UNIVERSITI PUTRA MALAYSIA

EFFECTS OF STRUCTURED INQUIRY-BASED TEACHING ON THINKING SKILLS OF BIOLOGY STUDENTS

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By

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EFFECTS OF STRUCTURED INQUIRY-BASED TEACHING ON THINKING SKILLS OF BIOLOGY STUDENTS

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January 2018

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Inquiry-based teaching is said to have positive outcomes on students' performances especially for science students in the development of Science, Technology, Engineering and Mathematics (STEM). However, teachers seem to have some difficulties implementing inquiry teaching during class. These challenges include how to have effective discussions to promote inquiry teaching, how to implement an inquiry teaching and cover all the subject's content at the same time, how to manage an inquiry classroom effectively, and how to measure the effectiveness of the inquiry. Therefore, this study aims to suggest elements to better understand the effect of structured inquiry-based teaching on the thinking skills of biology students. These elements include the duration of teaching, planning and preparation, cooperative learning and hands-on practices. In addition, the present study investigated students' curiosity levels which act as an extraneous variable that needed to be controlled before the treatment begins. A quantitative quasi-experimental (pre-,post-test) was conducted in Kuala Lumpur, Malaysia for 8 weeks. Two intact classes were taken from Form 4 Biology students. The study was to compare structured inquiry-based teaching (S-IBT) and traditional teaching (Con-T) on the effectiveness of Biology students' thinking skills, knowledge retention and learning gain among the students. A total of 64 responses were analysed using the SPSS software. Univariate statistical analyses were employed to inspect and explain the data in this study. There were no significant differences between the two groups for their pre-test and also curiosity level. After the treatments, the post-test was administrated, followed by a knowledge retention test after 3 weeks. Learning gain ratio was measured by using pre-test and post-test thinking skills test scores. The findings showed that S-IBT students performed better than Con-T students in their post-test on thinking skills and knowledge retention. The effect size using eta squared shows a range from .18 to .74, indicating large effects. The medium amount of learning gain ratio leaves much room for improvement in future studies. Structured inquiry-based teaching can be seen as an effective teaching method in enhancing students' performances especially in thinking skills. Overall,

these four elements can be a guideline for whoever that wishes to apply structured inquiry-based teaching.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Doktor Falsafah

KEBERKESANAN PENGAJARAN BERASASKAN INKUIRI BERSTRUKTUR TERHADAP KEMAHIRAN BERFIKIR PELAJAR BIOLOGI

Oleh

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Pengajaran berasaskan inkuiri dikatakan memberi kesan yang positif terhadap prestasi pelajar terutamanya pelajar sains dalam pembangunan Sains, Teknologi, Kejuruteraan dan Matematik (STEM). Namun, guru sekolah seolah-olah menghadapi kesukaran dalam melaksanakan pengajaran inkuiri dalam kelas. Ini termasuk cara mempromosikan pengajaran inkuiri melalui perbincangan, cara melaksanakan pengajaran inkuiri di samping merangkumi semua kandungan subjek pada masa yang sama, cara menguruskan kelas inkuiri secara berkesan dan cara mengukur keberkesanan inkuiri. Oleh itu, kajian ini bertujuan mencadangkan unsur-unsur dalam pengajaran inkuiri berstruktur dan menilai tahap kemahiran berfikir pelajar Biologi. Unsur-unsur ini termasuk tempoh pengajaran, perancangan dan penyediaan, pembelajaran secara berkumpulan dan latihan amali. Di samping itu, kajian ini juga menyiasat tahap ingin tahu pelajar yang bertindak sebagai pemboleh ubah luar yang perlu dikawal sebelum rawatan bermula. Kajian kuasi-eksperimen (pra-ujian, pos-ujian) telah dijalankan di Kuala Lumpur, Malaysia selama 8 minggu. Dua buah kelas Tingkatan 4 Biologi telah dipilih untuk kajian ini. Kajian ini bertujuan membandingkan pengajaran inkuiri berstruktur (S-IBT) dan pengajaran tradisional (Con-T) dalam keberkesanan kemahiran berfikir, pengekalan pengetahuan dan peningkatan pembelajaran di kalangan pelajar. Seramai 64 respons dianalisis menggunakan perisian SPSS. Analisis statistik univariat dijalankan untuk memeriksa dan menjelaskan data kajian ini. Tiada perbezaan ketara antara kedua-dua kumpulan untuk pra-ujian dan tahap rasa ingin tahu. Selepas rawatan, pos-ujian telah dijalankan, diikuti dengan ujian pengekalan pengetahuan selepas 3 minggu. Nisbah peningkatan pembelajaran diukur dengan menggunakan skor ujian kemahiran berfikir pra-ujian dan pos-ujian. Keputusan menunjukkan bahawa pelajar S-IBT telah mencapai skor yang lebih baik bagi kemahiran berfikir dan pengekalan pengetahuan daripada pelajar Con-T dalam pos-ujian. Saiz kesan (besar) adalah di antara .18 hingga .74. Nisbah

peningkatan pembelajaran yang sederhana meninggalkan banyak ruang untuk penambahbaikan dalam kajian masa depan. Pengajaran inkuiri berstruktur boleh dilihat sebagai kaedah pengajaran yang berkesan dalam meningkatkan prestasi pelajar terutamanya dalam kemahiran berfikir. Secara keseluruhan, empat unsur boleh dijadikan pedoman untuk sesiapa yang ingin menerapkan pengajaran berdasarkan inkuiri berstruktur.

