Investigation of UAE Teachers' and Students' Perceptions and Practices of Formative Assessment of Inquiry-Based Learning

البحث في مفاهيم وممارسات المدرسين والطلبة لاستخدام اساليب التقويم المستمر في التعلم المستند إلى الاستقصاء

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Dedication

This dissertation aimed to develop science teaching and learning practices in the Arab region. I hereby dedicate this piece of work to all of the students in this region, in hopes that the results and recommendations would have a real impact on the current educational practices.

This achievement is also dedicated to my parents, husband and lovely children for their patience and support throughout the completion of this research.

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The completion of this research would not have been possible without the support of special people, who facilitated and directed my progress during the implementation.

I would like to express my thanks to my dissertation supervisor Dr. Sufian Forawi for his continuous support, valuable advice and constructive feedback that encouraged me to complete the work and produce this dissertation.

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Abstract

The use of inquiry-based learning (IBL) in science education is seen as one of the effective strategies to develop students' critical thinking skills and train them to become problem solvers for future problem**s**. Because the Researches and investigations concerning education in Arab countries are of limited scale, only a few data is available about science teaching and learning practices. Therefore, the purpose of this study is to investigate students' and teachers' perceptions towards formative assessment (FA) and inquiry-based learning in science classrooms, in addition to investigating how the formative assessment of inquiry-based learning is currently implemented and finding out the best practices in the educational field.

Multiple tools following the mixed method approach were used to achieve this study. The tools comprise two versions of formative assessment of inquiry-based learning questionnaire for teachers and students, in addition to lesson observation form that was used to collect and interpret the best practices in actual classroom environments. Three groups of participants contributed to the study with a total number of 535 students and 51 teachers who responded to the questionnaires, and 10 teachers volunteered for lesson observations.

The major results indicated that formative assessment strategies were implemented effectively in science lessons. However, inquiry-based activities were implemented with less efficiency in all science classrooms. A positive relationship between formative assessment and inquiry-based practices was found from teachers' perspective. Therefore, as a result of this study, several recommendations were provided to better prepare teachers to use FA to evaluate IBL activities and eventually promote students' performance in science education in the UAE.

Keywords: Formative assessment, inquiry-based learning, UAE, Science education

الملخص

إن اتباع أسلوب التعلم الذي يستند إلى الاستقصاء في تعليم العلوم يعتبر أحد أهم الاستراتيجيات الفاعلة لتطوير مهارات التفكير النقدي لدى الطلاب وتدريبهم لكي يتمكنوا من حل المشكلات في المستقبل. إن الأبحاث التي نفذت في الدول العربية فيما يتعلق بتعليم العلوم كانت على نطاق محدود، كما أن البيانات المتوفرة حول تعليم وتعلم العلوم قليلة جداً. لذلك، فإن الغرض من هذه الدراسة هو دراسة مفاهيم الطلبة والمعلمين نحو التقييم التكويني (الاستدلالي) والتعلم الذي يستند إلى الاستقصاء في فصول العلوم، بالإضافة إلى البحث في كيفية تطبيق التقييم التكويني للتعلم الذي يستند إلى الاستقصاء حالياً والتعرف على أفضل الممارسات في مجال التعليم.

وتم استخدام أدوات متعددة وفقاً لمنهجية البحث المندمج (المختلط) في هذه الدراسة. إذ تم توزيع نموذجين من استبيان التقييم التكويني للتعلم الذي يستند إلى الاستقصاء على المعلمين والطلبة؛ بالإضافة إلى نموذج المشاهدات الصفية الذي تم استخدامه لجمع وتفسير أفضل الممارسات في بيئة الصف الفعلية. وساهمت ثلاث مجموعات من المشاركين في هذه الدراسة: أجاب 535 طالباً وطالبة و51 معلماً ومعلمة عن الاستبيان و تطوع 10 معلمين للمشاهدات الصفية.

أشارت النتائج الرئيسة إلى أنه تم تطبيق استراتيجيات التقييم التكويني بشكل فعال في حصص العلوم، في حين تم تنفيذ الأنشطة المستندة إلى الاستقصاء بكفاءة أقل في جميع حصص العلوم. وجدت الدراسة علاقة إيجابية بين التقييم التكويني وممارسات التعلم الذي يستند إلى الاستقصاء من وجهة نظر المعلمين. وكنتيجة لهذه الدراسة، تم تقديم عدة توصيات للإرتقاء بمستوى إعداد المعلمين ليكونوا قادرين على استخدام التقييم التكويني لتقييم أنشطة التعلم الذي يستند إلى الاستقصاء، وبالتالي تطوير أداء الطلبة في مواد العلوم بدولة الإمارات العربية المتحدة.

الكلمات الرئيسة: التقييم التكويني، التعلم الذي يستند إلى الاستقصاء، دولة الإمارات العربية المتحدة، تعليم العلوم

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CHAPTER ONE
INTRODUCTION

One of the major challenges of education in the current rapidly growing civilization is to nurture new generations able to effectively contribute to shaping the future of this world. Numerous technological advances had taken place, people's daily lifestyles became more complex, and various types of unpredictable challenges are expected to face societies in the future. Accordingly, living in such a catalytic society requires people to develop their skills in order to become effective and successful citizens. Today, students should be provided with all the required higher thinking skills that would enable them to become successful leaders and allow them to participate in the future knowledge economy (UAE Ministry of Education 2015). Science education in particular has made a major contribution in advancing students' skills and improving their cognitive and meta-cognitive abilities (Hanauer&Bauerle, 2012). Subsequently, improving science teaching instructions and adopting IBL approach would promote students to practice problem solving and enable them to tackle future challenges (Harrison, 2014). Thus, teachers should develop assessment strategies to collect evidence of students' mastery of scientific concepts and practices, which call for effective feedback procedures through FA (Clark, 2012).

1.0 Research problem

Educational reform efforts focus on developing students' skills to construct outstanding critical thinkers and problem solvers so they can contribute in solving future challenges (Clark 2012), which mean building new generations who are able to think, live, and positively respond to potential challenges. This approach requires that students must be provided with guidance and assistance to become self-learners and enable them to educate themselves (Bandura, 1997).

Science education research has focused on the importance of using proper assessment of IBL activities (Harrison, 2014). However, many studies have identified challenges that hinder its proper implementation in science classrooms in two major areas: teachers' attitude towards the efficiency of IBL to report on the performance of each student (DiBiase& McDonald 2015; Harrison 2014), and students' readiness to take responsibility of their own learning, and use self-regulated learning skills to improve their performance (Shawer 2010). On the international scale, PISA results in 2012 for different non-OECD (Organization for Economic Cooperation and Development) countries showed that Singaporean students had scored higher than the OECD students, while four Arab countries had scored lower than the students in OECD countries (PISA 2012). Investigation of the science education framework in Singapore to identify the best strategies and procedures of science education adopted in their educational system revealed that teaching science through inquiry is the core of the Singaporean science curriculum; teachers are trained to be inquiry leaders and students are trained to be inquirers, and responsible for their own learning (Singapore Ministry of Education 2013). In addition, teachers monitor students' learning by providing support and effective feedback (Hogan 2014). In comparison, in spite of the limited number of studies about science education in Arab countries, it has been contended that poor students' performance is due to serious problems caused by outdated science curricula and teaching instructions, lack of teacher professional development, and insufficiency of budget (Boujaoude, Ayoubi&Jaber, 2008).

The United Arab Emirates (UAE) has attempted to implement various improvements in its educational system that aim to meet world-class education standards; the main objectives set by His Highness Sheikh Mohammad Bin Rashid Al Maktoum include: "The preparation of a generation of UAE nationals capable of serving their nation, characterized by ambition and aspiration to develop the nation, as well as the provision of the best electronic educational tools and modern laboratories, improving curricula to match actual developments on the ground, and providing online training for students through a special gateway for the project" (Ministry of Education 2015). The Ministry of Education Strategy 2010–2020 has highlighted a major objective of their strategic plan: "Delivering a student-centered model focused on improving student outcomes, school life, and equality to meet world class standards as well as promoting national identity”(MoE Strategy 2010-2020). In order to achieve the aforementioned goals, educational efforts should focus on constructing new generations who are able to positively contribute to future development.

When compared with the international context, UAE students’ ranking in science and mathematics subjects was 41 out of 65 countries that participated in the PISA testing in 2010, specifically, 61% of the students demonstrated basic science skills. This compares to 82% in the OECD countries (National Qualifications Authority 2013). Such results urgently call for the need for improvement of science education in the UAE. The NQA have recommended various improvements in the curriculum and instructions to raise UAE students’ proficiency in science, “build educational capacity, encourage technical knowledge and innovation in the curriculum” (NAQ 2013, p. 13).

Moreover, while revising criteria of evaluation of Abu Dhabi Educational council (ADEC) inspection reports for several private schools in Abu Dhabi, it was found that Irtiqa’a inspection reports have listed promoting independent learning as an area to develop in most of the reports that were revised. Other areas that should be improved, according to the reports, are assessment strategies to ensure students’ progress, and designing challenging activities for the students (Irtiqa’a 2015).

Changes in instructional practices are required to develop students’ conceptual understanding, and embracing IBL in science lessons. However, challenges in the UAE include lack of science teachers’ and students’ readiness, as both are not prepared to implement IBL instructions. Teachers require continuous professional development to gain the required expertise in selecting appropriate teaching methods in order to deliver particular science concepts. The identified areas of improvement mentioned by Irtiqa’a are addressed in this study, and were investigated to include the best instructional practices that can be implemented to use FA and IBL effectively.

1.1 Background and significance of study

The main aims of education are to provide students with the essential skills required to solve future problems and achieve success across various aspects of life (Clark 2012). Torrance (2012) and Clark (2012) agree that FA processes enhance students' self- regulating learning (SRL) skills. They recommend various teaching strategies that would promote students to generate feedback and transform from passive to active learners. If students were responsible for their own learning, they will develop metacognitive skills which improve their ability to reflect on their understanding, and plan how to gain the required knowledge and skills to achieve a certain target (Clark 2012).

In addition, both Hickey (2015) and Clark (2015) agree in their recent studies that using FA strategies would increase students' conceptual understanding and enhance self-regulating learning skills. This means that students will be able to take control of their own learning by developing their self-efficacy and metacognitive skills to reflect upon their understanding. Thus, enabling students to solve problems, stand up to difficulties and achieve improvements. However, Tabari (2014) has indicated a challenge that faces the UAE education system, which is students' ability to become self-regulated learners and take the responsibility of their own learning, as teachers in the study pointed out students' current attitudes towards education that could mar the former.

As per science education research, when science teachers incorporated IBL activities using a student-centered approach in their instructions to improve students' scientific ways of gaining knowledge, there has been a great impact on students' level of understanding and performance (Forawi & Liang 2011; Hanauer&Bauerle 2012; Harrison 2014). On another note, Nagle (2013) has recommended teaching for the sake of understanding, to better prepare high school students to be problem solvers in future. They should experience challenging tasks that require the application of their understanding, rather than evaluating their knowledge on the memorization level. Similarly, being involved in a challenging task would enhance students' understanding of the concept, and improve their skills (Clark 2015). As reported by science education literature, inquiry-based learning (IBL) would be an ideal application to allow students to experience challenging tasks that require higher order thinking skills

(Asay&Orgill 2009; Llewellyn2010; Nehring, Tiemann&Belzen 2013; Stone 2014).

Research in IBL has led to a construction of a theoretical framework that identifies phases of inquiry and various inquiry cycles that are referred to in this study to present FA strategies. Other studies have also proceeded to make suggestions on how to operate this framework in science classrooms in relation to FA processes (Pedaste et al.2015).

In expounding FA and IBL implementations, researchers have highlighted several challenges that could hinder smooth application of both strategies which include teachers' ability to utilize the IBL process using various FA strategies, and students' abilities to understand and engage in IBL activities (DiBiase& McDonald 2015) which are the same challenges that were also identified in the UAE context.

Science education researchers recommend further studies to identify the best practices and efficient methodologies in FA, in order to assess and evaluate students' performance, and accordingly improve their conceptual understanding and achievement (Clark 2015). Furthermore, additional studies suggest putting IBL into action in science classrooms, by proposing new procedures and providing the required professional development to support science teachers (DiBiase & McDonald 2015).

The Centre for British Teachers (CfBT) Education is an educational organization that aids in school inspections. The organization is currently working with ministries of education in several Arab countries and has proposed ten pertinent features of an inspection procedure towards achieving 'outstanding' evaluation which prioritize analysis of students' performance, and evidence of students' learning (Raleigh 2012). During CfBT's inspection cycles in Bahrain, it was found that from 202 government schools, only 3% were outstanding, 60% good, 47% satisfactory and 20% were judged as unsatisfactory (Churches & McBride 2013). In relation to this, several school reports for the year 2010 were reviewed in order to identify the situation of FA and science education in these schools. Good schools had presented better teaching and learning strategies, yet, they were advised to improve their students' academic achievement by including critical thinking in instruction, sharing best practices, and using assessment for learning. However, schools with unsatisfactory judgment were also advised to develop the quality and effectiveness of their instructional strategies, embrace higher thinking skills in the classroom, and use assessment for learning, which requires improving FA strategies (NAQQAET 2014).

Research addressing science education quality in the UAE is limited, so in order to investigate the current situation in the government and private schools, various inspection reports from the Knowledge and Human Development Authority (KHDA) and ADEC were reviewed to investigate the current situation of FA in science teaching classrooms. Results revealed that in ADEC, none of the private schools were categorized as outstanding in the academic year 2014-2015, and the areas of improvement included promoting continuous assessment of students' progress and integrating scientific activities that promote higher-order thinking skills. On the other hand, the KHDA report included only two schools categorized as outstanding, with their strengths including the presence of an innovative curriculum paired with teaching and learning approaches that were novel and led to high levels of engagement. Inspection reports issued by the KHDA and ADEC have indicated that schools should promote challenging activities to enhance students' critical thinking and problem solving skills (Irtiqa'a 2015; KHDA 2015). This situation calls for undertaking research that investigates the current situation of science educational practices in the UAE.

A limited number of earlier studies have linked the use of FA to evaluate and assess students' progress in science classrooms. Most of the literature describes FA as an independent strategy that leads to adopting various instructional strategies. Clark (2015) contends that instructional strategies such as collaboration through discussions, and inquiry within smaller groups and peer work are good examples of FA tools. Besides using higher cognitive skills in problem solving and utilizing students' responses to emphasize their conceptual knowledge, other research discuss IBL as an important process to teach science practices, and enrich students' abilities to become self-regulated, intelligent, and capable of solving future challenges (Hanauer & Bauerle 2012; Harrison 2014; Nowak et al. 2013).

Therefore, the intention of this study is to investigate students' perceptions towards FA, and identify best methodologies that can be applied in the UAE, investigate students' and teachers' perceptions of IBL, and to identify the most efficient strategies that effectively use IBL as a central teaching approach in science classrooms. Additionally, this study aims to link between FA's instructional strategies and the phases of IBL, which involve collaboration, discussion and questioning to be implemented within class groups. Hence, the study elaborates on how to properly assess IBL activities in science classrooms, and it is expected to formalize the reciprocal instructions that hinder the FA of IBL activities to develop students' conceptual understanding, and accordingly their achievement in science subjects.

1.2 Purpose and study questions

The purpose of this study is to investigate UAE teachers' and students' perceptions and practices of FA of IBL. This was achieved through utilizing various comprehensive studies which identified attributes of FA and IBL that can enhance students' self-regulatory learning skills and make them independent learners, able to contribute in future innovation (Clark 2015; Pedaste et al. 2015). The following research questions drive this study:

1. What are the teachers' and students' perceptions of formative assessment in science classrooms?
2. What are the teachers' and students' perceptions of inquiry-based learning in science classrooms?
3. How well do teachers use formative assessment of inquiry-based activities in science classrooms?

Corresponding to the preceding studies regarding FA, the research results of those studies proposed that if students received proper and effective feedback in day-to-day practices, they will be able to generate internal feedback about their own learning (Clark 2012). This enables students to plan how to gain the required knowledge and skills to develop proper understanding of various concepts (Clark

2015; Torrance 2012). Regarding IBL, prior research has suggested a theoretical framework concerning phases of inquiry that can be implemented to improve instructional practices, which focus on higher order thinking skills. Research results revealed that students who receive instruction that tackle higher-order thinking skills were able to explain scientific problems and presented a deeper understanding of the concepts (DiBiase & McDonald 2015). This study came up with recommendations to develop FA of IBL activities, in order to build proper scientific skills in the new generation to enable students to serve the nation and meet the leaders' expectations.

1.3 Context of the study

This study was conducted in the Applied Technology high school system, which is committed to providing high quality education to UAE youth and provide career-oriented programs. Grade 9 and 10 levels serve as a basic foundation to all students, allowing them to develop the required skills to enter a specific career cluster in grade 11. This study was conducted with grades 9 and 10 students to investigate their understanding of FA and IBL.

All participating students are UAE nationals between 14-16 years old totalling 2800 students from 14 different schools. In addition to this, 80 science teachers were selected to participate in the survey to obtain teachers' perceptions. Selected science teachers were observed across the schools to elaborate on their utilization of the FA process to evaluate inquiry based activities.

1.4 Structure of dissertation

Chapter one presented in this section highlighted the importance of the topic and related the significance of the study to previous research. It also explained the UAE's position regarding FA and IBL, and presented the questions that drive this research. Chapter two discusses the theoretical framework behind FA and IBL and their history, significance of improving students' understanding and learning progress. Chapter three explains the methodology used to conduct this study, and provides details on the samples and instruments used within the realm of a mixed methods approach. This is followed by chapter four, which outlines the results of the study. Chapter five discusses the data, draws conclusions and presents recommendations and limitations of the study.

CHAPTER TWO

LITERATURE REVIEW

The aim of this chapter is to provide an overview on the use of formative assessment (FA) strategies to assess inquiry-based learning (IBL) activities in science classrooms. It consists of two sections: the theoretical framework of the study and the literature review pertaining to FA of IBL, which in turn includes three parts: The first elaborates on the definition of FA, its implementation in science classrooms, and outlines the results of several empirical studies regarding the effectiveness of some FA strategies in developing students' learning. The second part explains how IBL was defined, structured into different inquiry cycles, and utilized to build students' scientific literacy, in addition to discussing the results of empirical studies concerning IBL. The last part focuses on the use of FA to assess IBL activities and how educational research has investigated teachers' and students' perceptions, and practices regarding the FA of IBL activities in the international scene and in the Arab countries particularly in the UAE.

