarain (2014) found that some teachers felt that direct explanations are more successful because of the huge class sizes that prevent them from effectively facilitating and enabling equal interaction with all students (Johnson 2005).
Moreover, the academic supervisors asserted in the interviews that they are working on a progressive action plan that reflect better quality of science education offered to their students to improve their cognitive skills as well as their content knowledge. Consistent practice and successful implementations of IBL besides explicit teaching of scientific skills can potentially launch many of the students in the direction of improving their TIMSS benchmarks levels (Jocz, Junqing & Ling 2014) from low to intermediate.

5.4 Implications

The current study has different implications for IBL implementation and its impact on students’ achievements

5.4.1 Practical Implications

Activities-based IBL instruction enhances students’ science process skills and promotes their interest to learn science. Teachers’ perceptions about IBL are developed according to professional workshops that focus on IBL design and its implications. Ironically, some teachers are able to effectively plan IBL class as an open inquiry where students pose their questions for investigation, collect and analyze data, test hypotheses, draw conclusion and reflect on their learning. Guided inquiry learning is conducted in some chemistry classes where teachers pose the questions and students plan procedures to find the most logical conclusion. As such, many scientific skills are developed such as observing, comparing, classifying, discussing, explaining and reporting. Majority of the chemistry students use technology applications to support their learning which is beneficial to enhance high-order thinking skills. Science teachers confirmed the importance of applying IBL features as they enrich students’ investigating abilities and scientific skills that are measured in TIMSS exams.

5.4.2 Professional Implications

In spite of the teachers’ sound awareness of IBL elements and all their attempts to implement its activities in their classes some teachers still face difficulties that prevent them from successfully applying this technique. Students’ low scores in previous TIMSS exam indicates that students’ content knowledge as well as scientific skills were not at the required level to achieve at least the
average score in chemistry. Accordingly, the schools’ new program to support science education is beneficial in which students become more conscious of inquiry activities and develop basic skills that are essential to relate their learning to real life scenarios. In order to achieve the advanced benchmarks, students should work more consistently on open and guided inquiry classes to accelerate the development of their scientific skills such as researching, gathering data, analyzing, calibrating, criticizing and inventing. Some students show difficulty in posing a question which is an essential element in IBL. Teachers are recommended to plan sessions that focus only on teaching such required skills. Interestingly, teachers’ academic qualifications are crucial to update their teaching practices. It is also recommended that pre-service and in-service teachers further their education or pursue a Masters degree to develop skills and knowledge, and gain access to pedagogical trends in education.

5.4.3 Research Implications

Students’ intrinsic motivation, teachers’ lesson plans and class management are factors that have not been measured in this study but were noted to affect the flow of IBL process as observed during the class visits. Further studies should be conducted in order to follow up the effect of IBL program on students’ achievements after the next TIMSS exam. Noticeably more effort is required to inspect the questioning techniques that are used in science classes. One of the interesting implications that were revealed in this study is that students who act as passive recipients were willing to change their attitudes and roles by taking responsibilities that fit their abilities through a healthy and cooperative environment.

5.5 Conclusion

The current study was conducted to determine teachers’ and students’ perceptions of IBL instruction that enhance students’ acquisition of scientific skills and affect students’ achievements.

This study found that science teachers at the schools have good pedagogical knowledge about IBL instruction and they have the potential to practice different types of IBL in their classes.
However, teachers’ practices are more frequently a mix of both structured and guided inquiry than pure guided and open inquiry learning in their classes. This reflect the schools’ attempts to develop its active teaching instruction which leads learners to take deep learning approach and become more self-directed (Biggs & Tang 2007; Justice et al. 2002). Utilizing a skill-based assessment system which is adapted from TIMSS benchmarks to measure students’ progress is a fruitful step that will help teachers to self assess and modify their practices.

Furthermore, many inquiry activities are done in science in which students have gained many acquisitive, communicative and organizational skills. More manipulative skills’ practices should be planned for students because they are significantly affected by teachers’ qualifications. Hence, they are affected by the way they were taught and their competence. Schools are responsible to offer professional development programs to enrich not only their pedagogical knowledge but also their practices. In addition, peer observation and collaboration among teachers, as well as group discussions can have profound effects in extending their successful implementations and encouraging their creative ideas. By evaluating the previous results, as long as schools care about IBL programs to enhance their teachers’ instructional strategies towards developing students’ skills and helping them better understand scientific concepts, then it is anticipated that their TIMSS scores would gradually improve to the required international level.

To sum up, IBL instruction is recommended as a required trend in science education in the UAE. It is expected that participating teachers would be pleased by many of the results as they show they do not resort to lecture-mode in class (Gordon & Aubrecht 2008), and that they are profoundly aware of IBL elements and are working towards developing their students’ pertinent scientific skills which are measured in TIMSS exams. In addition, this study indicates that majority of the students are interested in chemistry and enjoy their learning experience.

5.6 Limitations

This study is limited because of its small sample and small number of observed classes. Another point is that measuring educational skills is difficult and requires many tools to collect reliable data. Interviewing students is a useful tool that could be conducted in further studies. Additionally, analyzing teachers’ responses to TIMSS 2011 questionnaires would add useful data
in helping develop teachers’ pedagogical knowledge from 2011 until now. It would also have been beneficial to interview master students to determine if their professional practices contributed to enhancing students’ skills.
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