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I certify that a Thesis Examination Committee has met on 30 January 2018 to conduct the final examination of Lee Tze Jiun on her thesis entitled Effect Of Structured Inquiry-based Teaching On Biology Students' Thinking Skills in accordance with the Universities and University Colleges Act 1971 and the Constitution of the Universiti Putra Malaysia [P.U.(A) 106] 15 March 1998. The Committee recommends that the student be awarded the Doctor of Philosophy.

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CHAPTER 1

INTRODUCTION

Interest in applying inquiry-based teaching methods has increased in recent years as science educators or researchers became determined to enhance their students' learning outcomes (Ghumdia, 2016; Magee & Flessner, 2012). Researchers believe that inquiry-based teaching give the chance for students to master their science processing skills (Ural, 2016), have a better understanding of the scientific inquiry process (Kazempour & Amirshokoohi, 2014), achieve higher mean scores in their academic achievement (Nijoroge, Changeiywo, & Ndirangu, 2014) and gain other benefits. These positive outcomes are important as rapid technology change, extreme competition, and new market developments are expected, especially in Science, Technology, Engineering and Mathematics (STEM). The United States of America, one of the leading-edge countries with massive breakthroughs in technology also highlighted the urgent need for students to achieve work-based learning related to STEM. The chairman of the National Science Board (NSB) addressed the importance of STEM learning in the document *A National Action Plan for Addressing the Critical Needs of the U.S. Science, Technology, Engineering and Mathematics Education System.* All educational levels should cooperate together for STEM learning. A strong STEM 'skeletal system' is able to strengthen students' fundamental in STEM education and it should start from the lowest level to highest level of education (National Science Board, 2007). The NSB is also demanding for more STEM research-based input, bridging the knowledge gap between colleges and industries, the involvement of various sectors in STEM education, the upgrading of facilities and infrastructure for STEM learning, and the improvement of teachers' quality in teaching. Unfortunately, various countries (Australia, Africa, Japan and etc) reported that the number of students taking up STEM subjects has declined recently (Kennedy, Lyons, & Quinn, 2014; Mabula, 2012; Mohammad, Azzam, & Masri, 2012; Ogura, 2005). The STEM pipeline seems to have a hole that causes students drop out during their education. Malaysia is also facing an unavoidable situation where the percentage students who enrol in science stream has decreased to a low of 29% in 2012 compare a high of 37% in 1998 (Malaysia, 2012). Realizing the importance of producing STEM professionals in different areas reflected in a country's income per capital, the shift toward STEM with a focus on inquiry-based teaching is highly expressed among educators or researchers.

The definitions of inquiry has evolved and gained a wider perspective. Rutherfort (1964, p.80) commented that 'inquiry as content' or 'inquiry as pedagogic technique' emphasised more on scientific inquiry rather than inquiry in general. An inquisitive person should display an attitude of being interested in something; he is eager to know, question, and is able to look for the solutions at the end (Rutherfort, 1964). The statement was supported by Ramey, Tomlin, Basista, and Slattery (1998), where a person with scientific inquiry is able to develop a comprehensive conceptual understanding of basic scientific ideas and constructivism in handling science. A science student is said to be able to enhance their interpretation of science and perform science within the bounds of their proficiency (National Research Council, 1996). According to the National Research Council (1996, p.2) inquiry is 'central to science learning' and having merged scientific knowledge with argumentation and critical thinking skills, learners are said able to define a phenomenon, enquire, explain new meanings of knowledge, make arguments and share their thoughts or ideas with others. On top of that, they are able to identify their hypothesis, use higher order thinking skills (namely critical and logical thinking) and deal with different explanations (National Research Council, 1996).

On contrast, traditional teaching is more teacher-centered and likely to be adapted by teachers. This is because the method is a one-way transmission of knowledge, and teachers can easily control the whole lesson, allowing them to finish the lesson where it supposed to on that day. As a result, the teachers have to take the whole responsibility in students' learning outcomes instead of sharing it with his or her students (Pham Thi, 2010). Traditional teaching includes the rote memorization approach which lacks active participation from students and decreases students' creativity (Khalid & Azeem, 2012). The emphasis of traditional teaching is more on content knowledge and the replication of affirmed knowledge; it can be called a conformation approach (Letina, 2015). The same goes for science students where traditional teaching instructs them to take notes during lecture instead of generating new ideas (Candrasekaran, 2014). Kamei, Cook, Puthucheary, and Starmer, (2012) commented that traditional science teaching expects students to attend the class, listen and memorize the basics of science. The researchers further describe the students striving to excel in memorizing facts instead of expanding their skill in thinking, inquiry skills, solving problems, and cooperative learning. The content of a subject can be easily forgotten and knowledge can retention hardly be gained for long-term using the memorization approach (Khamees, 2016).

1.1 Inquiry-based teaching

Inquiry is further described by U.S the National Science Education Standards in their national inquiry-based teaching guide, alerting educators that 'inquiry is in part a state of mind – that of inquisitiveness' and that students should be able to grasp three types of scientific skills: a. problem solving b. communication and c. thinking (National Research Council, 2000, p.14). Furthermore, the National Research Council (2000, p.44-45) stressed five important components in inquiry-based teaching and learning that can be practised across different school levels, namely i) 'Learners are engaged by scientifically oriented questions' ii) 'Learners give priority to evidence, which allows them to develop and evaluate explanations that address scientifically oriented questions' iii) 'Learners formulate explanations from evidence to address scientifically oriented questions' iv) 'Learners evaluate their explanations in light of alternative explanations, particularly those reflecting scientific understanding', and v) 'Learners communicate and justify their proposed explanation'.