2.1 Theoretical framework of the study

Based on Vygotsky's theories of education, students' cognitive development is based on cultural context, social relationships and input from others (Slavin 2014). It is important to focus on FA during any learning experience including IBL approaches. According to Vygotsky, FA had a major role in building students' self-regulatory skills by supporting his 'zone of proximal development (ZPD)' which is "a region of an imaginary learning continuum between what a child can do independently and what the same child can do with assistance" (Hammond & Branfford 2005, pp. 279). When students' work with peers to achieve a certain task through IBL activities, they will develop the level of their understanding, and master new concepts as a result of the assistance they gained from others within their ZPD. Further developments in science education enhanced scaffolding, and open class discussions that encourage students' reasoning and their ability to relate different scientific concepts, providing scientific evidences to support hypothesis, which provided a perfect opportunity to implement FA (Hammond & Branfford 2005; Mintzes,Wandersee & Novak 2005).

A comprehensive study analyzed 32 articles discussing implementing IBL in the classroom identified five inquiry phases, and proposed alternative inquiry cycles that can be implemented in the classroom. This model provided flexibility in implementing inquiry cycles that allow FA during implementation. The inquiry's main phases include: orientation, conceptualization, investigation, discussion and conclusion. Each of these phases consists of sub-phases that are related, completing different inquiry cycles in which interactive collaboration and discussion are required after each phase. The study provided a conceptual framework, shown in Figure 1, which clearly illustrates the inquiry cycles that can be implemented in the science classroom. The first main phase of the inquiry cycle – orientation - aims to stimulate students' interest about the topic, and that is usually driven through discussion. The second inquiry phase – conceptualization- can be implemented by either questioning or generating a hypothesis through classroom interactions. These interactions could be either a direct communication of ideas between peers, or open discussions requiring each group of students to reflect and explain their questions to other class members. Another important inquiry phase -investigation- can be implemented through various sub-phases, including exploration, experimentation and data collection. Different levels of discussions are also required, so students can communicate and reflect their experiments or other exploration procedures they may follow. The last main phase of inquiry is conclusion. Students are expected to interpret the data they had collected to come up with a final conclusion and share it with their colleagues through communication and reflection.

The current study uses the proposed framework to collect data from lesson observations and responses to the questionnaires, and then relate FA strategies to inquiry cycles, and elaborate on how to properly assess IBL activities in a science classroom, that is done through tracing alternative inquiry cycles related to the interactions among students, and between the teacher and students. Following this, various best practices can be generated to support teachers in planning and implementing FA of IBL activities in science classrooms. This is expected to formalize reciprocal instructions which hinge on FA of IBL activities to develop students' conceptual understanding, and subsequently, their achievement in science subjects.

This proposed framework can be used by experts and educators to guide and support teachers to apply continuous FA of IBL activities in the classroom and allow the implementation of a student-centered environment through various stages as required by the UAE strategy.

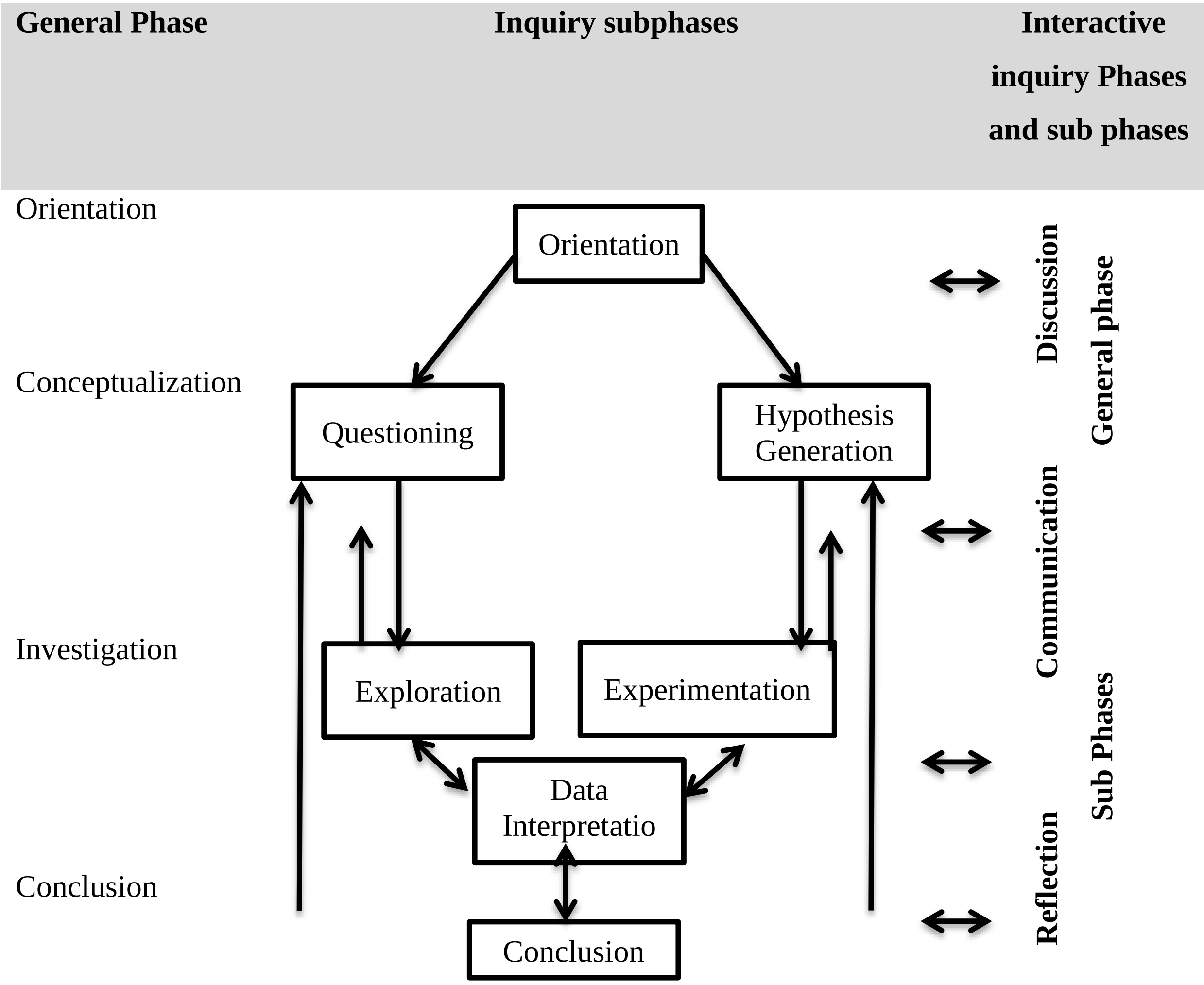

Figure 1: Inquiry-based learning general phases and sub-phases and their relations (Pedaste et al., 2015).

2.2 Previous empirical studies

Numerous empirical studies were identified and reviewed in the literature about FA and IBL as isolated concepts. However, fewer studies addressed the relation between them. In this part, different results of previous studies are presented. The conceptual framework in figure 2 below summarizes the major parts of this section.

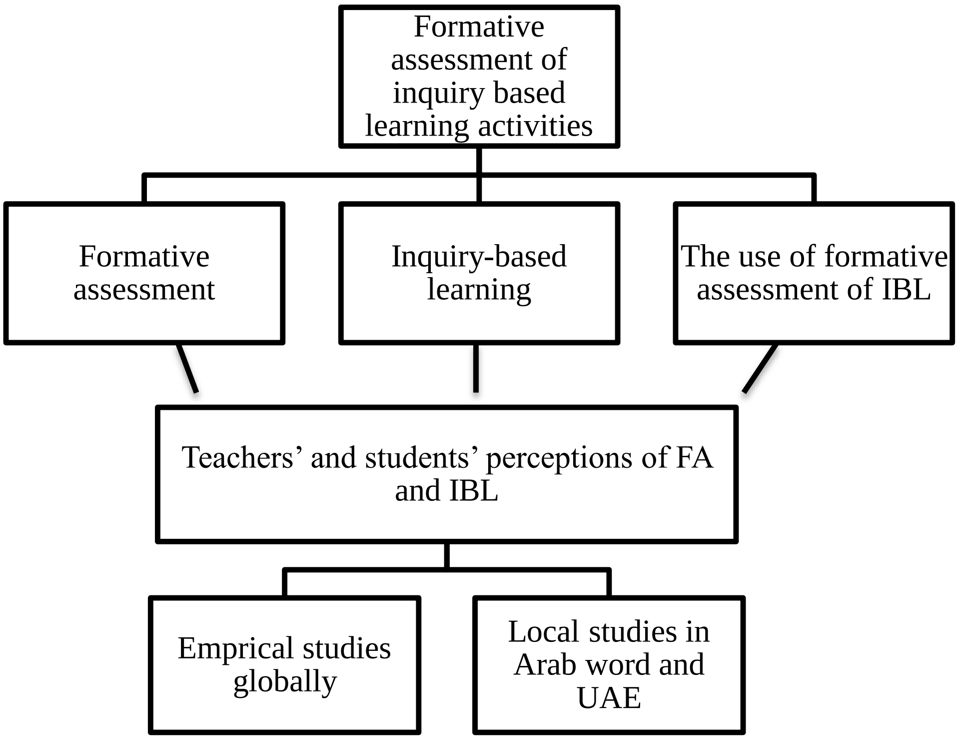

Figure 2: The conceptual Framework of the current study

2.2.1 Formative assessment

Literature described FA according to its role in the learning process; Torrance (2012) and Dunn and Mulvenon (2009) found that FA and summative assessment data can be used to inform the learning process depending on the purpose of using the assessment data, as teachers can use them to adjust the teaching and learning strategies. They recommended further research to identify best practices of FA strategies and prove their on students' achievement. According to the behaviorist perspective, assessment is used to measure what a student has achieved from the planned learning outcomes. On the other hand, the constructive perspective considers the FA as a process that measures not only what students mastered in the curriculum but also the various skills that students' gain to accomplish different tasks in collaboration with their peers (Bennett 2011; Torrance 2012; Kumar 2013). In light of this, Hickey (2015) and Torrance (2012) referred to the assessment used to appraise and reconstruct classroom instructions as 'conformative'; and the assessment used to gauge students' achievement as 'deformative'. Different categorization was proposed by Clark (2012) and Bennett (2011) as they classified FAinto two types: assessment for learning (AFL) to control students' progress in order to master the main learning outcomes, and assessment as learning (AaL) to evaluate students' reflections and evidences of learning. Clark (2015), Torrance (2012), Pinchok, and Brandt, (2009) and Roskos, &Neuman, (2012) further clarified that the assessment can be called formative only if evidences of students' learning and progress were collected, and used to identify gaps in students' understanding, then adjusting learning strategies to close these gaps.

2.2.1.1 Formative assessment strategies

FA strategies should encourage learners to reflect on their own understanding, provide a plan to overcome obstacles, and offer thorough learning opportunities. Bandura have clarified that "A fundamental goal of education is to equip students with the self-regulatory capabilities that enable them to educate themselves" (1997, p. 174). In the same context, Ya-Su (2015) has proposed that if educators were able to develop students' commitment towards learning, students will use the effective feedback given by teachers to generate internal feedback, and learn how to assess their own performance, not only supporting their ability to understand the instant outcomes, but also helping them in shaping their future, and figuring out how scientific knowledge contributes to their learning throughout their life. Likewise, Hickey (2015),Torrance (2012) , and Bennett (2011) suggested that students who received effective feedback had a better opportunity to learn than students who were not offered this chance, making FA an essential component of education that accelerates the learning process.

Science education literature have agreed on several criteria that describe the best FA strategies, including: establishing a class environment that depends on students' interactions, informing students about what and how they will learn, and what is expected from them after the learning process is completed. They should be also given clear instructions about the tasks that will be implemented in the class, clarifying rubrics and criteria that are used to evaluate their work, and providing several opportunities for them to discuss ideas and opinions, different questioning strategies that evoke students' critical thinking skills should be used , allowing reflection time to enhance students' meta-cognitive skills and giving them opportunities to reflect upon their understanding, and asking questions to boost students' thinking about their opinions. There has to be class activities that develop students self-efficacy and motivate them to learn, provide opportunities for collaborative learning, and develop students' self/peer assessment skills (Bennett 2011; Clark 2012; Clark 2015; Hattie 2009; Hickey 2015; MacLeod & Fraser 2010; Slavin 2014; Torrance 2012; Walani&Timperley 2007)

2.2.1.2 Formative assessment in global context

Fletcher and Shaw (2012) have researched the use of assessment for learning in elementary level classrooms in Australia, their results indicated that students had presented positive learning engagement when they identified their learning goals and were responsible for their self-assessment, through displaying constructive emotional, behavioural and cognitive contribution in the classroom.

Sach (2012) confirmed that teachers agreed on the importance of FA to promote learning. However, they were not able to include effective strategies ofFA in their classroom. In addition, she found a relation between teachers' teaching phase, years of experience and their perception of using FA strategies, as middle school teachers presented a higher rate of using peer assessment in their instructions than high school teachers. Teachers with more than 20 years' experience were more confident that FA can promote students to make progress in learning. The current study used Sach'sfindings to design the attributes of the FA questionnaire in order to investigate teachers' and students' perceptions towards FA. An additional study done by Lee, Lin & Tsai (2013) in Taiwan, indicated that limited studies discussed students' perceptions towards FA in science classrooms and recommended further research to correlate between students' perceptions about science assessment and their ability to develop their learning skills for different scientific concepts.

Three recent studies investigated the effectiveness of different FA strategies in the first year in college, although these studies have addressed the college freshmen, similar approaches would be beneficial and can develop educational practices in high school level. The first study by Siegel, et al. (2015) explored the relationship between effective collaborative assessment during class instructions and students' performance. They recommended considering group assessment during course design and using it to adjust core outcomes and instructional activities to develop students' achievement. The results of their study indicated that collaborative group testing was effective in energizing students' thinking skills, and communication and reducing test nervousness. Second, Kearney and Perkins (2014) who created an "authentic self- and peer assessment learning" called ASPAL model, and investigated its advantages and limitations for college freshmen. Their results indicated that students' perceptions were positive towards FA strategies used in the model. Finally, Rodgers, et al. (2015) investigated first year students' perceptions regarding the feedback provided by teacher assistants and peers. Their results indicated that helpful feedback should be specific, constructive and leads to change. Thus, the authors recommended further research on how to provide high quality feedback, and improve the effectiveness of authentic comment.

2.2.1.3 Formative assessment in the Arab region

In the Arab region, few studies have investigated FA in the high school system. A study conducted in Oman (Alkharusi, Aldhafri, &Alnabhani, 2014) investigated the effect of authentic assessment strategies on students' self-efficacy. They found that if teachers use various types of alternative assessment tools, such as laboratory observation and collecting evidence of class academic achievements, students' academic self-efficacy beliefs will increase, developing their academic achievement. Alkharusi et al. recommended further studies using the qualitative approach and collecting data through lesson observations,and interviewing studentsto provide deeper understanding of the effect of FA on student motivation and learning engagement. An additional study by Tabari (2014) investigated teachers' views of change, and factors impeding reforms in Ras Al Khaimah Schools. She interviewed teachers usingquestions thatfocused on different reform attributes that included students-teacher interaction, student-centered educational approach, and students' attitude to learning. The results indicated that most teachers were positive towards reforms. Nevertheless, they thought that new methods were time consuming and would prevent them from completing the curriculum. Tabari concluded that teachers may resist reforms based on professional working conditions and should be given adequate professional development training and support to implement new changes. Tabari recommended further research to investigate teachers' views of the educational reform across the UAE. The current study investigates teachers' perceptions of FA of inquiry based-learning in 14 different schools located across the UAE.

2.2.2 Inquiry-based learning

National Science Education Standards (NSES 2000, p. 23) defined scientific inquiry as "diverse ways in which scientists study the natural world and propose explanations based on the evidence derived from their work", and inquiry in classroom as " the activities of students in which they develop knowledge and understanding of scientific ideas, as well as an understanding of how scientists study the natural world". Additionally, "The Science as Inquiry Standard in NSES includes the abilities necessary to do scientific inquiry and understanding about scientific inquiry" (National Science Teachers Association 2004 p. 33).IBL is defined as a process of active learning used to enhance students' higher cognitive abilities in a student centered classroom (Asay&Orgill 2010; Coberna et al. 2014; Forawi& Liang 2011).

Dewey (1910) stated that the native human mind begins all thinking processes by questioning the facts, collecting more information, and performing experiments in order to believe in them; he called this process "reflective thoughts" (p. 8). He also declared that children learn more through enhancing their curiosity while linking facts based on observations to come-up with conclusions, and facts regarding the universe around them (Dewey 1910 pp. 150-152). Furthermore, the constructivist learning theory implies that students learn best by being exposed to multiple learning approaches in which they are active, and play a significant role in building their own new knowledge; in addition, students should also have enough time to reflect upon their understanding using metacognitive activities (Ronis 2008).Harlen (2000),Nowak et al. (2013), and Abell and Lederman (2010) defined scientific literacy as a term used to describe values, knowledge and practices students will gain by studying different science subjects. One of the major components of scientific literacy is IBL, which is an educational approach that supports scientific practices and thinking skills that should be gained by students. Accordingly, efforts to develop science education should consider the nature of the human mind, as explained by Dewey, and the constructivism theory, that perfectly line up with building scientific literacy through IBL.

Abell and Lederman (2010) stated that researchers agree that the current formal instructions in science classrooms do not help students to understand the main scientific concepts. Change in science instructions is required to make sure that students are learning what educators want them to learn. They have clarified that in order to understand IBL as a constructivist learning approach, it should include four important elements: an interactive learning environment, the use of prior knowledge and conceptions to construct new concepts, the use of various contexts to develop new understanding and depending on cooperative learning strategies (Abell and Lederman2010 pp. 809).

Building scientific literacy in the new generation will enable them to handle complex situations in future (Harrison 2014; Forawi& Liang2011). The body of science education research has agreed that there is a great impact on students' level of understanding and performance when science teachers incorporated IBL activities using student-centered approach (Forawi& Liang 2011; Hanauer & Bauerle 2012; Harrison 2014). IBL can be implemented over a range of methodologies starting with simple guided inquiry activities, and ending with open discovery which is applied when students are responsible for all the learning processes as demonstrated in figure 3 (Llewellyn 2010).

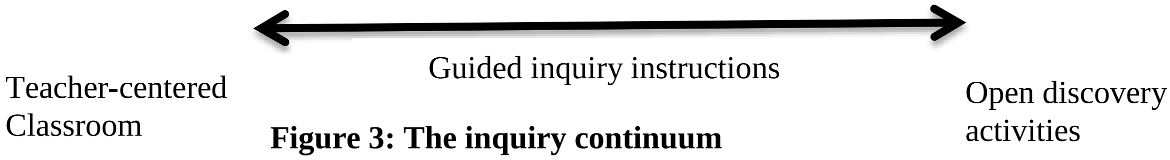

Figure 3: The inquiry continuum

IBL is an essential factor to achieve high level of education. To enforce reform in science education, teachers' and students' roles should be guided to a new orientation that focuses on changing a student into a self-directed learner, able to process and interpret information, design his own activities and arrive at appropriate conclusions, in addition to the teacher's role as a facilitator to the educational process (Abell& Lederman 2010; Anderson 1996). IBL is classified according to the level of students' engagement and contribution in the inquiry process demonstrated in Table 1 below. (Banchi& Bell 2008; Llewellyn 2010; Randy, Bell, Smetana &Binns 2005).