Basically, inquiry-based teaching can be categorized into several forms. It depends on how much the students rely on their teacher's guidance and how much the teacher provides guidance, instruction and structure to the students for them to inquire. There are four types of inquiry (Banchi & Bell, 2008): Confirmation inquiry, Structured inquiry, Guided inquiry and Open inquiry. In Confirmation inquiry, the teacher provides research problems, hypotheses, procedures and solutions. This means that students can foresee the result before the experiment begins. In Structured inquiry, research question and procedures are given by the teacher but students need to first generate the hypothesis, then find the solution and evidence for the problem and give explanation at the end. In Guided inquiry, the teacher provides only the research question and the students need to come up with their own procedures or methodology to answer their research question and explain data collected. In Open inquiry, students would have full authority in deciding a research question, designing the experiment, conducting hands-on investigations, and interpreting their outcomes. This level requires students to have higher level scientific reasoning and cognition.

1.1.1 Inquiry-based teaching in Malaysia

To develop students' creativity and sharpen their critical mind, teachers use various approaches and instructional strategies in teaching. The Ministry of Education Malaysia has recommended several approaches and strategies in the school curriculum in order to provide teachers with guidelines for effective instructional. It marked a shift from a teacher-centered pedagogy to a student-centered one which is aimed at promoting students' higher order thinking skills (HOTS) (Curriculum Development Centre Ministry of Education Malaysia, 2012), especially in science education. Despite of that, Malaysian science teachers are still struggling to instruct their students in order to enhance their higher order thinking skills in scientific understanding (Saat & Ismail, 2003; Yunus, Ismail, & Raper, 2004). Since the new curricula emphasises higher order thinking skills in science literacy, many of the teaching approaches were invented by researchers and instructors from all education levels. In the Ministry of Education Malaysia Curriculum Development Centre (2014a), there are five teaching and learning strategies (PdP, *Pengajaran dan Pembelajaran*) recommended in the planning and execution of the pedagogy of HOTS elements: 1) Constructivism, 2) Context-based learning, 3) Project-based learning, 4) Inquiry-based learning and 5) Future studies. Science is one of the STEM subjects that commonly uses constructivism and inquiry-based teaching to enhance students' science processing, manipulation, and critical thinking skills (National Research Council, 2000). Ever since then, Malaysian science teachers and researchers have tried their best to modifiy their teaching methods in the classroom to more practical, inquiry-based, and critical thinking approaches (Hiong & Osman, 2013; Lee & Kamarudin, 2014; Salih, 2010; Tan & Halili, 2015).

Generally, inquiry-based teaching has already been adapted and adopted by some science educators in Malaysia. The different level of inquiry-based teaching applied by the teachers are varied according to the subject content, number of students, available time, available apparatus or support from the school management (Shamsudin, Abdullah, & Yaamat, 2013; Sim & Arshar, 2010; Umar & Maswan, 2007). Sometimes, a teacher who decided to teach inquiry also take other factors into consideration such as the age of students, students' cognitive level, student's experiences, and the investigation matter or expected results (J. R. Wang, Wang, Tai, & Chen, 2010). In the Malaysian context, most of the time, science students are not given the freedom or chances to do what is not told by their teachers. Under the teacher's supervision, the students have to follow exactly the activities or procedures that are set by the teacher and the results should match as closely as possible to the teacher's marking schema (Bevins, Windale, Ong, & Bill, 2001; Pandian & Balraj, 2010). This type of teaching matched one of the inquiry types mentioned before which is the confirmation inquiry, where research problems, procedures and results are already prepared by the teacher and the outcomes can be foreseen by the teacher and the students. The reason the teachers apply Confirmation inquiry may be to save time as time given per lesson is constrained. Some teachers also try to avoid student injuries or material damages due to the school's budget (Abdullah, Mohamed, & Ismail, 2007; Ahmad, Osman, & Halim, 2010; Fadzil & Saat, 2014).

Besides that, the disappointing results shown by Malaysian students who participated in the Trends in Mathematics and Science Studies (TIMSS) and The Programme for International Student Assessment (PISA) in recent years (Malaysia Education Blueprint 2013 - 2025, 2012; Martin, Mullis, Foy, & Stanco, 2011), which revealed students lack of higher order thinking skills, becomes an agenda for the nation to be concerned about our educational system. Educators are urged to 'upgrade' their teaching approaches in order to produce better student outcomes for the future. In the meantime, the question of how to 'upgrade' to better teaching approaches and obtain higher order thinking from students by using inquiry-based teaching is still an issue for science teachers to proceed.

1.1.2 Structured inquiry

Recently, science educators are keen to switch Confirmation inquiry to Structured inquiry which is at a higher level. This is to ahcieve the end where a science student will have the skills to conduct and plan their experiment and find the answer to their research problem instead of relying on his or her teacher for learning (Kim, 2011; Sadeh & Zion, 2011). As mentioned above, Structured inquiry can be directed by both the teacher and the students; the teacher provides research questions and procedures while students generate the hypothesis, find the solution and evidence for the problem and give an explanation at the end. This is why science educators are predisposed to Structured inquiry, where students can now share the responsibility for their learning outcomes with the teachers instead of Confirmation inquiry (Furtak & Alonzo, 2009). According to Hughes (2014), biology graduate teaching assistants (GTAs) achieve better learning outcome when using structured inquiry teaching for their students' laboratory activities. The outcomes include improvement in the ability to teaching, higher level cognitive skills for science inquiry, and reflecting content effectively. Furthermore, with the improved ability to teach Structured inquiry, students taught by GTAs have the chance to ask more questions and find solutions among their peers instead of fully relying on the GTAs. This fulfills the basic requirement of inquiry teaching in science as it enables students to ask questions whenever they have doubts and to find solutions for research questions through cooperative learning (National Research Council, 2000). This is supported by K.

Salim & Tiawa (2015), saying that Structured inquiry can promote active learning among students, enable them to develop concepts of a subject, and enhance their problem solving skills. Based on the description above, the Structured inquiry model becomes a better teaching approach than confirmation inquiry and can be applied in this study in hopes of increasing students' learning outcomes.

In order to let biology students exhibit the skills (eg. laboratory skills, problem solving skills etc) mentioned above, laboratory hands-on investigation would be the key approach to deliver science constructivism to cultivate students with higher order thinking skills (Hafizan, Halim, & Meerah, 2012; Hiong & Osman, 2013; Pandian & Balraj, 2010; Sim & Arshar, 2010). Many researchers are in agreement that by conducting laboratory experiments, students would be able to develop higher order thinking skills thus giving them the chance to improve their laboratory skills (Dika & Sylejmani, 2012; Pich-Otero & Molina-Ortiz, 1998; K. R. Salim, Puteh, & Daud, 2012). But first, time is one of the major concerns that influences the use of a laboratory as well as the type of laboratory approach. Students spend their time in the laboratory as much as possible so that they can understand and apply their prior knowledge in connection with the real world by conducting experiments using laboratory skills they have learned (Basey, Sackett, & Robinson, 2008). The efficient use of time is important for students to learn and apply the content. Proper time allocation for different laboratory activities may help the students with deductive reasoning, better understanding of the nature of science, correcting misinterpretation, examining details, evaluating the results, and having time for reflection (Basey et al., 2008; Meyer, 2003). According to Meyer (2003), time becomes a precious resource which must be used effectively to achieve the targeted learning outcome for students and also for the individuals who control it. Secondly, time is very limited for conducting a class (about 35-50 minutes) and teachers will try their best to let the students gain as much knowledge as they can (Meyer, 2003; Toh, Ho, Chew, & Riley, 2004). Thirdly, the number of activities to the objective of learning is also dependent on the amount of time needed to complete a task from the beginning until the end for different subjects (Altun, Demirdağ, Feyzioğlu, Ateş, & Çobanoğlu, 2009; Meyer, 2003). Fourthly, different teaching approaches have different way to use time: direct transfer knowledge from one to another through lecturing or writing takes less time compared to the constructivist approach where learners need to construct knowledge by experiencing it (eg. hands-on) and then gaining the learning outcomes (Collins, 2008; Meyer, 2003). Even though the constructivist approach may a take longer time than the direct learning approach, it gives overall better results in education (Bimbola & Daniel, 2010; Khalid & Azeem, 2012).

Despite the time factor, a conducive laboratory environment should be set up in such a way that promotes students' active learning which will ultimately enhance their conceptual understanding. Hence well-planned laboratory activities with proper physical equipment and psychosocial factors (eg. student cohesiveness, integration, material environment) will influence students' thinking skills and communication skills (Osman, Ahmad, & Halim, 2011). Basically, a science laboratory is an environment or setting in which the students either work together in small groups or individually to investigate scientific phenomena. It involves a unique mode of instruction and learning environment where students interact with materials and instrumentation to observe and understand the natural world, thereby allowing them to learn science (Hofstein & Mamlok-Naaman, 2007; Hofstein, Nahum, & Shore, 2001). Students gain laboratory skills that cannot be learned on paper by conducting laboratory experiments (Salim et al., 2012). A well-set up laboratory should be able to enhance the effectiveness of a student's learning and at the same time allow the student to enjoy exploring scientific phenomena (Deacon & Hajek, 2010). According to Smith A. et al. (2005), cooperative learning can enhance critical thinking through face-to-face communication; students need to communicate with each other to explain orally and solve a problem, discuss the concepts of the topic being taught, transfer the knowledge among peers, fill the knowledge gaps, and give motivation to peers for their learning efforts. Nevertheless, science students also need to effectively communicate technical scientific facts with their peers (Walton & Baker, 2009). Explaining scientific phenomena from raw data, interpreting the finding (eg. graph or table) and sharing ideas among peers are important in stimulating the students' thinking from lower order to higher order (Mamlok-Naaman & Barnea, 2012). Reasoning skills can also be pushed to a higher level when students discuss their finding in a small group. The students have the chance to exchange ideas or explanations with their peers, to critique their peers' theories or their own regarding what they have observed during the experiments and last to verify their hypothesis (Murphy, Bianchi, McCullagh, & Kerr, 2013). Through group learning, students are able to fill in the knowledge gaps and help each other clarify their misconceptions (Felder & Brent, 2007).

1.1.3 Biology

What is science? Science is '*a methodical approach to studying the natural world. Science asks basic questions…Science is a determination of what is most likely to be correct at the current time with the evidence at our disposal*' (Christine, 2006, p.1). Science is an intellectual and practical activity which a country would likely invest on, in order to become a high income country due to high-technology R&D-based innovation (OECD, 2012). For that reason, science is been given a lot of attention in education due to its impact and applicable to everyday life.