Level of Inquiry	Question	Procedure	Solution
Confirmed **Students perform an investigation to confirm a principle, results are known in advance**	Provided by the teacher	Provided by the teacher	Provided by the teacher
Structured **Students investigate a question proposed by the teacher and follow a specific procedure**	Provided by the teacher	Provided by the teacher	Students generate
Guided **Students investigate teacher-presented question**	Provided by the teacher	Students generate	Students generate
Open **Students are responsible for their investigation**	Students generate	Students generate	Students generate

Table 1 Levels of Inquiry (adapted from Banchi& Bell, 2008, p 27)

Doing science in classroom requires students to practice important skills that include proposing questions, making observations, planning investigations and using suitable tools to gather data and finally, using higher cognitive skills of interpreting and predicting to draw proper conclusions (DiBiase& McDonald 2015; Nowak et al. 2013). IBL is designed to enhance students' skills and ensure they have understood required concepts in depth due to their active engagement in the assigned tasks. In addition, it is known to be efficient in developing critical thinking and problem solving skills (Asay&Orgill2010; Coberna et al.2014; DiBiase& McDonald 2015).

2.2.2.1 IBL in global context.

Forawi (2011) examined pre-service teachers' perceptions of the nature of science and the use of IBL teaching strategies through a pre- and post- survey with pre-service elementary science teachers, after they had studied a course regarding methods of teaching science for elementary grades. The results revealed a significant change in teachers' perceptions of the nature of science which was positively related to teachers' skills in using IBL in their instructions. This result indicates that if teachers received sufficient professional development on the nature of science within IBL environment, they will gain effective skills to teach science through inquiry.

Another study was performed by Lombard and Schneider (2013) who completed a design-based research that aimed to ensure the right direction of the inquiry process and simultaneously maintain student' ownership of the inquiry process. They concluded that four main instructional rules are required to achieve their aim: learning goals should be collaboratively developed by students and teachers, students should organize their data as questions and answers to discuss each concept, authentic feedback from peers and teachers with the presence of reliable resources, and finally, the teachers' role as a guide to facilitate students' ownership of the inquiry process. More work on inquiry design was done by Kogan and Laursen (2014) who investigated the impact of IBL on the academic achievement of college students. The result of their study indicated that students who received IBL instructions were able to gain significant and long lasting knowledge, even though they received less amounts of information to adopt the required time for implementing an IBL approach. Recently, DiBiase and McDonald (2015) conducted a study to investigate teachers' perceptions regarding IBL they reported that 75% of the teachers they surveyed found IBL as an effective tool to engage all the students in class and 99% thought that IBL is an important process in science education. Conversely, about 72% of the teachers expressed their worries towards assessing IBL activities, and the amount of time required to develop suitable activities and implement them in the classroom. 60% of the teachers were concerned about not being prepared to design and use IBL in the classroom. A recent study (Hong & Vargas 2015) conducted in the USA used semi-structured interviews with newly-qualified science teachers to investigate their perceptions and experience regarding implementing IBL activities. The findings indicated that participants agreed that teaching science should depend on the constructivist view of gaining knowledge that is built through empirical research and depends on active involvement of students in the class. However, the participants presented superficial understanding of IBL. All the results of teachers' perception of IBL call for further studies to locate best practices and provide the required professional development support for teachers, which is the aim of the current study. Further studies suggested putting IBL into action in science classrooms by providing required professional development to science teachers (DiBiase& McDonald 2015; Pedaste et al. 2015; Stone 2014).

In the UAE context, Dickson and Kadbey (2014) examined the effect of providing the required knowledge and training of science learning strategies to pre-service teachers on their IBL perceptions. The findings indicated that two groups of students in science education programs in the first year and the fourth year expressed their willingness to become dynamic science teachers using student-centered approach, and presenting science concepts through inquiry-based instructions. Hence, there was no significant relationship between the way that the first and fourth year students were taught and their plan for implementing IBL in their teaching methodologies, indicating that professional development can change teachers' opinions regarding their previous experience in learning science, and develop their skills to implement new methodologies. A similar study done by Tairab (2014) discussed the level of disciplinary knowledge and confidence of students in science education program regarding their ability to teach science. His results indicated that the students in science education program had a shallow base in scientific knowledge. Nevertheless, they were confident that they could implement various pedagogical strategies to teach science through IBL activities for elementary classes, which indicated that training programs can support teachers and develop their teaching skills. The results of both previous studies are aligned with the national science education standards regarding inquiry based learning “Standard D: Building Professional Development Programs for IBL and Teaching” (National Research Council 2000).

2.2.3 Effectiveness of formative assessment of inquiry based learning in science education

In contrast to traditional teaching strategies, assessment of IBL should focus on the progress of students’ conceptual understanding and their proficiency to perform inquiry (National Research Council 2000). FA leads to adoption of various instructional strategies including: collaboration through discussions, questioning with in smaller groups and peer work, besides, using higher cognitive skills in problem solving, and utilizing students’ responses to emphasize their conceptual knowledge(Bennett 2011; Clark 2015). In a similar approach, Hanauer and Bauerle (2012) emphasized that teachers should transform their instructions to be interactive and require students to use higher order thinking skills to promote innovation. These instructional strategies are evident in IBL (Hanauer&Bauerle 2012; Harrison 2014; Nowak et al. 2013).The UK learning development center identifies “adaptive learning” as aprocess that requires learners to use existing theories and concepts to solve problems in different situations,and link it to perform challenging tasks(Bennett 2011; Clark 2015). Appropriately, as reported by science education literature, IBL would be an ideal application, allowing students to experience challenging tasks that require higher thinking order skills (Asay&Orgill, 2009; Llewellyn 2010; Nehring et al.2013; Stone 2014).

Lyon (2013) recommended that if science teachers were equipped with various strategies that can be used for FA, and gained the skill to select an appropriate assessment tool for each topic, they will be able to successfully implement FA and enhance their students’ understanding. The current study elaborates on usingFA of IBL in science classrooms, and investigates their effect on students’ learning skills. Similarly, Harrison (2014) reported that teachers were more confident assessing their students' abilities when they applied assessment for IBL activities, as teachers stated that their students were willing to raise new questions, and learn from their mistakes. However, he reported that teachers faced some challenges when they attempted to assure their students' understanding during IBL activities such, as their inability to collect accurate data regarding every student in all activities. Overall, when teachers followed FA of IBL activities, they were encouraged to do more IBL work with students, leading students to gain novel skills.

Although DiBiase and McDonald (2015) had reported that 75% of the teachers in their survey found it difficult to meet the standards of the summative assessment if they followed IBL methodology, Stone (2014) stated an opposing view, where she found that using instructional strategies that enhance students' inquiry skills, in addition to appropriate assessment tools would increase students' conceptual understanding.

Park et al. (2015) developed a model to support science teachers and enhance effective FA through proper science instructions. They conducted their study in Korea and cooperated with three science teachers teaching biology, physics, and Earth Science to implement their model. Their study was based on qualitative lesson observations, as they developed the Korean teacher observation protocol (KTOP) that included 30 items to record their data, followed by collaborative effort with the science teachers to improve science instruction, and finally, compared the attributes that developed after discussion and support sessions. However, the KTOP is a relatively long checklist and a researcher might not be able to observe all the required items in one lesson. In addition, items specified to check the IBL activities were general and did not include specific identification to distinct inquiry stages or inquiry cycles being observed in the class. In contrast, the observation tool used in the current study was simpler as it had only 18 items, and the part specified for inquiry investigates the detailed steps in addition to the interaction between students and their teachers during the inquiry cycles.

Locally, a limited number of studies mentioned earlier have examined teachers' perceptions' of implementing IBL in K-12 school systems, and students' perceptions' of the use of FA as an important component of the class environment. The intention of this study is to elaborate on and investigate teachers' and students' perceptions of the use of FA strategies to assess inquiry-based activities in science classrooms, across the UAE. The next chapter outlines the study design and methodologies, including the context of the study, participants and tools used.

CHAPTER THREE
METHODOLOGY

The present study investigates teachers' and students' perceptions and practices of FA of IBL in the UAE. Accordingly, it seeks to identify perceptions and best teaching strategies that utilize FA to assess IBL activities, which will enable students to use scientific skills to solve future society problems. This chapter will extrapolate the study design and methods including the site, study instrumentation, sampling and participants, and ethical consideration. It also describes how validity and reliability were ensured by conducting pilot study, and give details on ethical considerations and study limitation.

3.1 Study design

The hypothetical basis behind this study is deemed to be practical, as it aims to identify best practices of using FA of IBL activities in science classrooms in a group of high schools in the UAE. The study will apply a simultaneous mixed-method approach in which collecting means and data analysis are done using quantitative and qualitative tools concurrently, then merging the data to come up with answers and explanations on the study topic and questions (Creswell 2011; Laban 2012). Applying quantitative methods in this study follows the positivistic paradigm which requires collecting data through closed-ended questions regarding FA of IBL practices in science classrooms, and using the statistical data to obtain generalizations and recommendations (Creswell 2002; Laban 2012). This deductive method of research provides statistical data with correlations to examine different causes and factors in classroom daily practices that may affect the FA of IBL activities (Laban 2012). A quantitative questionnaire provides data regarding current perceptions and practices regarding FA and IBL from teachers' and students' perspectives, which answers the first two research questions. In order to answer the third question, it is required to merge the quantitative data with data collected by observing teachers and students in the classroom along with documents that describe how FA of IBL activities is implemented (Creswell 2011; Laban 2012). The qualitative section of this study which is built on the constructivist paradigm, recorded the detailed interactions of teachers and students to understand and conclude best practices of implementing FAof IBL activities in the science classroom (Creswell 2002).The weight is distributed equally between both quantitative and qualitative research to strengthen the type of data collected, and increase the validity and reliability of the results which allows proper generalization and recommendations (Laban 2012).

3.2 Study methods

One of the best tools that can be used to track the effectiveness of teaching strategies to improve the classroom environment is obtaining information about students' and teachers' perceptions and daily classroom practices. Questionnaires are suitable when assessing the degree of which the classroom environment is consistent with new insights in teaching science, and providing required support for teachers to reshape their teaching practices (Abell& Lederman 2010). Particularly, in the current study, questionnaires were used to investigate the implementation of FA of IBL in science classrooms. Abell and Lederman (2010) recommended collecting the feedback concerning the class environment from teachers and students, because they have different perceptions of the class environment. Therefore, two types of questionnaires were developed to detect teachers' and students' perceptions and practices, both included two main scale terminology: IBL activities and FA practices. The quantitative part of this study was complemented by qualitative lesson observations that were used to identify best practices of FA of IBL activities through observing the relationship between teachers and students, and students' interactions during the class. Abell and Lederman (2010) emphasize that the qualitative part of science education research would help researchers provide consistent information that can be linked to the quantitative scores obtained from the questionnaire.

The study design and methods used are described in Figure 4. (Bell 2010; Cresswell 2011). The steps of the data collection were as follows:

1. Quantitative data from the teachers' questionnaire "Formative Assessment Of Inquiry-Based Activities Questionnaire" was used to identify teaching practices implemented in the classroom, regarding FA and the IBL approach.
2. Quantitative data from students' questionnaire "Formative Assessment Of Inquiry-Based Instructions Questionnaire" was used to identify actual practices in the classroom regarding FA and students' conceptual understanding of IBL.
3. Qualitative lesson observations to record data regarding best practices of usingFA of IBL .

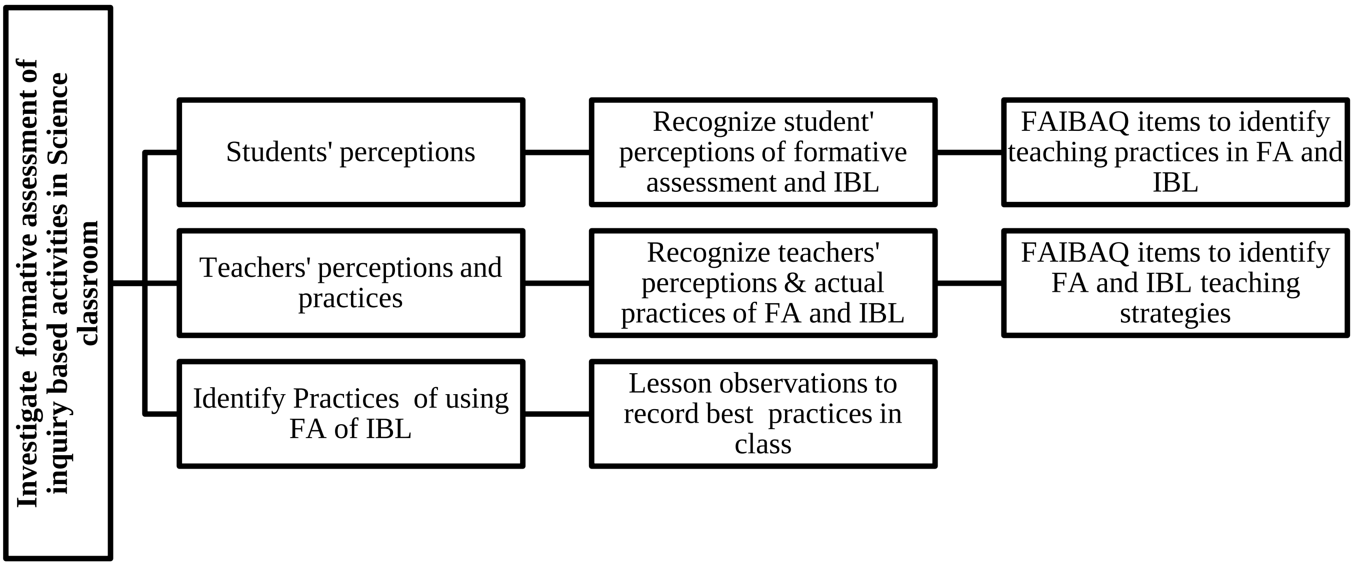

Figure 4: Design of the study and data collection instruments.

To investigate the use of FA of IBL activities in the science classroom, it is important to explore the implementation from different perspectives; any educational situation should be observed from the teachers' view, students' view and the actual daily practices in the classroom. Therefore, questionnaire items were designed to identify students' perceptions of FA and IBL, and additionally, detect teachers' perceptions and actual practices in their instructional methodologies. Hence, different items were included to detect actual implementation of FA and IBL processes in the classroom. More details about the tools are described in section 3.2.2 that discusses the study's instruments.

3.2.1 Context

This study was conducted in semi-governmental applied technology high schools in the UAE in 14 different locations. The purpose of choosing these particular schools is due to the management efforts to carry out curriculum and educational reforms to improve learning outcomes and align them with international standards. New programs for all science subjects are designed carefully according to college board science standards and next generation science standards (NGSS) (see appendix 4). The teaching of science aims to provide students with scientific literacy skills, and enable them to employ their scientific thinking to solve real life problems. It is planned that these high school graduates attend top universities in the UAE and abroad. These expectations correspond with the purpose of this study, which is to improve instructional methods to utilize FA practices in order to stress value of using the IBL approach in daily teaching and learning practices.

Data collection was performed during regular school day schedules, science lessons are located either in 90 minute blocks each, or one period of 45 minutes. Teachers' and students' questionnaires were sent to participants during the last studying term, and responses were received over the preceding three weeks.

3.2.2 Study instruments

The nature of this study requires a mixed-method approach in which quantitative and qualitative methods are applied with three different instruments. The quantitative data was collected via teachers' and students' responses to FAIBA questionnaires that are used to identify teachers' and students' perceptions and practices with regard to FA of IBL. The qualitative part was completed by observing ten various science lessons to investigate teaching and learning practices related to FA of IBL activities in science classrooms.

3.2.2.1 Teacher questionnaire

A quantitative questionnaire directed towards teachers was developed to investigate their perceptions and current practices regarding IBL and FA (Abell&Lederman 2010; Bell 2010; CohenManion& Morrison 2000; Creswell 2002; Creswell 2011). The FA of IBL questionnaire (FAIBAQ) was designed to answer the teachers' part of research questions 1 and 2 (see appendix 1). It consists of three main parts. First, demographic items to identify teachers' gender, age, and teaching experience. Second, items focus on the main criteria of IBLactivity in a classroom which were adopted from Harlen, Nowak, Tiemann and Belzen (2013) who identified the requirements of IBL. These criteria include observing, procedure of collecting data or experimenting, and proofs to construct new conclusions and concepts to provide explanations to natural phenomena. Items from 1 to 10 focused on teachers' practices regarding inquiry cycles in science lessons, and to what extent do students contribute in implanting inquiry-bases learning activities. This would help to discover the common type of inquiry utilized in classes and where it is located on the inquiry continuum. The items regarding teachers' perceptions and practices were adopted from principles of inquiry tool developed by Campbell et al. (2010). The third part consists of 20 questions to examine daily FA practices, such as the amount of students' contribution in class discussions, the effectiveness of group work assessment, the nature of teachers' feedback, and how efficiently it is used to support student' learning. Items regarding the use of FA by teachers were modified from a questionnaire (WIHIC) developed by Dorman, Aldridge and Fraser (2006), as their questionnaire was targeted at students. The last 10 items in the questionnaire were developed based on the criteria of best FA procedures from the literature (Torrance 2012; Walani 2009). Responses in the second and third sections were collected though a semantic differential scale (with 1 being implementing the item every science lesson) in which teachers choose how frequently they implement each of the items in their teaching practices (Cohen et al. 2000). The questionnaire in the current study intended to collect data from grade 9 and 10 teachers' population at one time.

Validity was checked by an expert panel including a university professor and three educators in the field who advised changing some options to make them more appropriate to the context conditions.

3.2.2.2 Students' questionnaire

Student questionnaire (see appendix 2) is a quantitative descriptive tool used to measure students' perceptions regarding FA and IBL activities implemented in science classrooms. The tool consisted of three main parts: first, factual information including students' grade and campus location. The second included 8 questions focusing on students' understanding of IBL, and the extent of which students are involved in classroom activities. This reflects the type of inquiry used and its location on the inquiry continuum. The questions were modified from "principles of inquiry" questionnaire developed by Campbell et al. (2010) for students.

The ten items in the third part regarding FA were adopted from questionnaire (WIHIC) by Dorman, Aldridge and Fraser (2006). The last 10 items were developed to measure the effects of constructive feedback on students' learning, how students reflect upon their understanding, and to which extent are they involved in designing rubrics for each task in the classroom. Responses to all items were in the form of the Semantic Differential Scale to indicate how frequently each item was implemented in the classroom (Cohen et al. 2000). The questionnaire was simultaneously available in both Arabic and English to avoid misconceptions and misunderstandings in students' responses. It was sent to a professional translator, then sent to the supervisor for approval.