Biology is one of the science subjects that requires a learner to form a relationship between biology itself and the natural world with the evidence they gather from their surroundings. It is an essential subject for various fields of learning such as medicine, agriculture, biotechnology, zoology and others. As a biologist of the 21st century, he or she is expected to be adept in a multitude of competencies to be on the forefront of innovative trends, '*The New Biologist is not a scientist who knows a little bit about all disciplines, but a scientist with deep knowledge in one discipline and a "working fluency" in several*' (National Research Council, 2009, p.20). The New Biologist makes science a multifaceted learning experience in STEM education. Finding the interconnection between the concepts of biology and skills to learn biology would always be the wishes for any biology students despite of just achieve a good result in their academic (Diki, 2013). Despite that, biology students should gain diverse knowledge and understanding at different levels that will enable them to apply knowledge during problem-solving, to make interpretations and find interconnectedness among multiple disciplines (Schonborn & Bogeholz, 2009). This means that Biology students should also be able to exhibit skills of the knowledge, comprehension, and application level in order to amplify their higher order thinking skills (Jensen, McDaniel, Woodard, & Kummer, 2014). By mastering these skills, students are expected to prepare themselves to apply the scientific skills and self-sustaining in the 21st century economy.

1.2 Thinking skills

There are many ways to teach thinking skills for different curricula. Students may be taught to compare two matters for the purpose of explanation or justification (Salih, 2010); they may be taught by letting learners leaners take part, and testing them with higher order questions (Barak & Dori, 2009); or they may be taught to co-teach where teachers and students get together and learn the subject together (Murphy et al., 2013). Generally, educators from different curricula acknowledge that it is possible to enhance learners' thinking skills through teaching practices (Akınoğlu & Karsantık, 2016; Bahr, 2010; Cotton, 1991).

One of the ways to develop the thinking skills of science students is through laboratory work as mentioned earlier (Fadzil & Saat, 2014; Özgelen, 2012). The need for a laboratory for science students becomes vital and it is a platform for the students to understand the concepts of science, gain scientific inquiry skills, and apply their scientific knowledge (Mamlok-Naaman & Barnea, 2012). Overall, a well-planned laboratory should allow the students to (National Council for Curriculum and Assessment, 2003; Reid & Shah, 2007):

a. justify theories and facts that have been taught

b. formulate hypotheses

c. learn problem-solving

d. apply their knowledge and skills in different scenario

e. design an experiment according to hypotheses

f. manipulate apparatus and materials for an experiment

g. carry out an experiment using laboratory skills

h. training observation and recording skills

i. report and interpret data obtained from experiment

j. interact and reflection their ideas with peers

k. experience science through actual experiments

l. undergo the critical thinking process through an experiment until an idea develops into long-term memory.

Therefore, it is very important that the activities provided to the students through laboratory practices are aligned with learning goals that enhance students' thinking skills. The quality (thinking skill) of students' learning can be measured through some assessment methods. The most popular method is Bloom's Taxonomy of Cognitive Domains (Krathwohl, 2002). According to Bloom's revised taxonomy (Krathwohl, 2002) of cognitive process dimensions, there are six different levels that categorize the types of thinking: remember, understand, apply, analyse, evaluate and create. In biology, Bloom's taxonomy has been used in testing the effect of introductory biology (Jensen et al., 2014), in achievement tests on cognitive levels, (Chen, 2014) and in design guidelines for question papers (Shahzad, Qadoos, Badshah, Muhammad, & Ramzan, 2011). The written test, such as structured or essay questions is one of the assessments commonly applied at most school levels. For Biology students in Malaysia, there are no exceptions. In Malaysia, students (Form Four and Five) who take the Biology subject will take the Biology Paper 3 examination. The Biology Paper 3 is to let the students demonstrate their knowledge and mastery of science process skills which include recording data, making observations, making inferences, controlling variables, writing hypotheses, plotting graphs, interpreting graphs, writing operation definitions, making predictions, analyzing data, comparing, and planning an experiment (Ministry of Education, 2015). These science process skills are the thinking skills utilized by the students to construct knowledge in order to master problem solving skills and provide significant results (Özgelen, 2012). Nevertheless, these thinking skills can be assessed following the six Bloom's cognitive process dimensions by setting a question according to the verbs provided under each dimension. For example, after a student collects data from an experiment, the teacher can generate a question to test his level of 'analysing' by asking a question using one of the Bloom's taxonomy verbs: *Explain the relationship between A and B that you have found during the experiment* (Krathwohl, 2002). Here, 'explain' is a verb that can allows the teacher to create a higher order question that requires making connections among concepts (Anderson & Krathwohl, 2002). Hence, one of the assessment tools in this study will be given to the students according to the Bloom's verbs.

1.2.1 Thinking and inquiry skills in Biology

Without doubt, the Malaysian education system is constantly trying to improve; not only does it envision the students equipping themselves with strong knowledge and skills – the 3 Rs (Reading, Writing and Arithmetic) in science, mathematics and language, it also intends to develop higher order thinking skills (HOTS) among students of all levels (as laid out in the Malaysia Education Blueprint 2013 - 2025, 2012). In fact, in the Malaysia Education Blueprint (2012), six elements were introduced by the Ministry of Education (MOE) to all the school leaders, teachers, parents, and members of the community to realise the National Education Philosophy's vision of ensuring our young generations are on the right track towards achieving aspirations which included thinking skills, knowledge, leadership skills, bilingual proficiency, ethics and spirituality and national identity. To this end, the MOE has planned to increase the percentage of HOTS questions in the Malaysian Certificate of Education or *Sijil Pelajaran Malaysia* (SPM) in stages as shown in Table 1.1 (Curriculum Development Centre Ministry of Education Malaysia, 2014b).

Table 1.1: Percentage of HOTS questions raised from 2013 until 2016 in SPM

	2013	2014	2015	2016
Implementation of HOTS questions in SPM	10%	20%	30%	50%

To increase the ratio of questions that focus on HOTS, the Ministry suggests the implementation of practical (*amali*) testing in the coming SPM national examination (Malaysia Education Blueprint 2013 - 2025 (Preschool to Post-Secondary Education), 2013). As such, all curriculum assessment framework will be upgraded and support will be given to schools or teachers still struggling to implement the HOTS instructional method (Curriculum Development Centre Ministry of Education Malaysia, 2012, 2014a, 2014c).

"*Just like any developing nation, Malaysia needs experts in the fields of Engineering, Science, Medicine and other Technological sectors. A drop in interest in Science subjects may stunt efforts to improve technological innovations to make Malaysia a high income nation*" (Malaysia Education Blueprint 2013 - 2025 (Preschool to Post-Secondary Education), 2013, p.4-7). This statement by the MOE in the Blueprint emphasises the need to intensify the transmission of Science, Technology, Engineering and Mathematics (STEM) across our education system. According to the MOE, science is one of the core subjects for lower secondary education (Form one to Form Three). After the completion of lower secondary education, students can enter the science stream with at least two pure science subject options for SPM (Biology, Chemistry or Physics) (Malaysia Education Blueprint 2013 - 2025, 2012).

Ideally, teachers can enhance the thinking skills of biology students through inquiry-based teaching. Inquiry-based teaching is one of the instructional approaches emphasizing higher order thinking skills (Gutierez, 2015; Thoron & Burleson, 2014). In biology, inquiry-based teaching means that teachers are able to let the students engage in science, feels free to ask questions, perform lab work and form groups for conducting activities (Thoron & Burleson, 2014). Others comment that inquiry-based teaching (in biology) also allow students to do conduct deeper investigation of a research problem, formulate new ideas, evaluate outcomes (Diki, 2013), interpret data collected from an experiment (Šorgo & Kocijančič, 2012) and have discussion among peers (Sadeh & Zion, 2012). The activities that posed through inquiry-based teaching as described above are said to enhance learners' thinking skills (Avsec & Kocijancic, 2014; Friedel et al., 2008; P William Hughes & Ellefson, 2013; Trna, Trnova, & Sibor, 2012). Thinking skills can be categorized into lower order and higher order thinking. Most researchers from different curricula are eagerly immersing students into higher order thinking through their interventions as well as teachers into their daily teaching (Mardigian, 2011; Ramos, Dolipas, & Villamor, 2013; Zohar, 2004). But according to Guo (2008), a student should not only be tested on higher order thinking. Guo argues that at different stages of education, assessments should reflect different objectives in sequential order (chronological). This means that students should also be tested with lower order thinking assessments, not solely tested on higher order thinking. The researcher advises educators to not take the risk of assessing students' higher order thinking without knowing well whether the students are equipped with basic knowledge of the subject. Therefore in conclusion, Guo advises educators to also take lower order thinking assessment into consideration and identify gaps in students' ability of basic knowledge before heading towards higher order thinking assessments.

1.3 Knowledge Retention

As mentioned above, a teacher should be able to let his or her science students construct knowledge after experiencing inquiry-based laboratory work (National Council for Curriculum and Assessment, 2003). It is also important that the student should be able to memorize whatever ideas or suggestions generated through inquiry and apply them in the future. It means that a student needs to construct his or her ideas into long-term memory, or known as knowledge retention (Matz, Rothman, Krajcik, & Holl, 2012; Reid & Shah, 2007).

The laboratory experience therefore can be seen as part of a route for students to learn science thus enabling the laboratory to be a part of their learning process and have better knowledge retention. In the inquiry-based teaching method, the teacher also should consider cooperative learning among students, which has been shown to enhance students' retention (Tran, 2014). Cooperative learning is the social interaction among groups of people and completing the same task together (Guvenc, 2010). In cooperative learning, students are able to interact face-to-face, maximize support, assist, and complement each other's hard work. When students get involved in supporting peers' learning, cognitive activities can occur including solving problems through verbal explanation, examining and talking about a concept being taught, transferring knowledge among one another and constructing new ideas from prior knowledge (Johnson & Johnson, 1994). These elements of cooperative learning aid in laboratory practices and may result in better retention of knowledge as members fill in each other's knowledge gap verbally or by observing their peers during practical work (Abdulwahed & Nagy K, 2009; Leary & Styer, 2010).

The verbal and observation actions mentioned above can be categorized under different learning styles. There are seven types of learning styles in educational: print, aural/audio, interactive, haptic, visual, kinaesthetic and olfactory (Davis, 2007; Institute for learning styles research, 2003). Basically, to know the learning style a person is good at, the person needs to restore memories of what he or she had performed when learning such actions or materials. For example, when asked if a person is better at hands-on or audio learning, the person shall recall the events when he or she had been assigned those types of activities and then memorize its execution (Kratzig & Arbuthnott, 2006). An individual should choose the optimal learning environment that enables them to use all the learning styles which can enhance one's long-term memory with various types of sensory stimuli (Abdulwahed & Nagy K, 2009; Gambari, Yaki, Gana, & Ughovwa, 2014). Thus, inquiry-based laboratory work is supplying the students with various sensory stimuli which, when supplemented with cooperative learning, is strongly believed to enable the students to construct their own ideas and retain them for longer periods (Castolo & Rebusquillo, 2007; Reid & Shah, 2007).