3.2.2.3 Lesson observation tool

For the lesson observations, a qualitative observation tool (Bell 2010; Creswell, 2002; Cresswell 2011; Richards 2003) was used as an instrument to investigate teaching situations comprehensively, and identify best teaching practices in class. It is agreed that lesson observations provide precise information regarding the actual teaching practices (Richards 2003). Symon and Cassell (2004) believe that lesson observation is a tool in which the researcher's opinion is heard and is a place to show his input, as it is an opportunity for the researcher to look into day-to-day teaching practices, and observe various learning strategies. Therefore, identifying the best teaching and learning strategies is important to implement proper FA of IBL activities.

Observations were planned for grades 9 and 10 in a total of three chemistry lessons, three biology lessons and four physics lessons. All lesson observations were recorded during term three (April- June) in the academic year 2014-2015. Volunteer teachers from three different schools participated in lesson observations, and classes were conducted in the laboratories or in normal classrooms. Recording data during lesson observations was done through initial note taking, including a description of the setting in the classroom or the laboratory, the sequence of events and different interactions between students in groups, and between students and their teacher. All events were recorded to help collect detailed and comprehensive data related to the research topic (Symon & Cassell, 2004). In addition, teacher-student interactions were also observed, which included both on-going constructive feedback and the availability of scaffolding techniques. The researcher of this study remained solely as an observer of the process, and did not participate during the instructional process (Creswell 2002; Symon & Cassell 2004). However, teachers were given feedback to acknowledge best practices, and identify how to improve missing items. Finally, the notes were used to complete the structured lesson observation form developed by the researcher (see appendix 3).

Data collected from lesson observations provided the necessary information to answer the third research question: How well do teachers use FA of inquiry-based activities in science classrooms? According to previous research, the key factors that influence the use of FA strategies to assess students' progress in IBL activities are the existence of inquiry cycles, various FA strategies used to evaluate the inquiry cycles, and how this approach is achieved in the class by looking at teacher-student interactions in the classroom (Harrison 2014; Pedaste et al. 2015). Data collected from lesson observations was classified into four categories according to the main aspects of the lesson observation tool, which are to recognize pros and cons observed in different science classrooms, in addition to collective reflection concerning teachers' feedback and the researcher's experience (Symon & Cassell 2004).

Lesson observations were used to determine authentic results and establish ideal teaching and learning methodologies that can be used to achieve the best implementation of FA of IBL activities. Finally, results regarding best practices were related to quantitative results, identifying and reporting recommendations of the best strategies and practices that can be used to enhance FA of IBL activities.

The researcher ensured that the data collected regarding IBL activities and FA practices in the observed lessons could be used to describe the best practices of interactions that may aide students' learning. In addition, diverse samplings in lesson observation (e.g. male and female teachers, subjects observed were biology, physics and chemistry) also indicated the degree to which the recommendations from this research could be generalized.

3.2.3 Participants

Participants consisted of two groups: students and teachers. Students were from grades 9 and 10 and teachers participating were science teachers assigned to teach those grades. The method of choosing students was based on purposeful sampling (Creswell 2009). The chosen grade levels were 9 and 10 because students at this stage are prepared with strong foundation in all sciences, and are expected to gain enough knowledge and practical skills to enable them to enter grade 11, where they would study a career-oriented curriculum. Implementing proper FA of IBL at this stage enables students to gain self-regulated learning skills that will help them face different challenges in the future.

The population of teacher participants included 80 science teachers working in 14 different campuses, plus their students, about 2800. For lesson observations, ten volunteer teachers showed interest in participating in the research. An invitation to participate in the research study was sent to all grade 9 and 10 science teachers. Data was collected from those who responded to the questionnaire.

Another invitation was sent to 2800 students studying in nine boys' and five girls' campuses. All students access the same science curricula for science subjects (physics, chemistry and biology). However, some students in grade 10 are taught advanced physics, chemistry and biology curricula. The main science outcomes are required in both regular and advanced programs, except for slight differences in the depth of knowledge. The number of students in each class ranged between 18-25 (average 20). Responses to students' questionnaire were compared to address the research questions.

3.3 Pilot studies

Laban (2012) described validity as an important factor that should make sure the research instruments are measuring what they should, and that results can be generalized among different persons, times and settings. To ensure internal validity, an expert panel consisting of the research supervisor and three educational experts working in the field, advised and approved the questionnaire items and the main factors to be measured in lesson observations. Cohen, et al. (2000) recommended piloting the questionnaire to ensure validity and reliability. Thus, the questionnaires were piloted before the study and results were used to adjust some items in the actual questionnaires.

Data collected from the pilot studies satisfied the purpose of the tools that ensure validity (Creswell 2011). Split-Half reliability Spearman Brown formula (Frankel, Wallen, & Hyun 2015) was used to calculate the reliability figures for students' and teachers' questionnaires as shown in table 2.

Questionnaire	Correlation coefficient	Reliability figure
Students' Q. Items regarding inquiry (1-8)	0.45	0.62
Students' Q Items regarding FA (9-28)	0.77	0.87
Teachers' Questionnaire all items	0.85	0.9

Table 2: Students' & Teachers' questionnaire reliability

The students' questionnaire was piloted on small groups of 25 grade 9 students. Pilot data indicated implementation difficulties, as the question regarding the subjects was within the demographic questions. As a result, students didn't respond to the three science subjects equally, which affected the consistency of the pilot results. That was avoided when the actual questionnaire was released.

Students also faced difficulties in recognizing the operational meaning of inquiry and investigation, thus providing imprecise responses, and causing the correlation coefficient for the inquiry part to be low (0.45). In the actual questionnaire, an additional description of the terms and was provided with clarifying examples. The teachers' FAIBAQ questionnaire was piloted by 25 science teachers from different campuses, and the reliability figure was (0.9).

The pilot sampling included physics, chemistry and biology male and female teachers from various schools representing all population categories to ensure validity. Appropriate instrumentation was confirmed by submitting the questionnaire to a panel of experts to be answered and checked. Their feedback was used to edit the range of responses. The result of the pilot study reflected consistency in responses, making it applicable in real life.

3.4 Ethical considerations

The researcher was granted official permission from the applied technology high school management to perform this research study in different campuses to maintain research integrity (Bell 2010; Cresswell 2011). Accordingly, classroom access for lesson observations, and conducting a survey study were also granted. In addition, the researcher sent an official email to all participants (see appendix 5) to explain the aim of the research, and to assure that all responses and lesson observation data will be used for research purposes only, and will remain anonymous and confidential (Bell, 2010). Anonymity was secured, because the questionnaire did not require teachers to mention their names, grade level taught or location, and students were not required to mention their names. As such, the researcher is not able to identify individual participants (Bell, 2010). Besides, all teachers who contributed to lesson observations were also not identified to maintain confidentiality.

3.5 Limitations of the study

The limitations of this study include the relatively small number of participants, as the students' questionnaire was sent to 2800 students, yet only 535 responded, and only 51 teachers responded to the questionnaire. The qualitative part of this study included 10 lesson observations distributed among physics, chemistry and biology lessons which resulted in small samples for each subject, making it difficult to generalize the results, and make definite conclusions based on this small number of teachers.

This study was performed within a series of schools following the same system; centralized curriculum documents are distributed to teachers to implement certain instructional strategies, which reduces teachers' freedom in changing the instructions, and makes it difficult to find significant differences regarding implementing inquiry-based activities

CHAPTER FOUR
RESULTS AND DATA ANALYSIS

The aim of this study is to investigate students' and teachers' perceptions and practices of the FA of IBL activities. This chapter presents two types of data collected in order to answer the study questions: quantitative results of FAIBAQ questionnaires for teachers and students, in addition to qualitative data regarding the best practices in which FA of IBL activities were observed during lesson observations.

4.1 Demographic information

Three different tools were used in this study. Students' FAIBAQ questionnaire which was sent to 2800 students from grades 9 and 10 in 10 different locations. 535 students responded, whereby 55% were from grade 9 and 45% from grade 10. They were distributed across female and male campuses of which 57.7% were males, and 43.3% were female students.

The teachers' questionnaire was sent to 80 science teachers, 51 of them responded- 39.6% being male, and 60.4% being female. 50% of those who answered were physics teachers, while about 24% of them were chemistry teachers, and 26% were biology teachers. 24% had more than 20 years of experience, 14% had 16-20 years, 20% had between 11-15 years, 22% had 6-10 years' experience, and 20% had 1-5 years of teaching experience.

For lesson observations, 10 teachers participated, 4 male and 6 female. 40% of the participants were physics teachers, 30% were chemistry teachers and 40% were biology teachers. 20% had more than 20 years of experience, 30% had between 11-15 years, 20% had 6-10 years of experience, and 30% had 1-5 years of teaching experience.

4.2 Quantitative results

The reliability test SPSS analysis was used to find Cronbach's Alpha, presented in table 3 below (Frankel, Wallen& Hyun, 2015).

Questionnaire items	Cronbach's Alpha
Students' Q items related to IBL	.943
Students' Q items related to FA	.966

Teachers' Q	.905

Table: 3 Reliability test results

The data collected was used to answer the following research questions:

- What are the teachers' and students' conceptions of FAin science classrooms?
- What are the teachers' and students' conceptions of IBL in science classrooms?
- How well do teachers use FA of IBL activities in science classrooms?

We reported several best practices regarding the implementation of FA of IBL activities in science classrooms.

4.2.1 Students' perceptions of formative assessment and inquiry-based learning strategies.

Students' FAIBLA questionnaire was designed to recognize students' perceptions of FA and IBL learning strategies implemented in science classrooms. The percentage numbers of responses per item per subject sample results are presented in Table 4.

		Responses to IBL Items %	Responses to FA%
Physics	A: Every Science Lesson	43	55
	B: Once biweekly	22	18
	C: Once per month	10	8
	D:Once per term	10	5
	F: Never	14	14
Chemistry	A: Every Science Lesson	42	48
	B: Once biweekly	21	20
	C: Once per month	11	9
	D:Once per term	10	6
	F: Never	15	17
Biology	A: Every Science Lesson	31	38
	B: Once biweekly	20	18
	C: Once per month	10	8
	D:Once per term	9	6
	F: Never	30	30

Table 4: Overview of teachers responses to items regarding IBL and FA items

The results indicate that about half of the students had experienced various FA strategies during physics (50%) and chemistry (48%) lessons. However, less students reported experiencing IBL strategies in physics (43%) and chemistry

(42%) lessons. Additionally, it can be realized from the table that students' responses about biology were classified into two major groups: about 38% of the students reported that they have applied FA and 31% of them reported learning through IBL activities in every biology lesson, whereas a third of the students (30%) reported that they never learned through FA or IBL activities.

After analyzing students' responses to particular items of FA (see appendix 6), several results were revealed, as the majority of students (70%) reported that they were asked questions every physics lesson, 63% in chemistry, and 51% in biology lessons. 66% of the students also agreed that they had the chance to ask questions in every physics lesson, 61% in chemistry, and surprisingly only one third (31%) had an opportunity to ask questions during biology lessons. In addition, the majority of participating students (70% in physics, 67% in chemistry and 53% in biology) reported that the teachers re-explain points that students do not understand. Looking at the items about cooperative learning in average, about (50%) reported that they practice proper teamwork, as they discuss problems and activities with peers and learn from them in physics and chemistry, while in biology, about (44%) of the students reported proper cooperative learning. When it came to objective clarity, more than half of the students (61% in physics and 57% in chemistry) reported that they know what is required from each task and relate it to the topic in every lesson, while less than half (43%) reported that in biology. As for the feedback and time given to think and reflect about answers, 56% of students reported that they did indeed experience that in every physics lesson, and 47% reported the same in every chemistry lesson.

Regarding IBL instructions, about half of the students (52%) reported that they receive detailed instructions to make investigations in chemistry lessons. 48% reported that they are able to relate conclusions with the main scientific concept in physics, and 46% in chemistry. Students' responses regarding inquiry-based instructions revealed that one third of the students reported that they were able to connect scientific investigations to the main concept in every science lesson. On the contrary, one third of the students reported that they never experienced that in a biology lesson.

Tables 5, 6 and 7 demonstrate the results of further analysis using the independent t-test (t-test for Equality of Means) to measure the relationship between students' perceptions regarding inquiry-based and FA responses, and different genders in the three science subjects. Only the items with significant values where the probability significance (2-tailed) is less than 0.05 are listed.

Biology	Male			Female			t-statistics	degree of freedom	Sig. (2-tailed)
IBL and FA items	Mean	Std. Deviation	Std. Error Mean	Mean	Std. Deviation	Std. Error Mean			
My teacher conducts the experiment and I observe	3.44	1.597	.117	3.05	1.623	.119	2.368	370	.018
I can connect the conclusion with the scientific concept	2.95	1.695	.124	2.59	1.596	.117	2.092	370	.037
I explain my ideas to other students	3.30	1.667	.124	2.80	1.598	.123	2.857	347	.005
I discuss with other students how to go about solving problems.	2.57	1.707	.127	2.14	1.582	.122	2.479	347	.014
I learn from other students in this class.	2.82	1.723	.128	2.23	1.508	.116	3.399	347	.001
I cooperate with other students on class activities	2.72	1.684	.125	2.13	1.533	.118	3.465	347	.001

Table 5: Independent t Test values based on gender in Biology

Table 5 shows the items with the significant differences of students' perceptions regarding biology lessons based on their gender. Results show that items listed in table 6 were better implemented in female classes.

Physics	**Male**			**Female**			**t-statistics**	**degree of freedom**	**Sig. (2-tailed)**
FA Variables	**Mean**	**Std. Deviation**	**Std. Error Mean**	**Mean**	**Std. Deviation**	**Std. Error Mean**			
The teacher asks me questions.	1.48	1.025	.076	1.22	.623	.048	2.841	347	.005
My ideas and suggestions are used during classroom discussions.	1.99	1.432	.106	1.56	1.071	.083	3.195	347	.002

I ask the teacher questions.	2.21	1.491	.111	1.78	1.171	.090	2.983	347	.003
I explain my ideas to other students	1.78	1.306	.097	1.48	1.055	.081	2.325	347	.021

Table 6: Independent t Test values based on gender in Physics

Table 6 summarizes items with significant differences in students' perceptions about the physics classroom. Results showed differences only in four FA items that focus on the nature of class discussion and how students' ideas are utilized during the lesson. Female students reported better implementation of these items as well.

Chemistry	**male**			**Female**			**t-statistics**	**degree of freedom**	**Sig. (2-tailed)**
FA Variables	**Mean**	**Std. Deviation**	**Std. Error Mean**	**Mean**	**Std. Deviation**	**Std. Error Mean**			
I discuss with other students how to go about solving problems.	2.04	1.392	.103	1.73	1.292	.100	2.127	347	.034
I am asked to explain how I solve problems.	2.50	1.618	.120	2.09	1.516	.117	2.426	347	.016
I cooperate with other students when doing assignment work.	2.36	1.595	.119	1.92	1.259	.097	2.862	347	.004
When I work in groups in this class, there is teamwork.	2.34	1.561	.116	1.94	1.366	.105	2.518	347	.012
I learn from other students in this class.	2.09	1.463	.109	1.71	1.139	.088	2.732	347	.007
I cooperate with other students on class activities	2.03	1.503	.112	1.56	1.093	.084	3.306	347	.001
I am encouraged to take control of my own learning.	2.23	1.516	.113	1.78	1.191	.092	3.046	347	.002
I know what should be accomplished by the end of each task	2.52	1.642	.122	2.18	1.499	.116	1.985	347	.048

Table 7: Independent t Test values based on gender in Chemistry

Table 7 indicates several items with significant differences in students' responses based on gender, in which female students reported better implementation of eight items regarding FA, including cooperative learning strategies, and building students' self-regulatory learning skills.

4.2.2 Teachers' perceptions and practices regarding formative assessment and inquiry-based learning.

FAIBAQ teacher questionnaire was designed to investigate teachers' perceptions and current practices regarding IBL and FA in science classrooms.

Table 8 demonstrates the percentage results of the teacher FAIBAQ responses for the IBL and FA items.

	Every Science Lesson	Once biweekly	Once per month	Once per term	Never
IBL Items	25%	26%	25%	12%	13%
FA items	74%	19%	5%	1%	1%

Table 8: Overview of teachers responses to items regarding IBL and FA items

The majority of teachers (74%) reported that they use FA in their teaching practices in every science classroom, while about one fourth (26%) reported using IBL activities once biweekly, and 25% reported using IBL activities in every science lesson.

Answer Options	Every Science Lesson	Once biweekly	Once per month	Once per term	Never
Students are given opportunity to discuss ideas in the class	92%	6%	2%	0%	0%
Questions are fairly distributed between students	84%	14%	2%	0%	0%
Students' ideas and suggestions are used during the lesson	73%	22%	4%	2%	0%
Students are given opportunity to ask questions in the class	96%	4%	0%	0%	0%
Students share ideas with peers	73%	25%	0%	2%	0%
Students discuss with peers how to solve a problem	75%	22%	4%	0%	0%
Students are asked to explain how did they reach a solution	78%	16%	6%	0%	0%
I encourage students to take control of their learning	82%	16%	2%	0%	0%
I explain the target of each task	88%	8%	4%	0%	0%
I provide my students with rubrics used to assess their task	53%	25%	12%	8%	2%
My feedback helps students identify their strengths and weakness points	64%	30%	6%	0%	0%
My feedback requires students to practice the concepts they didn't master	65%	33%	2%	0%	0%
My feedback enhances my students to do actions to increase their performance	71%	24%	6%	0%	0%
I address all misconceptions after a task is done	80%	16%	4%	0%	0%
Students can relate the task result with the lesson topic	82%	10%	6%	2%	0%

Wait time is used to get students to think about their answers	84%	12%	0%	2%	2%

Table 9: Best teachers' responses to items regarding FA

Table 9 summarizes best responses given by teachers regarding FA which shows that the majority of teachers (more than 70%) reported that they frequently practice strategies related to FA during every science lesson, including asking questions, allowing students' questions, distributing questions equally, using students' ideas and suggestions during the lesson, allowing students to share ideas with peers, discuss how to solve a problem, and explain how they reached a solution. Moreover, they reported controlling group work and encouraging students to take control of their learning, and explaining the target of each task in every science classroom. About half of the teachers reported that they explain the rubrics required to assess studentsin every science lesson.