1.4 Gain Ratio

There are many factors that influence the efficiency of an instructional design. The efficiency of an instructional design can affect students' learning outcome to achieve the least waste of time and effort by the instructor (Khalid & Azeem, 2012; Kington, Regan, Sammons, & Day, 2012; Wang, Wang, Tai, & Chen, 2010). Inefficient instruction is unable to help students understand the subject engage with the subject as a whole. Students might show passive learning, be uninvolved in the activities prepared by the teacher, and lastly, be unable to develop concepts. Meanwhile, efficient instruction will give a meaningful and interesting lesson to the students. Students will actively involve themselves with high flexibility, and at the same time their needs are met responsive. Well-designed lessons will enhance students' understanding thus improving future achievement (Alias, Siraj, Azman, & Hussin, 2013; Johnson, Zhang, & Kahle, 2012; Kington et al., 2012). Yet, how does an educator measures the efficiency of his design? Arman & Shams (2009) suggested that, by comparing students' pre-test grade and post-test grades, the gain in grade can determine the efficiency of an instructional design. Gain in students' learning can be achieved individually or in a group as an outcome of an educational intervention. Due to the influences of many factors on the intervention such as confounding effects, testing effects or maturation, the group's performance would be taken into consideration in measuring the effectiveness of the intervention (Colt, Davoudi, Murgu, & Rohani, 2011). The students' learning gain can tell us that how much improvement has occured over the intervention of instruction. (Mcgowen & Davis, 2012).

1.5 Curiosity

In this study, curiosity acts as extraneous variable that needs to be controlled before the treatment begins. Nevertheless, curiosity has been reported to be one of the most important elements for science students in academic achievement. Curiosity is seen as a denominator that motivates students to seek more and more information about the modern world today; the greater the understanding of being connected to the world (with its different components) they live in, the higher their curiosity towards it (Binson, 2009). Jirout and Klahr (2012) argued that a person's curiosity about the world can be shown at a very early. Curiosity has been tied to a person's basic aptitude, an intrinsic system that facilitates them in acquiring something unfamiliar, reducing mortality rate, and finally high-tech upgrading (Arnone, Small, Chauncey, & McKenna, 2011). However, much research has pointed out that curiosity does not only occur naturally, leading to better learning or academic achievement, but can also be stimulated by various sources such as technology, curriculum, teaching instructional methods, classroom facilities etc. (Arangala, 2013; Arnone et al., 2011; Arnone, 2003; Gottlieb, Oudeyer, Lopes, & Baranes, 2013; Litman & Jimerson, 2004; Pica, 2005). Arangala (2013) reported that letting students to have hands-on activities (environment) encourages them to form related questions (hypothesizing). Further questioning fuels their curiosity even more so much so that it would motivate students to take ownership in accomplishing their project. Hence it is not surprising Kashdan and Yuen (2007) reported that students with high curiosity were able to perform better than less curious students both in the classroom and on national achievement tests when their school provided them with a challenging academic environment. Therefore, curiosity needs to be controlled in this study to allow the researcher to focus more on the effectiveness of inquiry teaching methods.

1.6 Statement of problem

One of the reasons students leave science is because of poor instruction. According to Ejiwale (2013), poor preparation of a teacher during class is critical and might lead to students' low academic achievement. The teacher's poor preparation might be because he or she cannot find an effective way to teach science, or the teacher might have had a bad experience during his or her school time as well (Kazempour, 2014). In Kazempour's (2014) study, one of his interviewees, a teacher (Lisa) who was a science student as well, recalled her science experience during elementary school. Lisa described her science class as disconnected, boring, repetitive, and lacking hands-on experiences, which made her struggle with science concepts and feel demotivated in learning science in the end. Lisa's demotivated feeling towards science continued during her middle high school, where her teacher more often used the lecture approach instead of laboratory practices to teach science. This frustrated Lisa as she cannot make any sense of her science learning and could not explain a phenomena scientifically.

Inquiry-based teaching is said to have positive outcomes on science students' performances. However, inquiry-based teaching seems like a very tough mission for teachers to implement during class. These challenges include having effective discussions to promote inquiry-based teaching, implementing inquiry-based teaching while covering all the subject content, managing an inquiry-based classroom effectively and measuring the effectiveness of the inquiry-based teaching (Quigley, Marshall, Deaton, Cook, & Padilla, 2011). Due to that, traditional teaching in delivering science concepts is still vital in enhancing students' higher order thinking skills in scientific understanding. This is because traditional teaching allows easier control of the flow of the content delivery, less discussions as to teachers provide students with ready-made answers, and easier classroom management and organisation because teachers control students' activities (Domin, 2007; Wang, 2007). Because of these, it is still hard to convince teachers to change from traditional teaching to inquiry-based teaching.

Weak achievement in Biology has been noticeably to science educators and researchers (Ali, Toriman, & Gasim, 2014). Various factors have been corresponded for this issue (Cimer, 2012). These include the teaching methods used in curriculum (Ghumdia, 2016), overcrowded classrooms (Juweto, 2015) and not adequate laboratory facilities for the students (Ali et al., 2014). In Malaysia, Examination Syndicate Ministry of Education Malaysia has revealed the shortfall in the effectiveness of delivery knowledge across different levels of biology, whether in horizontal or vertical directions (Ministry of Education, 2014, 2015). Horizontal transfer means a learner is able to apply his knowledge from one scenario to another at the equal level of any learning subject organization, while vertical transfer needed a learner to apply his knowledge to different levels of any learning subject (Schonborn & Bogeholz, 2009). Laboratory hands-on experimentation act as inquiry-based approach, would be one of the alternative to implement it. The teacher needs to carefully plan activities and materials to motivate the students to recontruct their science concepts through inquiry-based teaching. Unfortunately, some of the teachers still feel reluctant to apply the hands-on experimentation through inquiry-based teaching (Hafizan et al., 2012) even after the focus is shifted to enhancing students' HOTS by MOE. The hands-on activities are highly suitable for any type of classrooms application of constructivism as it can help the students to construct their own ideas and explanations, paving the way for students to conceptualise precisely the scientific knowledge in nature phenomena (Koch Janice, 2011; Zion & Mendelovici, 2012) while intensifying their higher order thinking skills.