Answer Options	Every Science Lesson	Once biweekly	Once per month	Once per term	Never
Students formulate questions which can be answered by investigations	24%	31%	20%	10%	16%
Students develop their own research questions	6%	37%	22%	18%	18%
Students are given step-by-step instructions before they conduct investigations	43%	33%	20%	2%	2%
Students design their own procedures for investigations	10%	20%	20%	24%	27%
Students conduct their own procedures of an investigation	12%	10%	32%	22%	24%
The investigation is conducted by me in front of the class	22%	30%	32%	6%	10%
Each student has a role as investigations are conducted	36%	20%	34%	8%	2%
Students determine which data to collect	22%	25%	24%	12%	18%
Students develop their own conclusions for investigations	36%	24%	20%	10%	10%
Students connect conclusions to scientific knowledge	35%	27%	24%	10%	4%

Table 10: Teachers' responses to items regarding IBL

Different results presented in Table 10 uncover the actual practices of IBL activities. The top three components of IBL presented in table 10 are: first, less than half of the teachers (43%) reported that students are given step-by-step instructions before they conduct investigations in every science lesson. Second, about 36% of the teachers reported that each student has a role as investigations are conducted. Third, 36% of the teachers reported that students develop their own conclusions for investigations. Full data regarding teachers' perceptions and practices is included in Appendix 7.

The ANOVA statistical test results compared teachers' perceptions according to their specialization, four items regarding FA were statistically significant: giving students opportunities to discuss ideas in the class, fairly distributing questions between students, having teachers address all misconceptions after a task is done, and students being able to relate the task result with the lesson topic. None of the items regarding IBL showed significant differences between the three groups of teachers according to their specialization. ANOVA analysis results for all FA and IBL items are demonstrated in appendices 8 and 9.

Further analysis using the independent t-Test was performed to identify any significant differences in teachers' responses according to their total years of experience. Results are presented in appendix 10. Table 11 shows the results of the item that displayed significant values. All other variables related to inquiry-based and FA did not show significance in the (2-tailed) values as they were greater than 0.05.

	Less than 10 years' experience			More than 10 years' experience			t statistics	df	Sig. (2-tailed)
	Mean	Std. Deviation	Std. Error Mean	Mean	Std. Deviation	Std. Error Mean			
Students' ideas and suggestions are used during the lesson	1.68	.885	.203	1.21	.415	.085	2.163	24.230	.041

Table 11: Independent t-test for teachers' responses based on their experience years

4.2.3 Correlation test to link the best chosen formative assessment items with the best chosen inquiry-based items for both teachers' and students' results.

Descriptive statistics were used to analyze data and find the Pearson correlation coefficient to measure the relationship between different IBL items and FA items in the teachers' and students' questionnaires.

Table 12 presents a summary of the positive relation found between IBL items and FA items. Detailed results of Pearson correlation figures along with the significance (2-tailed) values are represented in appendix 12.

Inquiry based items #	Related FA items	r value

1	1	0.29
4	2	0.297
6	12	0.41
	13	0.336
7	2	0.36
	6	0.359
	9	0.381
	11	0.334
	13	0.342
	16	0.311
	18	0.314
8	2	0.308
	13	0.3
	15	0.3
9	1	0.337
	2	0.425
	6	0.331
	11	0.4
	13	0.38
	14	0.33
	16	0.314
	17	0.42
	18	0.38
	20	0.31
10	7	0.345
	8	0.293
	9	0.3
	10	0.41
	16	0.3
	17	0.33
	18	0.31

Table 12: Pearson correlation between related IBL and FA items in teachers' questionnaire.

The same correlation test was done to examine the relation between inquiry-based items and FA from the students' perspective. The SPSS was used to find the Pearson Correlation Factor along with the significance, considering the practices in the three science subject as one (see Appendix 11) . The results revealed a positive relation between several IBL items and FA items that had significant (2-tailed) less than 0.05. However, the magnitude of the relation (r) was very low (between 0.100- 0.162) which indicates a weak positive relation.

4.3 Qualitative results

All the events that occurred in the classroom were documented, and a checklist was used to report those events related to FA and IBL strategies implemented in each lesson. The section below represents some situations in which FA of IBL strategies were observed.

4.3.1 Using Scientific approach
Students worked independently in groups, formulated a hypothesis, set their procedure and found the solution. The teacher's role was to provide support when required, and use questioning techniques that tackle students' higher order thinking skills and deepen their understanding of the scientific concept. That was observed in three different laboratory lessons, one of which students were asked to predict which salt solutions would form a precipitate.

4.3.2 Effective Teachers' Observation
To collect evidences of students' understanding, teachers were circulating among groups, asking them about their procedure, providing supportive feedback, identifying the points of strength and weakness, and guiding them to identify the gaps in their understanding. This was implemented during one lab session and in another lesson that included an IBL activity.

4.3.3 Students' group work and peer collaboration
Students were required to work with peers and discuss information to understand a certain concept. This was observed in three lessons: one physics lesson where groups of students were asked to prepare and explain a scientific concept through implementing an activity. Throughout the classes, the responsible groups prepared activities and asked other students to explain their observations, later concluding the required information. Group work was also observed in two chemistry lessons, when students performed a lab lesson to identify the pH of unknown solutions. They were required to experiment using three different methods and compare their results to emphasize their conceptual understanding of pH.

4.3.4 Assessment worksheets
Assessment through worksheets is part of FA, where students receive feedback for solving a worksheet addressing a certain concept. Their use was observed in

several science classes: in a grade 9 biology lesson about karyotyping and hereditable disorders, in a grade 10 biology lab session exploring Tidal volume, and in a Grade 10 physics class in which five worksheets were given out to guide and assess students' work throughout the lab session. After submitting their solved worksheets, students were given a challenging question to evoke their critical thinking skills (see appendix 10).

4.3.5 Students' presentations to communicate learning experience

Students had to communicate their learning experience and explain their results to the rest of the class, so the teacher allowed peer discussion. Most importantly, the feedback presented at the end of the lesson identified the strengths and weaknesses of each group. This was observed in two situations: a lesson discussing karyotypes and genetic disorders, in which students were asked to prepare one PowerPoint slide that asks a question about one of the disorders, and gives a general description of it, then presents treatment options. In another example, the same concept was applied, in which students were asked to work in groups to design a model that represents breathing in lungs, then they were required to communicate their model and explain the main parts of the respiratory system and their functions.

4.3.6 Discussion to support Exploration and data analysis

Comprehensive discussion was observed when a physics teacher used a motion detector to collect and graph data in class. One of the activities involved groups of students discussing how to make a specific graph displayed on the screen, as they were given the opportunity to move in front of the motion sensor and match the displayed graph according to their discussions. Each group was given time to think about their motion example and explain how to better match the graph in a second trial, which required students to discuss the solution in groups, and communicate their predictions with other groups. The teacher facilitated an open class discussion to find the correct conclusion and provided precise feedback to individual students within groups.

4.3.7 Lab reports as a tool to assess inquiry lab work and provide proper feedback

All the lessons observed in the laboratory required students to write a lab report showing the main steps of their investigation. These reports were marked, and proper feedback was provided.

4.3.8 Using Online Platform to assess students' conclusions

Online testing was used as a closure for a grade 9 biology lesson about karyotypes and genetic disorders, in which an online platform (see appendix 12) was used to investigate case studies. In addition to using (SOCRATIVE) to evaluate individual students' understanding, it enabled the teacher to provide instant feedback, identifying each student's strong and weak elements.

4.3.9 Explaining concepts

Several observed instances reflected how students were given the opportunity to explain new concepts to their peers by using different strategies. Students were required to speak up in class, demonstrate self-confidence, and respond to other peers' and teachers' questions.

The main qualitative and quantitative results highlighted above reflected students' and teachers' perceptions regarding FA. Significant findings regarding the relation between FA and IBL from teachers' perspectives will be discussed and compared with the results of other research studies in chapter five, which will include the conclusion, recommendations and limitations of the current study.

CHAPTER FIVE
Discussions and Conclusions

The previous chapter indicated several findings. This chapter discusses and interprets the finding, presents conclusions with recommendations, study limitations and provide recommendations for further research to close the gaps in this area.

5.1 Discussion

Three major concepts revealed from both the qualitative and quantitative results will be discussed. These concepts are: students' perceptions of FA and IBL, teachers' practices and perception of FA and IBL, and the relationship between FA and IBL in science teaching and learning practices.

Students' responses revealed different important perceptions regarding FA and IBL in science lessons, which can be used to conclude some of the best practices to be followed to develop teaching and learning strategies in science education.

Most students expressed that FA strategies were used in nearly all physics and chemistry classes, while the responses to biology were different. Only one-third of the students agreed that FA practices are implemented in every science class, which indicates several points: subject matter nature, as Jacobya et al. (2014) reported that students always face limitations in achieving well in biology, and their level of engagement increases when they experience proper FA strategies, in addition to the possibility that biology teachers have less experience in using FA strategies in their daily practices. Lyon (2013) reported that teachers may lack the ability to organize a framework for the use of FA in class, and are advised to develop their knowledge and produce an assessment plan to guide their thinking during the lesson.

Results revealed that most of the students had an opportunity to contribute to class discussions, where their teacher would re-explain difficult concepts and facilitate their learning. This process would help the teacher locate student's misconceptions and adjust learning strategies to ensure students' understanding of the topic. This result is supported by Pinchok and Brandt (2009), and Kumar (2013) as they identified engaging students in constructive discussions with their teacher, collecting evidences of students' understanding and re-addressing misconceptions as one of the criteria of effective FA, as to ensure learning progression.

Students' results also indicated the implementation of cooperative learning strategies in science classrooms that would develop students' understanding of scientific concepts. As described by the constructivist theories, students can build conceptual understanding when they are exposed to social discussions through cooperative learning (Jacobsen et al. 2009; Palmer 2005). This is supported by the results of Park et al. (2015) and DiBiase and McDonald (2015) who found that students benefit from collaborative work during science lessons particularly laboratory work.

Similarly, students reported that they were able to link the activity that they were asked to do to the objective of the lesson. This is supported by Fletcher and Shaw (2012) concluded that students' awareness of the learning goals and contribution in identifying assessment criteria led to deeper learning. Yet, about third of the students reported that they are involved in building special rubrics to evaluate their work which requires more effort from teachers to plan for wider involvement for students in this area.

Two main conditions describe FA as an effective strategy: first, if it proved to be valid in adjusting instructional strategies; and second, if it supported the resulting influence on the learning process (Bennett, 2011; Denton, 2014; Roskos & Neuman, 2012). Current results also confirmed that students were given enough time to think about their teachers' feedback and reflect upon their own answers. Clarck (2012), Diaconu (2013), Hickey (2015) and Hickey, et al. (2012) suggested that proper feedback would increase students' understanding and lead them to better achievements in their final performance. Moreover, they should be asked to think about the different skills required to solve a problem, and should be engaged in group discussions before every IBL activity or problem solving session.

More results from students' responses suggest that nearly 40% of the students were confident that they are encouraged to take responsibility of their own learning. This is aligned with the results published by Haroldson (2012) who reflected that most of the students in chemistry courses were able to develop self-assessment skills when they were given the learning goals and proper feedback. However, about one fourth of the students do not think that science teachers are encouraging them to be self-learners. This is a disadvantage that should be avoided in order to develop science education, considering that Kumar (2013) and Lee, Lin and Tsai (2013) proved that making students accountable for their own learning is a main feature of science assessment that improves learning.

According to students' responses, IBL was implemented less than FA strategies. This can be justified by the fact that IBL was only recently introduced to science education in the UAE, and would require more effort to qualify teachers and allow proper implementation. Tabari (2014) and Kazempour and Amirshokoohi (2014) found that teachers would prefer participating in interactive professional development workshops that improve their understanding about inquiry, thus increasing their self-confidence when applying it. Considering responses to 8 items related to IBL in the students' questionnaire, it was found that students, in general, are conducting known procedures to answer a scientific question. Yet, they have to be able to collect and analyze data, then connect the main purpose of the task with the topic or scientific concept explained. This indicates that the instructions implemented in science lessons are classified as guided inquiry instructions (Bell, Smetana & Binns 2005). These conclusions are supported by Brickman, et al. (2009) who found that when students are exposed to laboratory work more frequently, they would have higher self confidence in implementing inquiry.

Some of the inquiry items were poorly implemented in biology. This can be caused by two different factors: first, the nature of biological science that has proved to require more effort when using inquiry to introduce its concepts. This is supported by the work of Kremer et al. (2014) who stated that students' beliefs about the nature of science are difficult to change through inquiry, especially in biology, as learners would require instructional support to connect inquiry stages to biology. Another study by Forawi (2011) provided a positive correlation between teachers' conceptions of the nature of science and their inquiry teaching skills. Second, biology as a subject was introduced only in the current academic year, which means that the curriculum was implemented for the first time, and teachers were new to the system, thus requiring more professional development and mentoring programs to adopt the new system and curriculum. This is aligned with the result of the study done by DiBiase and McDonald (2015) as they emphasized that teachers require guidance and mentoring to improve their knowledge and skills in using inquiry in daily practices.

Students in grades 9 and 10 did not report any differences in their IBL item responses based on the t-test analysis done. This indicates that science instructions received in grade 9 did not improve the students' inquiry skills in grade 10. This result was in line with the published results by Soobard and Rannikmäe (2014) as they did not find any difference in gaining science operational skills between grade 10 and grade 11 students, indicating that one year is not sufficient to develop the required scientific skills.

Further analysis of students' responses based on their gender revealed a significant difference in some of the FA and IBL items. Looking at all the items where females reported better implementation, we can conclude three things: first, teachers are better trained to implement IBL activities in cooperative context, second, female students, usually being easier to manage in a classroom, tend to be more cooperative with their teachers. Third, female students may be influenced by their teachers' opinion (Diaconu 2013). Supporting findings were reported by Abell and Lederman, (2010) who mentioned that single-sex classrooms allowed better classes management. Less implementation of cooperative learning strategies with boys can be also explained by Sinnes and Løken's (2014) conclusion that females are more ethically oriented than males which make them committed to classroom instructions and enjoy better benefit from collaborative work opportunities provided by their teachers. Yet, female students reporting more effective implementation of IBL and FA is dissimilar with several published results such as Soobard and Rannikmäe (2014) who found that female responses were less positive than male responses for the items relating to problem solving competencies. Similarly, Nehring, Nowak, Belzen and Tiemann (2015) reported that male students performed better than girls in inquiry skills. However, Slavin (2009) declares that performing educational comparisons based on gender has no definite results that males or females are better in their achievement. Still, he does imply that boys could be held back in their education more than girls.

Teachers' responses indicated the implementation of best practices to encourage students to take responsibility of their own learning. Clark (2015) and Bennett (2011) stated that creating opportunities for sociocultural learning and encouraging students to generate a system to evaluate their own work contributes to building self-regulatory learning skills. Moreover, Alkharusi, et. al. (2014) recommend that teachers should consider students' input during class interactions to develop students' self-confidence and increase their motivation towards the subject. About half of the teachers reported that they explain the rubrics required to assess students. Therefore, they can measure their students' level of understanding and make decisions regarding changing instructional practices. This result correlates with the results proposed by Boyd (2011), in which he indicated that experienced science teachers were able to provide examples of strategies used to raise the level of students' engagement in science classrooms.

Regarding IBL, only 25% of participants had reported implementing IBL requirements, which is relatively lower than FA implementation. This consistency between teachers' and students' responses can prove that the actual implementation of some inquiry activities is at the 2^{nd} or 3^{rd} level of inquiry: "structures" or "guided instructions" (Banchi& Bell 2008, p. 27). Digging deeper in teachers' data would reflect that inquiry in science classroom did not reach the stage where students suggest questions and design their experiments, which reflects poor teaching expertise in the actual meaning of inquiry and its authentic application. This result is in line with the work done by DiBiase and McDonald (2015) and Ji and Penelope, (2015) who commented that teachers were not confident in their inquiry teaching skills and asked for professional development in that area.

Teachers' response confirmed that there was a significant difference between teachers' perceptions according to their specialties regarding some items in IBL and FA. Two factors might have caused this difference in teachers' conceptions. First, the subject nature, asAbell and Lederman, (2010) described biology as a science that includes specific concepts that would require implementing various 21st century teaching strategies based on human cognitive development and social learning abilities. Physics was described as the dominant science that includes teaching science processes, and depends heavily on experiments. Chemistry was described as a science that has three main parts, macro, sub-micro and the symbolic triangle, and relating the three main parts might be the reason why many students may face difficulties in understanding chemical concepts. Another reason could be teachers' training and professional development that enable them to explain each subject using best teaching strategies. Similarly, Bulunuzand Peker (2014) concluded that all students participating in their study had misconceptions in five major topics in physics, which makes it logical that physics teachers spend more time in emphasizing physics concepts and reiterating difficult concepts. In addition, Kremer et al. (2014) found that teaching biology through inquiry will not easily change the students' beliefs in the nature of biology as a science. Regarding chemistry, another research study done in Turkey had similar results as chemistry teachers reflected their traditional beliefs in teacher-centered approach when they described the learning environment in their classroom (Al-Amousha et al. 2013).

Teachers' responses to all IBL items were similar. Unexpectedly, none of the items reflected a significant difference between teachers who had less than 10 years of experience and those with more than 10 years. This can be explained by the fact that teachers in the system are following a centralized curriculum and were required to implement similar science instructions, making it difficult to differentiate between the former and the inquiry-based activities they implement in the classroom, contrary to what Ji and Penelope (2015) reported that teachers who had less experience are quickly frustrated if they were not able to understand how to implement inquiry, and would develop a negative attitude towards the teaching profession. Regarding FA, only one item reflected a significant difference when teachers with less than 10 years' experience reported less utilization of students' ideas in the classroom. This is echoed by Sach (2011) indicating that teachers with more experience had better conceptions about the specific aspects of FA, propounding that "all children can make progress in learning, page 266" than teachers with less experience. In relation to teachers' perceptions of FA, Missett, et al. (2014) confirmed the importance of professional development for teachers to guide them how to utilize data collected from FA to create better learning opportunities for all students.

After interpreting the results of the teachers' questionnaire, some IBL items were positively related to FA items, meaning that teachers' practices could reflect using FA strategies to assess IBL activities. This result can indicate that teachers' perceptions and educational practices are reflecting an improvement in their beliefs about teaching and learning in science education (Abell & Lederman, 2010). One of the meaningful relationships was between IBL 6^{th}, 7^{th} and 8^{th} items which were positively related with six items of FA items. This relationship would explain how inquiry cycles are implemented in science classrooms, in parallel with the FA strategies used when teacher explains the steps of any investigation, and informs students about rubrics used to assess their work. This shows statistically significant results that prove the connection between asking students to conduct investigations, and encouraging them to take responsibility of their own learning. Furthermore, Clark (2012) indicated that informing students of the factors that affect their assessment will increase their ability to become accountable of their work and develop their self-learning strategies. According to Pedaste et al., (2015) this can be in five steps: first, orientation: through teachers' explanation and informing students about the rubrics used to assess their performance. Second, conceptualization: when students are given the opportunity to discuss with peers how to solve a problem. Third, investigation: when every student has a role in the investigation. Fourth, teachers' feedback to adjust learning. Fifth, data collection and relating the conclusion to the main topic explained.

IBL items 9 and 10 were positively related to various FA items. This relation is an evidence that using IBL instructions is an ideal method to enhance students' thinking and provide them with effective feedback and it also proves the importance of IBL activities in emphasizing teamwork and enhancing students' cooperative skills, in addition to evoking their metacognitive abilities when they are asked to reflect upon their work as a part of the communication process. This is aligned with the constructivist theories of education, which developed proceeding Piaget's ideas about using sensory data collected from different methods of communication to build new concepts and knowledge (Pritchard, 2010). One of the empirical studies that discussed different reform methods required for science education was done by Ston (2014) and Jalil and Ziq (2009) who found that using experimental learning strategies would strengthen students' 'working memory' via exposing students to problems that require higher cognitive thinking skills and through cooperative learning, as discussing problems among team members enhanced students' critical thinking skills. Similarly, Asay and Orgill (2010) clarified that processes like gathering evidences and forming conclusions to explain the data are considered features of a student-centered teaching approach. It is expected that after implementing FA of IBL for all science instructions students would have the same correlation that appeared from teachers' responses. As proved by Stone (2014), using different kinds of instructional tools would raise students' perceptive on application of the scientific inquiry.

Results were raised from interpreting lesson observations that were focused on situations in which FA of IBL activities was observed.

- Practices observed in science classrooms reflected the use of the scientific approach. As per Pedaste et al.'s (2015) model, the sequenceof the inquiry cycle involve the main and sub inquiry phases. Implementing this strategy in science classrooms would enable students to explain, connect and communicate scientific concepts, and get essential feedback that would provide them with a better understanding of the topic (Asay & Orgill, 2010), accordingly aiding in the development of their academic performance. Based on an experimental study, Gormally, et al. (2009) found that the students who received IBL instructions have developed scientific literacy better than the students who implemented traditional lab curriculum. However, students who experienced inquiry instructions did not like the new instructor's role with limited passive instructions. As for the qualifying of teachers, Harrison (2014) ,Hattie and Timperley (2007) and Towndrow et al. (2008) confirmed that it is important to reform practical science assessments and qualify teachers to better evaluate students' performance during laboratory work, by collecting evidences of students' understanding, thus providing a clear image of their performance, which is considered better than relying on limited written assignments.

- Peer collaboration that reflected independent group work was observed during various inquiry cycles, it enhanced students' self-regulated learning skills, thus, making them responsible for their own learning. However, in order to complete that process the teachers' role as a facilitator is required, using how and why questions to encourage students to rethink their answers, and evoke their critical thinking skills. This conclusion is supported by Paul and Elder (2004), who identified that using different questioning strategies that require students to gather information, interpret them to get reasonable conclusions, and eventually communicate their solutions to others would contribute to building students' critical thinking skills. Asay and Orgill (2010),Hayes and Devitt (2008), Clark (2012) and Clark (2015), also agreed with the pervious result, and added that students would also develop self –assessment skills through peer to peer communication, enabling them to locate their strength and weakness points, accordingly holding the accountability of their learning. This practice would support students to build self-confidence and enforce their understanding of science concepts. Since this process requires students to reflect upon their understanding and think about their answers, it would also strengthen their metacognitive skills.

Torrance, (2012) mentioned that this requirement meets an important goal of FA. Relating these observation to Pedaste et al. (2015), students were responsible for four sub-phases of inquiry cycles, including questioning, exploring, experimenting and communication.

- During a laboratory experiment it is important to assure that students understand and comprehend requirements of the experiment, and the rationale behind implementing it, which is where the role of the lab report comes. Cartwright and Stepanova (2012) clarified how important it is for students to write a lab report, especially when they are required to answer several questions that would relate the lab work with the main topic, and get the maximum benefit of the laboratory work.

  When worksheets were used after each inquiry step in the cycle, and were checked by the teacher directly, it served as a good tool for FA in class, and enabled students to adjust their misconceptions. These can be considered as sub phases that consist of the reflection and communication of students' understanding in the model presented by Pedaste et al. (2015). However, when the worksheet was submitted by the end of the lesson, it would not provide immediate feedback, requiring further follow-up from teachers. Clark (2012) indicated that when evidence of understanding is collected at the end of the lesson, and the feedback is not provided directly, it is called 'asynchronous', which could be used to prepare for the next lesson and address students' misconceptions, or as a homework task, otherwise it will not be an effective FA tool.

  Another method of measuring students' performance is using online platforms as they provide immediate feedback, and guide students to adjust their understanding. Clark (2012) confirmed that immediate feedback is an important feature of effective FA. Moreover, Keough (2012) reported that students preferred using clickers in the classroom, as it provided opportunities for class participation. Yet, students faced some difficulties caused by technical problems. Additionally, Lee et al. (2012) reported that 'Technology-Enhanced FA' (TEFA) utilization is affected by software or hardware problems, time constraints, pacing, and teachers' and students' readiness to use the technology.

5.2 Conclusion

This research study explored students' and teachers' perceptions and practices of FA of IBL activities in the teaching and learning environment in the UAE. Students' views regarding FA confirmed that the majority of science classes exhibit a cooperative learning environment and create opportunities for various discussions among learners, and between learners and their teachers. Likewise, students' views reflected the application of some guided inquiry learning activities, which is a step in implementing inquiry in teaching sciences. Students' results did not show any correlation between FA and inquiry-based practices in the classroom.

Teachers' practices and perceptions reflected strong commands of using FA in physics and chemistry lessons. However, biology teachers seemed to exhibit less experience in utilizing different FA strategies. Furthermore, the teachers presented less confidence when responding to IBL items, as they were implementing inquiry cycles less frequently in their lessons. An important and interesting result was conveyed by teachers' responses, which presented a strong relationship between different items of inquiry-based activities and FA. This was illustrated by the significant correlation between the various steps required in inquiry cycles, such as the requirement of explaining data, drawing conclusions and communicating results, along with cooperative learning strategies and effective feedback utilization to develop students' critical thinking and meta-cognitive skills.

The findings of this study also present various best practices of using FA strategies to assess IBL activities, such as using a scientific approach, effective teachers' observation, students' collaboration and peer work, the use of worksheets and lab reports, discussions, explanations and using online platforms to assess students' understanding.

To sum up, using FA strategies to evaluate inquiry cycles in science classrooms would enable teachers to collect authentic evidences regarding students' understanding of the scientific concepts, and adjust teaching strategies to address misconceptions considering various questioning techniques that would evoke students' critical thinking skills and require them to reflect upon their understanding. Accordingly, students will build self-regulatory learning skills and become able to evaluate their own understanding, enabling them to gain the essential knowledge and skills to build the required scientific literacy and contribute positively in building the future of their country.

5.3 Implications and recommendations

This study has two types of implications, one in the educational field at the school level, and the other in promoting further educational researches.

5.3.1 Implication and recommendations at school level

The result of this study suggests different strategies to improve the use of FA when assessing IBL activities. Mainly, the priority goes to supporting teachers when implement FA of IBL with confidence, and this would involve:

- Designing continuous professional development workshops that provide examples of implementing inquiry in science curricula, and clarify the real meaning of inquiry of science and its relation to the nature of different sciences: biology, chemistry and physics.
- Training teachers on different questioning skills, and evoking students' curiosity and critical thinking skills.
- Providing model lesson plans that include complete inquiry cycles with suitable FA strategies and help teachers to develop similar lesson plans.
- Organizing lesson observations to evaluate teaching and learning practices in science classrooms, and providing the required support to develop FA of IBL strategies.
- Designing curriculum documents and instructional guides that include learning outcomes targeting the development of inquiry skills.
- Designing various FA strategies to ensure that all students have mastered the needed skills to practice IBL.

- Considering time constraints and ensuring that the required topics can be taught through inquiry during the allocated time in the curriculum.

5.3.2 Implications on the educational research

This study has investigated students' and teachers' perceptions of FA and IBL in science classrooms in the UAE. The significant relationship between inquiry cycles and FA that appeared in this study would require further research to identify different IBL and FA items that are related and measure the effect of this relation on students' achievement, learning progress, self-satisfaction, self-efficacy and developing higher-order thinking to perform novel tasks and solve problems.

Further research is required to investigate the effect of using FA in IBL on the development of students' self-regulatory learning skills, and their ability to measure their conceptual understanding.

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Appendices

Appendix 1: Teachers' Questionnaire

Part 1

1- Total teaching Experience

1-5 6-10 11-15 16-20 More than 20

2- Gender

Male **Female**

3- Specialization

Physics Chemistry Biology

How frequent the following is implemented in your class.

A: Every Science Lesson B: Once biweekly C: Once per month D:Once per term F: Never

	Part 2: Principles of Inquiry					
		A	**B**	**C**	**D**	**F**
1.	Students formulate questions which can be answered by investigations					
2.	Students develop their own research questions					
3.	Students are given step-by-step instructions before they conduct investigations					
4.	Students design their own procedures for investigations					
5.	Students conduct their own procedures of an investigation					
6.	The investigation is conducted by me in front of the class					
7.	Each student has a role as investigations are conducted					

8.	Students determine which data to collect					
9.	Students develop their own conclusions for investigations					
10.	Students connect conclusions to scientific knowledge					
	Part 3 Formative Assessment Items					
		A	**B**	**C**	**D**	**F**
1.	Students are given opportunity to discuss ideas in the class					
2.	Questions are fairly distributed between students					
3.	Students' ideas and suggestions are used during the lesson					
4.	Students are given opportunity to ask questions in the class					
5.	Students share ideas with peers					
6.	Students discuss with peers how to solve a problem					
7.	Students are asked to explain how did they reach a solution					
8.	I use group work to enhance students to cooperate with peers					
9.	Students share their resources when doing an assignment					
10.	When students work in groups all team members participate					
11.	I encourage students to take control of their learning					
12.	I explain the target of each task					
13.	I provide my students with rubrics used to assess their task					

14.	My feedback helps students identify their strengths and weakness points					
15.	My feedback requires students to practice the concepts they didn't master					
16.	My feedback enhances my students to do actions to increase their performance					
17.	I address all misconceptions after a task is done					
18.	Students can relate the task result with the lesson topic					
19.	Wait time is used to get students to think about their answers					
20.	When designing the task rubrics, I consider my students' opinion					

Appendix 2: Students' Questionnaire:

How frequent the following is implemented in your class.

A: Every Science Lesson B: Once biweekly C: Once per month D:Once per term F: Never

	Student	**الطالب**	**Physics**	**Chemistry**	**Biology**
	Principles of Inquiry	**مبادىء الاستقصاء**	A: Every Science Lesson B: Once biweekly C: Once per month D:Once per term F:	A: Every Science Lesson B: Once biweekly C: Once per month D:Once per term F:	A: Every Science Lesson B: Once biweekly C: Once per month D:Once per term F:

			Never	Never	Never
1.	I formulate questions to be answered in investigation	أقومبصياغة الأسئلة التي يتعين الإجابة عليها من خلال التحقيق			
2.	I receive step by step instructions before I conduct an investigation	أتلقى التعليمات خطوة بخطوة قبل أن أجري تحقيقاً			
3.	I design my procedure for the investigation	أقوم بتصميم الإجراءات الخاصة بي للتحقيق			
4.	I conduct the procedure for an investigation	أقوم بتطبيق الإجراءات للتحقيق			
5.	My teacher conducts the experiment and I observe	يقوم أستاذي بإجراء التجربة وأنا أراقب			
6.	I decide which data to collect	أقرر ما البيانات التي ينبغي جمعها			
7.	I develop conclusions for the investigation	أضع الاستنتاجات للتحقيق			
8.	I can connect the conclusion with the scientific concept	أستطيع ربط الاستنتاج بالمفهوم العلمي			

How frequent the following is implemented in your class.

A: Every Science Lesson B: Once biweekly C: Once per month D:Once per term

F: Never

	Formative Assessment Items	**عناصر التقويم التكويني**	**Physics** A: Every Science	**Chemistry** A: Every	**Biology** A: Every Science

			Lesson B: Once biweekly C: Once per month D:Once per term F: Never	Science Lesson B: Once biweekly C: Once per month D:Once per term F: Never	Lesson B: Once biweekly C: Once per month D:Once per term F: Never
1.	The teacher asks me questions.	يسألني المعلم أسئلة			
2.	My ideas and suggestions are used during classroom discussions.	يتم استخدام أفكاري واقتراحاتي خلال المناقشة الصفية			
3.	I ask the teacher questions.	أسأل المعلم أسئلة			
4.	I explain my ideas to other students.	أقوم بشرح أفكاري للطلبة الآخرين			
5.	I discuss with other students how to go about solving problems.	أتناقش مع الطلبة الآخرين بشأن كيفية حلّ المسائل			
6.	I am asked to explain how I solve problems.	يُطلب مني أن أشرح كيف أقوم بحل المسائل			
7.	I cooperate with other students when doing assignment work.	أتعاون مع الطلبة الآخرين عندما نقوم بحلّ الفروض			
8.	When I work in groups in this class, there is teamwork.	عندما أعمل ضمن مجموعات في هذه الحصة، هناك عمل جماعي			
9.	I learn from other	أتعلم من الطلبة			

	students in this class.	الآخرينفي هذه الحصة			
10.	I cooperate with other students on class activities.	أتعاون مع الطلبة الآخرين في الأنشطة الصفية			
11.	I am encouraged to take control of my own learning.	يتمّ تشجيعي على أن أتولّى التعلّم الخاص بي			
12.	I know what should be accomplished by the end of each task.	أعلم ما الذي ينبغي إنجازه مع نهاية كل مهمة			
13.	I get clear rubrics and know how my work will be assessed.	أتلقى تعليمات واضحة وأعلم كيف سيتمّ تقييم عملي			
14.	I get feedback that helps me to identify my strength and weakness points	أتلقى تغذية راجعة تساعدني في التعرف على نقاط القوة والضعف لدي			
15.	The feedback represents a training that increases my self-confidence	تمثّل التغذية الراجعة تدريباً يزيد من ثقتي بنفسي			
16.	The feedback enable me to take some action to improve my performance.	تمكنني التغذية الراجعة من اتخاذ إجراء من أجل تحسين أدائي			
17.	My teacher re-explains points that I didn’t understand	يقوم المعلم بإعادة شرح النقاط التي لم أفهمها			
18.	I can relate the result of the task to the main concept of the lesson	أستطيع أن أجد علاقة بين نتيجة المهمة والمفهوم الرئيسي للدرس			
19.	I am given time to think	يتم منحي وقت للتفكير			

	about and reflect the work done	بالعمل الذي تم إنجازه			
20.	I am involved in determining the criteria and agreeing on a grading scale and assessment procedure.	أشارك في تحديد المعايير والاتفاق على مقياس الدرجات وإجراءات التقييم			

Appendix 3: Observation Form

Subject **Campus**

Grade **Room/Lab**

	Steps of Inquiry	**Yes**	**No**	**Comments**
Inquiry Cycles	Orientation			
	Conceptualization (questioning, hypothesis,...)			
	Investigation (Exploration, experimentation, ...)			
	Data collection and organization			
	Conclusion (provide solution)			
	Discussion (reflection and communication)			
	Assessment of Inquiry Cycles			
	Questioning strategies allow students time to process information and formulate appropriate responses			
	Note-taking supports understanding of objectives and represents synthesis of learning			

	Inquiry cycles are assessed frequently after each step			
	Use of lab report			
	Use of work sheets			
	Performance scales (i.e. rubrics) are clearly communicated and understood by students			
Interactions in the classroom	**Students' Interactions**			
	Classroom routines are established and facilitate cooperative learning			
	Interactions with instructional materials promote critical thinking and problem solving			
	Independent work demonstrates learning in authentic and relevant ways and enable assessment of individual effort			
	Teacher's students' Interactions			
	Feedback is constructive and specific, help students to identify strengths and weakness points			
	Scaffolding techniques (i.e. reflections) are applied to construct meaning and promote a deeper level of understanding			
	Ongoing feedback is timely, after each task			

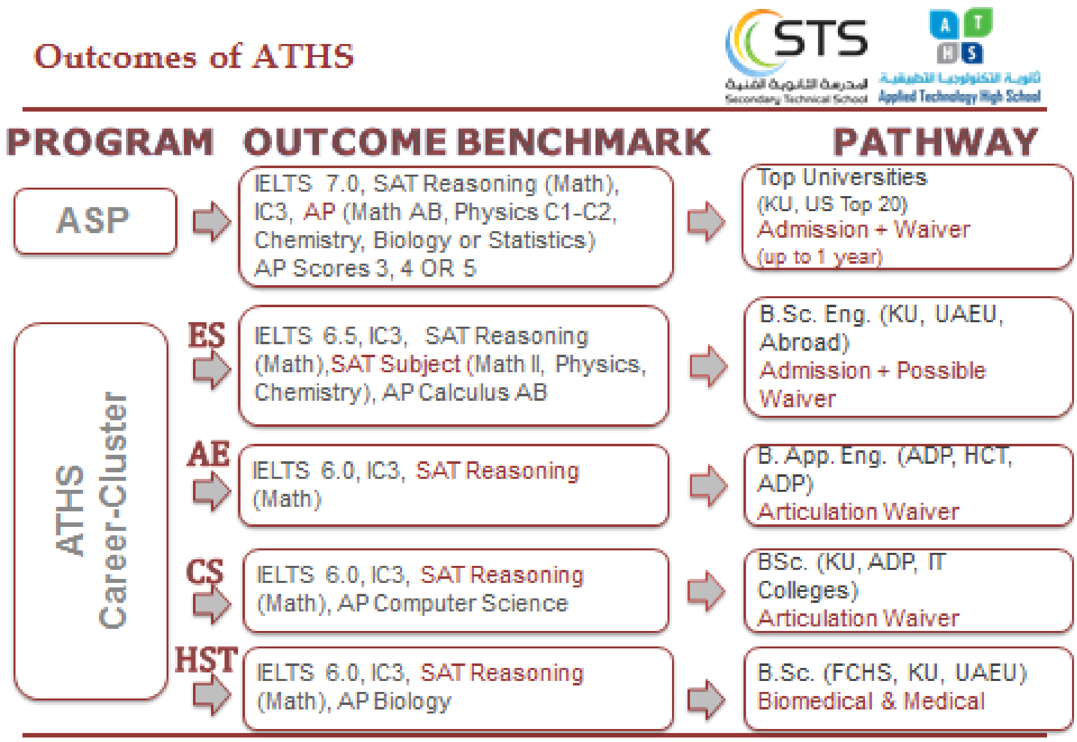
Observation Form

Subject	**Physics**	**Campus**	Al Ain
Grade	**9.52**	**Room/Lab**	Classroom
Class duration	**45-minutes**	**Lesson title**	Review of Motion Gra

	Steps of Inquiry	**Yes**	**No**	**Comments**
Inquiry Cycles	Orientation	×		The teacher started the lesson by as to build a mind map that related all required for the lesson and introduc the class which is to revise motion g
	Conceptualization (questioning, hypothesis,...)	×		The teacher introduced that student build a distance time graph and aske could their motion be detected and the screen
	Investigation (Exploration, experimentation, ...)	×		students used the motion detector a form a certain pattern of graph
	Data collection and organization	×		Different examples were used to sho collected differ when motion change
	Data analysis	×		Students practiced data analysis in v of graphs (distance/time, speed/tim
	Conclusion (provide solution)	×		Students were able to conclude mot depending on reading and analyzing
	Discussion (reflection and communication)	×		students were asked to discuss the s groups then they had to share their with other groups and finally get the conclusion after open class discussio
	Assessment of Inquiry Cycles			
	Questioning strategies allow students time to process information and formulate appropriate responses	×		Strategies used enhanced students s skills, and metacognition.
	Note-taking supports understanding of objectives and represents synthesis of learning	×		Students were taking notes through
	Inquiry cycles are assessed frequently after each step	×		The teacher ensured that all student mastered the concept after each step
	Use of lab report		×	No lab report was required
	Use of work sheets	×		Students were answering workshee mind maps that were sent to teache assessment
	Performance scales (i.e. rubrics) are clearly communicated and understood by students	×		Students were reminded by the rule commonly used in the class as they decide if all the answers were corre accepted

I n	**Students' Interactions**			

Appendix 4: Program outcomes of ATHS.



Appendix 5 Official emails& Permission letter

Science Teachers' Questionnaire .msg

FW Formative assessment questioni

الجامعة البريطانية في دبي

The British University *in* Dubai

26 April 2015

Technology High School System
United Arab Emirates

This is to certify that **Ms Sura Osama Sabri – Student ID No. 2013101132** is a registered part-time student on the Master of Education programme in The British University in Dubai, from September 2013.

Ms Sura is currently working on her dissertation. She is required to collect relevant data lesson observations and survey responses.

The British University in Dubai would like to request your support and cooperation in completing her dissertation research.

Any information given will be used solely for academic purposes.

This letter is issued on the Sabri's request.

Yours sincerely,

الجامعة البريطانية في دبي
الإدارة الطلابية
Student Administration
The British University in Dubai

Amer Alaya
Head of Student Administration

Approved

May 03, 2015

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Appendix 6: Percentages of students' responses per item

Item	A: Every	B: Once	C: Once	D:Once	F: Never	Total	A: Every	B: Once	C: Once	D:Once	F: Never	Total	A: Every	B: Once	C: Once	D: Once	F: Never	Total
I formulate questions to be answered in investigation	47	23	4	7	12	95	40	24	8	7	14	94	29	25	9	6	31	100
I receive step by step instructions before I conduct an investigation	40	24	8	7	14	94	52	17	7	7	10	93	38	21	7	9	25	100
I design my procedure for the investigation	35	28	10	9	18	100	35	25	13	8	20	100	26	23	11	8	32	100
I conduct the procedure for an investigation	45	21	12	9	12	100	42	23	10	10	15	100	32	21	10	8	28	100
My teacher conducts the experiment and I observe	37	16	14	17	17	100	36	14	14	18	16	100	24	14	11	16	36	100
I decide which data to collect	46	19	11	10	14	100	43	20	13	9	15	100	34	17	13	8	28	100
I develop conclusions for the investigation	44	20	13	11	13	100	41	21	13	9	15	100	31	20	12	7	31	100
I can connect the conclusion with the scientific concept	48	22	9	9	13	100	46	20	10	9	15	100	33	19	10	7	31	100
Average percentages of IBL responses	43	22	10	10	14		42	21	11	10	15		31	20	10	9	30	
The teacher asks me questions.	71	13	2	1	4	92	63	17	2	3	6	92	53	19	7	4	17	100
My ideas and suggestions are used during classroom discussions.	38	25	10	5	22	100	34	24	11	6	25	100	28	21	8	7	37	100
I ask the teacher questions.	66	20	5	2	7	100	64	17	7	3	9	100	31	27	13	8	21	100
I explain my ideas to other students	58	15	6	3	18	100	28	25	13	8	26	100	23	20	12	8	37	100

I discuss with other students how to go about solving problems.	61	20	5	5	10	100	58	19	6	6	11	100	49	16	5	5	25	100
I am asked to explain how I solve problems.	48	26	8	5	13	100	39	27	11	4	20	100	26	25	9	5	36	100
I cooperate with other students when doing assignment work.	57	19	8	4	12	100	53	19	10	6	12	100	46	18	8	4	24	100
When I work in groups in this class, there is teamwork.	59	14	8	5	13	100	51	16	9	6	19	100	45	16	7	5	27	100
I learn from other students in this class.	51	22	8	6	13	100	48	23	9	5	15	100	40	20	8	5	27	100
I cooperate with other students on class activities	57	19	9	5	11	100	51	18	10	5	16	100	44	18	7	7	25	100
I am encouraged to take control of my own learning.	48	16	7	4	24	100	45	17	7	6	25	100	38	12	9	5	37	100
I know what should be accomplished by the end of each task	64	18	6	4	8	100	56	22	7	4	11	100	43	18	8	4	27	100
I get clear rubrics and know how my work will be assessed.	57	15	9	5	14	100	51	16	10	8	16	100	36	21	10	6	28	100
I get feedback that helps me to identify my strength and weakness points	39	22	14	4	21	100	38	20	14	6	23	100	29	14	11	7	37	100
The feedback represents a training that increases my self-confidence	47	19	9	6	20	100	43	19	9	7	21	100	33	18	5	8	36	100
The feedback enable me to take some action to improve my performance.	48	20	10	5	17	100	43	19	12	6	19	100	34	19	8	8	32	100
My teacher re-explains points that I didn’t understand	72	12	5	4	7	100	67	14	4	5	10	100	53	14	6	4	24	100
I can relate the result of the task to the main concept of the lesson	59	19	7	4	11	100	54	20	8	5	12	100	40	21	7	5	27	100

I am given time to think about and reflect the work done	56	18	6	5	16	100	47	19	8	7	19	100	37	16	8	6	34	100
I am involved in determining the criteria and agreeing on a grading scale and assessment procedure.	38	17	9	9	27	100	31	18	11	8	31	100	25	15	9	7	45	100
Average percentages of FA responses	55	18	8	5	14		48	20	9	6	17		38	18	8	6	30	

Appendix 7: Percentages of Teachers' responses per item

Answer Options	Every Science Lesson	Once biweekly	Once per month	Once per term	Never
Students formulate questions which can be answered by investigations	24%	31%	20%	10%	16%
Students develop their own research questions	6%	37%	22%	18%	18%
Students are given step-by-step instructions before they conduct investigations	43%	33%	20%	2%	2%
Students design their own procedures for investigations	10%	20%	20%	24%	27%
Students conduct their own procedures of an investigation	12%	10%	32%	22%	24%
The investigation is conducted by me in front of the class	22%	30%	32%	6%	10%
Each student has a role as investigations are conducted	36%	20%	34%	8%	2%
Students determine which data to collect	22%	25%	24%	12%	18%
Students develop their own conclusions for	36%	24%	20%	10%	10%

investigations					
Students connect conclusions to scientific knowledge	35%	27%	24%	10%	4%
Average percentages of IBL responses	25%	26%	25%	12%	13%
Students are given opportunity to discuss ideas in the class	92%	6%	2%	0%	0%
Questions are fairly distributed between students	84%	14%	2%	0%	0%
Students' ideas and suggestions are used during the lesson	73%	22%	4%	2%	0%
Students are given opportunity to ask questions in the class	96%	4%	0%	0%	0%
Students share ideas with peers	73%	25%	0%	2%	0%
Students discuss with peers how to solve a problem	75%	22%	4%	0%	0%
Students are asked to explain how did they reach a solution	78%	16%	6%	0%	0%
I use group work to enhance students to cooperate with peers	63%	31%	6%	0%	0%
Students share their resources when doing an assignment	64%	28%	8%	0%	0%
When students work in groups all team members participate	66%	26%	8%	0%	0%
I encourage students to take control of their learning	82%	16%	2%	0%	0%
I explain the target of each task	88%	8%	4%	0%	0%
I provide my students with rubrics used to assess their task	53%	25%	12%	8%	2%
My feedback helps students identify their	64%	30%	6%	0%	0%

strengths and weakness points					
My feedback requires students to practice the concepts they didn’t master	65%	33%	2%	0%	0%
My feedback enhances my students to do actions to increase their performance	71%	24%	6%	0%	0%
I address all misconceptions after a task is done	80%	16%	4%	0%	0%
Students can relate the task result with the lesson topic	82%	10%	6%	2%	0%
Wait time is used to get students to think about their answers	84%	12%	0%	2%	2%
When designing the task rubrics, I consider my students' opinion	45%	16%	14%	6%	20%
Average percentages of FA responses	74%	19%	5%	1%	1%

Appendix 8: ANOVA for teachers' responses regarding FA items based on their specialization

		Sum of Squares	df	Mean Square	F	Sig.
FA1	Between Groups	.910	2	.455	3.827	.029
	Within Groups	5.590	47	.119		
	Total	6.500	49			
FA2	Between Groups	1.151	2	.576	3.574	.036
	Within Groups	7.569	47	.161		
	Total	8.720	49			
FA3	Between Groups	.794	2	.397	.900	.413
	Within Groups	20.726	47	.441		
	Total	21.520	49			
FA4	Between Groups	.080	2	.040	1.025	.367
	Within Groups	1.840	47	.039		
	Total	1.920	49			
FA5	Between Groups	.326	2	.163	.463	.632
	Within Groups	16.554	47	.352		
	Total	16.880	49			
FA6	Between Groups	.254	2	.127	.419	.660
	Within Groups	14.246	47	.303		
	Total	14.500	49			
FA7	Between Groups	.394	2	.197	.590	.558
	Within Groups	15.686	47	.334		
	Total	16.080	49			
FA8	Between Groups	1.286	2	.643	1.775	.181
	Within Groups	17.034	47	.362		
	Total	18.320	49			
FA9	Between Groups	.083	2	.042	.096	.908
	Within Groups	19.917	46	.433		
	Total	20.000	48			
FA10	Between Groups	.160	2	.080	.187	.830
	Within Groups	19.677	46	.428		
	Total	19.837	48			

FA11	Between Groups	.188	2	.094	.462	.633
	Within Groups	9.125	45	.203		
	Total	9.313	47			
FA12	Between Groups	.206	2	.103	.492	.614
	Within Groups	9.814	47	.209		
	Total	10.020	49			
FA13	Between Groups	3.996	2	1.998	1.827	.172
	Within Groups	51.384	47	1.093		
	Total	55.380	49			
FA14	Between Groups	.563	2	.282	.750	.478
	Within Groups	17.273	46	.376		
	Total	17.837	48			
FA15	Between Groups	.311	2	.155	.553	.579
	Within Groups	13.209	47	.281		
	Total	13.520	49			
FA16	Between Groups	.989	2	.495	1.432	.249
	Within Groups	16.231	47	.345		
	Total	17.220	49			
FA17	Between Groups	1.871	2	.936	3.909	.027
	Within Groups	11.249	47	.239		
	Total	13.120	49			
FA18	Between Groups	3.583	2	1.792	4.398	.018
	Within Groups	18.333	45	.407		
	Total	21.917	47			
FA19	Between Groups	1.211	2	.605	1.077	.349
	Within Groups	26.409	47	.562		
	Total	27.620	49			
FA20	Between Groups	1.821	2	.911	.356	.703
	Within Groups	120.359	47	2.561		
	Total	122.180	49			

Appendix 9: ANOVA for teachers' responses regarding IBL items based on their specialization

		Sum of Squares	Df	Mean Square	F	Sig.
IQ1	Between Groups	.443	2	.221	.111	.895
	Within Groups	93.337	47	1.986		
	Total	93.780	49			
IQ2	Between Groups	5.233	2	2.617	1.842	.170
	Within Groups	66.767	47	1.421		
	Total	72.000	49			
IQ3	Between Groups	1.393	2	.697	.792	.459
	Within Groups	41.327	47	.879		
	Total	42.720	49			
IQ4	Between Groups	4.671	2	2.336	1.325	.276
	Within Groups	82.849	47	1.763		
	Total	87.520	49			
IQ5	Between Groups	3.432	2	1.716	1.048	.359
	Within Groups	75.343	46	1.638		
	Total	78.776	48			
IQ6	Between Groups	.422	2	.211	.139	.871
	Within Groups	69.823	46	1.518		
	Total	70.245	48			
IQ7	Between Groups	1.974	2	.987	.820	.447
	Within Groups	55.373	46	1.204		
	Total	57.347	48			
IQ8	Between Groups	5.692	2	2.846	1.481	.238
	Within Groups	90.308	47	1.921		
	Total	96.000	49			
IQ9	Between Groups	8.609	2	4.304	2.523	.091
	Within Groups	78.493	46	1.706		
	Total	87.102	48			
IQ10	Between Groups	1.650	2	.825	.603	.552
	Within Groups	64.350	47	1.369		
	Total	66.000	49			

Appendix 10: Independent t-test for teachers' responses based on their experience years

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	T	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
IQ1	Equal variances assumed	2.154	.150	.670	41	.507	.289	.432	-.583	1.162
	Equal variances not assumed			.652	33.732	.519	.289	.444	-.613	1.192
IQ2	Equal variances assumed	2.018	.163	.387	41	.701	.147	.380	-.620	.914
	Equal variances not assumed			.383	37.387	.704	.147	.383	-.629	.923
IQ3	Equal variances assumed	.975	.329	1.233	41	.225	.344	.279	-.220	.908
	Equal variances not assumed			1.183	30.891	.246	.344	.291	-.249	.938
IQ4	Equal variances assumed	.230	.634	.919	41	.363	.382	.415	-.457	1.220
	Equal variances not assumed			.915	38.004	.366	.382	.417	-.463	1.226
IQ5	Equal variances assumed	.849	.362	.323	41	.748	.129	.400	-.679	.937
	Equal variances not assumed			.319	36.410	.752	.129	.406	-.693	.952
IQ6	Equal variances assumed	.000	.995	.658	41	.514	.257	.390	-.531	1.044
	Equal variances not assumed			.660	39.068	.513	.257	.389	-.530	1.043
IQ7	Equal variances assumed	1.384	.246	.991	41	.327	.338	.341	-.350	1.026
	Equal variances not assumed			1.008	40.639	.319	.338	.335	-.339	1.014
IQ8	Equal variances assumed	.811	.373	1.471	41	.149	.627	.426	-.234	1.488
	Equal variances not			1.452	36.494	.155	.627	.432	-.249	1.503

	assumed									
IQ9	Equal variances assumed	.799	.377	.744	41	.461	.307	.413	-.527	1.141
	Equal variances not assumed			.725	34.032	.474	.307	.424	-.554	1.168
IQ10	Equal variances assumed	.225	.638	.219	41	.828	.075	.340	-.613	.762
	Equal variances not assumed			.219	38.466	.828	.075	.341	-.616	.765
FA1	Equal variances assumed	1.710	.198	.617	41	.541	.075	.121	-.170	.319
	Equal variances not assumed			.579	26.845	.567	.075	.129	-.190	.339
FA2	Equal variances assumed	13.018	.001	1.720	41	.093	.232	.135	-.040	.505
	Equal variances not assumed			1.598	24.653	.123	.232	.146	-.067	.532
FA3	Equal variances assumed	11.838	.001	2.335	41	.025	.476	.204	.064	.888
	Equal variances not assumed			2.163	24.230	.041	.476	.220	.022	.930
FA4	Equal variances assumed	.110	.742	.166	41	.869	.011	.066	-.123	.145
	Equal variances not assumed			.163	36.433	.871	.011	.067	-.125	.147
FA5	Equal variances assumed	.779	.383	.184	41	.855	.035	.190	-.349	.420
	Equal variances not assumed			.175	28.947	.862	.035	.200	-.375	.445
FA6	Equal variances assumed	1.988	.166	.438	41	.664	.077	.175	-.278	.431
	Equal variances not assumed			.419	30.366	.678	.077	.183	-.297	.451
FA7	Equal variances assumed	.062	.805	-.378	41	.708	-.070	.186	-.446	.305
	Equal variances not			-.371	35.787	.713	-.070	.189	-.454	.313

	assumed									
FA8	Equal variances assumed	1.875	.178	.254	41	.801	.046	.181	-.320	.412
	Equal variances not assumed			.245	31.456	.808	.046	.188	-.338	.430
FA9	Equal variances assumed	1.181	.283	.509	41	.614	.099	.194	-.293	.490
	Equal variances not assumed			.497	34.772	.622	.099	.198	-.304	.502
FA10	Equal variances assumed	8.603	.005	1.235	41	.224	.235	.190	-.149	.618
	Equal variances not assumed			1.168	27.981	.253	.235	.201	-.177	.646
FA11	Equal variances assumed	7.628	.009	1.346	41	.186	.191	.142	-.095	.477
	Equal variances not assumed			1.269	27.348	.215	.191	.150	-.118	.499
FA12	Equal variances assumed	.194	.662	.227	41	.822	.033	.145	-.260	.326
	Equal variances not assumed			.224	36.543	.824	.033	.147	-.265	.331
FA13	Equal variances assumed	.746	.393	1.007	41	.320	.322	.320	-.324	.969
	Equal variances not assumed			.979	33.579	.335	.322	.329	-.347	.992
FA14	Equal variances assumed	.365	.549	.023	41	.982	.004	.195	-.389	.397
	Equal variances not assumed			.022	35.219	.983	.004	.199	-.399	.407
FA15	Equal variances assumed	2.916	.095	.842	41	.404	.140	.167	-.196	.477
	Equal variances not assumed			.819	33.652	.418	.140	.171	-.208	.489
FA16	Equal variances assumed	.002	.969	.184	41	.855	.035	.190	-.349	.420
	Equal variances not			.186	39.774	.854	.035	.189	-.347	.417

	assumed									
FA17	Equal variances assumed	5.514	.024	1.533	41	.133	.254	.166	-.081	.589
	Equal variances not assumed			1.492	33.833	.145	.254	.170	-.092	.601
FA18	Equal variances assumed	.636	.430	.346	41	.731	.077	.222	-.371	.525
	Equal variances not assumed			.335	32.588	.740	.077	.229	-.390	.543
FA19	Equal variances assumed	1.770	.191	.860	41	.395	.213	.247	-.287	.712
	Equal variances not assumed			.824	30.543	.416	.213	.258	-.314	.740
FA20	Equal variances assumed	3.603	.065	.711	41	.481	.340	.478	-.626	1.305
	Equal variances not assumed			.690	33.205	.495	.340	.493	-.662	1.342

Appendix 11: Pearson correlation between IBL and FA in students' questionnaire

		IQ1_PHY	IQ1_CHM	IQ1_BIO	IQ2_PHY	IQ2_CHM	IQ2_BIO	IQ3_PHY	IQ3_CHM	IQ3_BIO	IQ4_PHY	IQ4_CHM	IQ4_BIO	IQ5_PHY	IQ5_CHM	IQ5_BIO	IQ6_PHY	IQ6_CHM	IQ6_BIO	IQ7_CHM	IQ7_BIO	IQ8_PHY	IQ8_CHM	IQ8_BIO
FA1_PHY	Pearson Correlation	.331**	.226**	.171**	.406**	.280**	.209**	.280**	.222**	.182**	.310**	.230**	.137**	.303**	.230**	.202**	.239**	.231**	.174**	.279**	.218**	.330**	.263**	.158**
	Sig. (2-tailed)	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.003	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.001
FA1_CHM	Pearson Correlation	.233**	.373**	.142**	.278**	.452**	.188**	.153**	.303**	.102*	.245**	.380**	.138**	.181**	.309**	.154**	.175**	.348**	.160**	.375**	.190**	.250**	.446**	.187**
	Sig. (2-tailed)	.000	.000	.002	.000	.000	.000	.001	.000	.028	.000	.000	.003	.000	.000	.001	.000	.000	.001	.000	.000	.000	.000	.000
FA1_BIO	Pearson Correlation	.185**	.134**	.458**	.182**	.156**	.520**	.120*	.122**	.427**	.168**	.176**	.479**	.114*	.157**	.391**	.113*	.144**	.493**	.200**	.512**	.149**	.153**	.492**
	Sig. (2-tailed)	.000	.004	.000	.000	.001	.000	.011	.010	.000	.000	.000	.000	.015	.001	.000	.017	.002	.000	.000	.000	.002	.001	.000
FA3_PHY	Pearson Correlation	.296**	.181**	.189**	.289**	.201**	.161**	.300**	.231**	.259**	.252**	.238**	.173**	.232**	.156**	.121*	.219**	.169**	.120*	.273**	.150**	.293**	.211**	.167**
	Sig. (2-tailed)	.000	.000	.000	.000	.000	.001	.000	.000	.000	.000	.000	.000	.000	.001	.010	.000	.000	.012	.000	.002	.000	.000	.000
FA3_CHM	Pearson Correlation	.244**	.332**	.193**	.229**	.386**	.226**	.198**	.295**	.209**	.247**	.358**	.220**	.154**	.297**	.160**	.153**	.301**	.165**	.434**	.205**	.291**	.404**	.245**
	Sig. (2-tailed)	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.001	.000	.001	.001	.000	.001	.000	.000	.000	.000	.000
FA3_BIO	Pearson Correlation	.176**	.175**	.422**	.146**	.218**	.434**	.184**	.229**	.461**	.154**	.246**	.418**	.119*	.177**	.326**	.054	.126**	.349**	.254**	.384**	.163**	.194**	.415**
	Sig. (2-tailed)	.000	.000	.000	.002	.000	.000	.000	.000	.000	.001	.000	.000	.012	.000	.000	.258	.008	.000	.000	.000	.001	.000	.000
FA4_PHY	Pearson Correlation	.232**	.138**	.075	.223**	.170**	.071	.287**	.220**	.156**	.248**	.206**	.112*	.242**	.141**	.072	.259**	.135**	.042	.207**	.111*	.309**	.213**	.150**
	Sig. (2-tailed)	.000	.002	.112	.000	.000	.136	.000	.000	.001	.000	.000	.019	.000	.002	.131	.000	.004	.380	.000	.020	.000	.000	.002
FA4_CHM	Pearson Correlation	.155**	.286**	.114*	.127**	.310**	.077	.203**	.337**	.120*	.186**	.310**	.110*	.151**	.281**	.069	.163**	.267**	.038	.374**	.143**	.202**	.370**	.160**
	Sig. (2-tailed)	.001	.000	.016	.006	.000	.105	.000	.000	.011	.000	.000	.021	.001	.000	.146	.000	.000	.426	.000	.003	.000	.000	.001
FA4_BIO	Pearson Correlation	.104*	.134**	.349**	.086	.126**	.365**	.178**	.185**	.400**	.093	.164**	.388**	.091	.099*	.308**	.084	.074	.354**	.191**	.414**	.124**	.156**	.433**
	Sig. (2-tailed)	.026	.004	.000	.071	.008	.000	.000	.000	.000	.052	.001	.000	.057	.039	.000	.078	.122	.000	.000	.000	.010	.001	.000
FA5_PHY	Pearson Correlation	.342**	.222**	.135**	.355**	.314**	.211**	.287**	.242**	.215**	.303**	.276**	.204**	.220**	.171**	.126**	.265**	.184**	.184**	.242**	.205**	.376**	.289**	.259**
	Sig. (2-tailed)	.000	.000	.004	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.008	.000	.000	.000	.000	.000	.000	.000	.000
FA5_CHM	Pearson Correlation	.252**	.306**	.104*	.242**	.362**	.184**	.211**	.274**	.126**	.261**	.336**	.160**	.155**	.245**	.095*	.212**	.299**	.174**	.379**	.239**	.325**	.404**	.230**
	Sig. (2-tailed)	.000	.000	.027	.000	.000	.000	.000	.000	.008	.000	.000	.001	.001	.000	.045	.000	.000	.000	.000	.000	.000	.000	.000

FA5_BIO	Pearson Correlation	.185**	.160**	.365**	.188**	.192**	.457**	.156**	.154**	.400**	.174**	.215**	.453**	.137**	.156**	.344**	.148**	.144**	.414**	.217**	.476**	.185**	.127**	.451**
	Sig. (2-tailed)	.000	.001	.000	.000	.000	.000	.001	.001	.000	.000	.000	.000	.004	.001	.000	.002	.003	.000	.000	.000	.000	.008	.000
FA7_PHY	Pearson Correlation	.262**	.164**	.146**	.331**	.268**	.211**	.267**	.206**	.196**	.318**	.247**	.245**	.310**	.138**	.201**	.266**	.196**	.184**	.188**	.184**	.319**	.207**	.190**
	Sig. (2-tailed)	.000	.000	.002	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.003	.000	.000	.000	.000	.000	.000	.000	.000	.000
FA7_CHM	Pearson Correlation	.218**	.273**	.092	.275**	.438**	.184**	.187**	.294**	.147**	.236**	.367**	.167**	.219**	.305**	.166**	.259**	.360**	.222**	.339**	.189**	.308**	.421**	.241**
	Sig. (2-tailed)	.000	.000	.052	.000	.000	.000	.000	.000	.002	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
FA7_BIO	Pearson Correlation	.128**	.096*	.333**	.141**	.140**	.444**	.148**	.149**	.413**	.179**	.194**	.457**	.187**	.146**	.425**	.162**	.162**	.473**	.197**	.488**	.169**	.109*	.500**
	Sig. (2-tailed)	.006	.041	.000	.003	.003	.000	.002	.002	.000	.000	.000	.000	.000	.002	.000	.001	.001	.000	.000	.000	.000	.023	.000
FA8_PHY	Pearson Correlation	.296**	.185**	.169**	.428**	.307**	.262**	.345**	.239**	.197**	.364**	.274**	.209**	.310**	.158**	.181**	.312**	.216**	.147**	.253**	.177**	.425**	.246**	.263**
	Sig. (2-tailed)	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.001	.000	.000	.000	.002	.000	.000	.000	.000	.000
FA8_CHM	Pearson Correlation	.228**	.285**	.172**	.319**	.411**	.251**	.223**	.295**	.160**	.263**	.352**	.190**	.180**	.278**	.172**	.241**	.307**	.146**	.388**	.227**	.331**	.424**	.289**
	Sig. (2-tailed)	.000	.000	.000	.000	.000	.000	.000	.000	.001	.000	.000	.000	.000	.000	.000	.000	.000	.002	.000	.000	.000	.000	.000
FA8_BIO	Pearson Correlation	.178**	.133**	.377**	.209**	.192**	.505**	.198**	.167**	.431**	.205**	.230**	.463**	.216**	.190**	.441**	.188**	.147**	.409**	.162**	.444**	.234**	.178**	.520**
	Sig. (2-tailed)	.000	.005	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.002	.000	.001	.000	.000	.000	.000
FA9_PHY	Pearson Correlation	.334**	.227**	.166**	.321**	.309**	.192**	.283**	.253**	.159**	.319**	.314**	.212**	.276**	.254**	.193**	.306**	.302**	.187**	.309**	.215**	.388**	.337**	.267**
	Sig. (2-tailed)	.000	.000	.000	.000	.000	.000	.000	.000	.001	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
FA9_CHM	Pearson Correlation	.239**	.302**	.159**	.237**	.397**	.243**	.171**	.258**	.149**	.220**	.321**	.165**	.179**	.368**	.202**	.211**	.336**	.187**	.372**	.185**	.306**	.420**	.266**
	Sig. (2-tailed)	.000	.000	.001	.000	.000	.000	.000	.000	.002	.000	.000	.001	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
FA9_BIO	Pearson Correlation	.188**	.187**	.396**	.187**	.228**	.484**	.164**	.192**	.419**	.164**	.240**	.460**	.176**	.189**	.421**	.129**	.187**	.417**	.248**	.480**	.223**	.205**	.511**
	Sig. (2-tailed)	.000	.000	.000	.000	.000	.000	.001	.000	.000	.001	.000	.000	.000	.000	.000	.008	.000	.000	.000	.000	.000	.000	.000
FA10_PHY	Pearson Correlation	.362**	.251**	.139**	.432**	.356**	.228**	.305**	.249**	.177**	.325**	.304**	.190**	.373**	.251**	.192**	.308**	.270**	.157**	.322**	.204**	.393**	.307**	.213**
	Sig. (2-tailed)	.000	.000	.004	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.001	.000	.000	.000	.000	.000
FA10_CHM	Pearson Correlation	.276**	.340**	.154**	.333**	.420**	.204**	.236**	.289**	.151**	.251**	.344**	.205**	.275**	.370**	.194**	.216**	.301**	.144**	.386**	.197**	.287**	.405**	.184**
	Sig. (2-tailed)	.000	.000	.001	.000	.000	.000	.000	.000	.002	.000	.000	.000	.000	.000	.000	.000	.000	.003	.000	.000	.000	.000	.000
FA10_BIO	Pearson Correlation	.187**	.177**	.404**	.220**	.234**	.521**	.153**	.172**	.450**	.149**	.219**	.480**	.229**	.202**	.439**	.139**	.166**	.416**	.259**	.498**	.142**	.159**	.467**
	Sig. (2-tailed)	.000	.000	.000	.000	.000	.000	.001	.000	.000	.002	.000	.000	.000	.000	.000	.004	.001	.000	.000	.000	.003	.001	.000

FA12_PHY	Pearson Correlation	.425**	.252**	.204**	.509**	.277**	.239**	.342**	.237**	.212**	.432**	.310**	.180**	.306**	.189**	.131**	.420**	.283**	.169**	.250**	.183**	.528**	.310**	.224**
	Sig. (2-tailed)	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.007	.000	.000	.000	.000	.000	.000	.000	.000
FA12_CHM	Pearson Correlation	.313**	.392**	.210**	.376**	.519**	.272**	.222**	.363**	.149**	.271**	.431**	.191**	.154**	.380**	.140**	.308**	.475**	.231**	.396**	.188**	.395**	.545**	.262**
	Sig. (2-tailed)	.000	.000	.000	.000	.000	.000	.000	.000	.002	.000	.000	.000	.001	.000	.004	.000	.000	.000	.000	.000	.000	.000	.000
FA12_BIO	Pearson Correlation	.190**	.152**	.514**	.237**	.177**	.626**	.153**	.184**	.508**	.167**	.204**	.528**	.113*	.149**	.436**	.161**	.171**	.515**	.179**	.573**	.215**	.165**	.577**
	Sig. (2-tailed)	.000	.001	.000	.000	.000	.000	.002	.000	.000	.001	.000	.000	.021	.002	.000	.001	.000	.000	.000	.000	.000	.001	.000
FA13_PHY	Pearson Correlation	.442**	.273**	.175**	.538**	.324**	.248**	.401**	.260**	.218**	.460**	.298**	.229**	.416**	.221**	.187**	.479**	.270**	.195**	.277**	.190**	.500**	.274**	.190**
	Sig. (2-tailed)	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
FA13_CHM	Pearson Correlation	.314**	.402**	.164**	.365**	.496**	.207**	.274**	.382**	.145**	.344**	.426**	.181**	.273**	.404**	.153**	.318**	.422**	.162**	.452**	.158**	.336**	.470**	.156**
	Sig. (2-tailed)	.000	.000	.001	.000	.000	.000	.000	.000	.003	.000	.000	.000	.000	.000	.002	.000	.000	.001	.000	.001	.000	.000	.001
FA13_BIO	Pearson Correlation	.230**	.181**	.454**	.273**	.208**	.589**	.253**	.246**	.509**	.225**	.221**	.529**	.241**	.188**	.496**	.183**	.133**	.470**	.244**	.574**	.212**	.177**	.511**
	Sig. (2-tailed)	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.007	.000	.000	.000	.000	.000	.000
FA17_PHY	Pearson Correlation	.371**	.224**	.142**	.467**	.297**	.167**	.312**	.208**	.175**	.325**	.243**	.136**	.357**	.163**	.151**	.315**	.213**	.136**	.227**	.151**	.417**	.257**	.161**
	Sig. (2-tailed)	.000	.000	.003	.000	.000	.001	.000	.000	.000	.000	.000	.005	.000	.001	.002	.000	.000	.005	.000	.002	.000	.000	.001
FA17_CHM	Pearson Correlation	.241**	.348**	.118*	.307**	.486**	.197**	.186**	.337**	.098*	.195**	.336**	.101*	.239**	.361**	.182**	.187**	.368**	.128**	.405**	.134**	.277**	.438**	.157**
	Sig. (2-tailed)	.000	.000	.015	.000	.000	.000	.000	.000	.046	.000	.000	.040	.000	.000	.000	.000	.000	.009	.000	.006	.000	.000	.001
FA17_BIO	Pearson Correlation	.199**	.163**	.441**	.239**	.212**	.587**	.176**	.174**	.507**	.189**	.212**	.508**	.210**	.189**	.475**	.159**	.150**	.469**	.233**	.544**	.208**	.158**	.533**
	Sig. (2-tailed)	.000	.001	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.001	.002	.000	.000	.000	.000	.001	.000
FA18_CHM	Pearson Correlation	.273**	.378**	.174**	.251**	.424**	.222**	.237**	.364**	.180**	.235**	.325**	.175**	.194**	.359**	.177**	.229**	.367**	.164**	.362**	.140**	.386**	.496**	.246**
	Sig. (2-tailed)	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.001	.000	.004	.000	.000	.000
FA18_BIO	Pearson Correlation	.165**	.155**	.472**	.199**	.166**	.590**	.172**	.178**	.493**	.222**	.228**	.548**	.175**	.191**	.463**	.177**	.177**	.516**	.191**	.543**	.209**	.177**	.570**
	Sig. (2-tailed)	.001	.001	.000	.000	.001	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
FA19_PHY	Pearson Correlation	.367**	.224**	.111*	.489**	.313**	.161**	.431**	.281**	.171**	.412**	.312**	.149**	.393**	.236**	.166**	.385**	.239**	.150**	.302**	.136**	.414**	.223**	.130**
	Sig. (2-tailed)	.000	.000	.022	.000	.000	.001	.000	.000	.000	.000	.000	.002	.000	.000	.001	.000	.000	.002	.000	.005	.000	.000	.008

Appendix 12: Pearson correlation between IBL and FA in Teachers' questionnaire

		IQ1	IQ4	IQ6	IQ7	IQ8	IQ9	IQ10
FA1	Pearson Correlation	.299*	0.123	0.171	0.26	0.209	.337*	0.247
	Sig. (2-tailed)	0.046	0.421	0.262	0.084	0.167	0.024	0.103
FA2	Pearson Correlation	0.232	.297*	0.265	.356*	.308*	.425**	0.232
	Sig. (2-tailed)	0.125	0.048	0.078	0.017	0.039	0.004	0.125
FA6	Pearson Correlation	0.187	0.024	0.203	.359*	0.191	.331*	0.246
	Sig. (2-tailed)	0.218	0.877	0.181	0.016	0.209	0.026	0.104
FA7	Pearson Correlation	0.251	0.122	0.176	0.242	0.259	.440**	.345*
	Sig. (2-tailed)	0.096	0.426	0.247	0.11	0.085	0.002	0.02
FA8	Pearson Correlation	0.166	0.029	0.07	0.273	0.288	.430**	0.293
	Sig. (2-tailed)	0.276	0.849	0.649	0.069	0.055	0.003	0.051
FA9	Pearson Correlation	-0.129	0.042	0.08	.381**	0.116	.337*	.304*
	Sig. (2-tailed)	0.399	0.782	0.6	0.01	0.45	0.023	0.043
FA10	Pearson Correlation	0.209	0.247	0.095	.492**	0.271	.516**	.412**
FA11	Pearson Correlation	0.063	0.236	0.121	.334*	0.166	.400**	0.265
	Sig. (2-tailed)	0.683	0.119	0.427	0.025	0.275	0.006	0.078
FA12	Pearson Correlation	0.057	0.032	.410**	0.276	-0.026	0.103	0.055
	Sig. (2-	0.708	0.836	0.005	0.066	0.865	0.5	0.721

	tailed)							
FA13	Pearson Correlation	0.12	0.038	.336*	.342*	.300*	.382**	0.192
	Sig. (2-tailed)	0.432	0.803	0.024	0.021	0.045	0.01	0.206
FA14	Pearson Correlation	-0.049	0.124	-0.009	0.18	0.274	.337*	0.201
	Sig. (2-tailed)	0.751	0.416	0.956	0.238	0.069	0.023	0.185
FA15	Pearson Correlation	-0.037	0.22	0.075	0.178	.310*	.302*	0.275
	Sig. (2-tailed)	0.81	0.147	0.624	0.243	0.038	0.044	0.067
FA16	Pearson Correlation	0.056	0.025	0.156	.311*	0.184	.314*	.322*
	Sig. (2-tailed)	0.716	0.872	0.305	0.037	0.226	0.036	0.031
FA17	Pearson Correlation	-.045	.115	-.064	.273	.217	.426**	.302*
	Sig. (2-tailed)	.769	.451	.678	.070	.153	.003	.044
FA18	Pearson Correlation	.149	.091	.161	.314*	.175	.387**	.316*
	Sig. (2-tailed)	.329	.551	.290	.035	.250	.009	.034
FA20	Pearson Correlation	.166	.126	.259	.268	.160	.300*	.263
	Sig. (2-tailed)	.276	.410	.086	.075	.295	.045	.081

Appendix 13: Sample worksheets form grade 10 physics class

20150601_102906-1.jpg 20150601_102940-1.jpg 20150601_102957-1.jpg 20150601_103014-1.jpg 20150601_103042-1.jpg

Review of motion graph.pdf

Appendix 14: Online website used to assess students' understanding through case studies

http://www.biology.arizona.edu/human_bio/activities/karyotyping/karyotyping.html