Basically, a science (Biology) student should have the skills to conduct and plan their experiment to find the answer to their research questions. However, students still have difficulties in outlining concepts in biology as a result of not having appropriate teaching and learning approaches in biology (Bahar, Johnstone, & Hansell, 1999; Cimer, 2012; Diki, 2013; Šorgo & Kocijančič, 2012). Students use memorization technique to commit to memory the concepts of scientific knowledge to pass their assessment. In the end, students may only understand a certain part of science which is insufficient for them to apply in the real world. This may give rise to complications when they plan and execute an experiment that requires higher order thinking skills (Crowe, Dirks, & Wenderoth, 2008). Moreover, learning biology can be hard when misinterpretation sets in and when it is difficult to relate biology topics with the surrounding environment (Diki, 2013), such as the concepts of diffusion or osmosis and enzyme which are real-life phenomena (Ferreira, 2011; Ozarslan & Cetin, 2014; Sanger, Brecheisen, & Hynek, 2001).

Reports summarised by the Examination Syndicate Ministry of Education Malaysia showed that our students performed poorly especially in experiment planning, graph interpretation, operation defining and inference making which require HOTS in the SPM Biology examination, (Ministry of Education, 2014, 2015). As stated by the Curriculum Development Centre of MOE, the aims of the Biology curriculum for secondary school are to provide learners with the knowledge and skills in science and technology, problem solving and decision-making in routine activities. However, the latest comments by our Examination Syndicate regarding the Biology performances in the SPM (Malaysian Certificate of Education) examination indicated that students are still weak in planning an experiment in terms of listing the variables, lists of apparatus, procedures of experiments and, presenting the data (Ministry of Education, 2015, p26-33).

TIMSS 2011 (Martin, Mullis, Foy, & Stanco, 2011) showed the average achievement in the science content domains for eighth grade students according to different countries from 2007 to 2011. It further highlighted that Malaysian students have significantly lower achievement scores for Biology in 2011 than 2007. The low Biology scores were attributed to a decrease in performance in science cognitive domains between 2007 and 2011, which are known as knowledge recall, application of knowledge in solving problems and ability to reason in working through problems. This is why, as mentioned earlier by Guo (2008), students should not only be tested in higher order thinking, but also lower order thinking to give students a solid foundation in the basic of science before heading to a higher level of learning.

Ideally, science students should be able to perform high level acquisition of scientific skills and knowledge to produce active learners, according to Malaysia Integrated Curriculum for Secondary Schools (Biology) Form Four (Muhamad, Zaman, & Ahmad, 2010). Throughout the teaching-learning process, the inquiry approach, thinking skills and strategies, and thoughtful learning should be taken into the consideration in learning science (Abdullah et al., 2007) and the responsibility should not only be on teachers. Some teachers still using the traditional teaching method which can be attributed to time restriction and the pressure to yield great academic achievement, heading the teachers to adopt the less troublesome instructional method. Yet, an ‘exam-oriented’ curriculum which focuses more on answering module questions, and time presses to finish the syllabus are some of the reasons that hinder the teachers from thinking out of the box, thus choosing to ‘spoon-feed’ their students by letting the students directly transcribe lesson notes from the whiteboard and provide students with answers whenever they requested it without asking them to find the answers on their own (Pandian & Balraj, 2010). These instructional approaches tell us that our teachers are still not prepared or capable of incorporating thinking skills in their teaching strategies (Rahil, Akmaliah Lope Pihie, Habibah, & Konting, 2004), and this worries the MOE as they predict 60% of today’s teachers will still be teaching in 20 years’ time (Malaysia Education Blueprint 2013 - 2025, 2012).

Another problem that hindered teaches them using inquiry teaching for their students is due to the lack of apparatus and materials during laboratory practices (Šorgo & Kocijančič, 2012; Tatli & Ayas, 2013). Generally, due to school budget concern, teachers will ask the students to form a group which consists of 4-5 students. Each group is provided only one set of apparatus and materials. The intention of the teacher is to let the students experience cooperative learning and learn from each other. But in reality, only one student performs the experiment and the rest of the members will become observers or assistants, and no learning occurs (Berg, 2009; Kibirige & Hodi, 2013). Students need practices and guidance to perform effectively in groups that then increases their thinking skills.

Therefore, this study proposes that a teacher should accompany structured inquiry-based teaching (laboratory) with theoretical teaching in the biology classroom in order to bridge the knowledge gap between students’ theoretical knowledge and real-world problems. At the same time, the researcher proposes the ‘replication’ method during laboratory practices: each student in a group takes turn to do their (same) experiment, collecting data, and then sharing their data among members, even though they have only one set of apparatus and materials per group.

1.7 Objectives of the study

This study attempts to investigate the effectiveness of structured inquiry-based teaching (S-IBT) (treatment) as a means for developing higher order thinking skills in Biology compared to traditional teaching (Con-T). Thus, there are five specific objectives as follows:

1. To compare the results of students' mean scores of lower and higher-order test between structured inquiry-based teaching and traditional teaching methods.

2. To compare the results of knowledge retention between structured inquiry-based teaching and traditional teaching methods.

3. To compare the results of 'Construct Table & Graph' and 'Planning Experiment' which fall under the higher order thinking skills items, between structured inquiry-based teaching and traditional teaching methods.

4. To compare the effectiveness obtained from learning the biology subject through two different instructional tools (gain ratio).

5. To compare the curiosity level between structured inquiry-based teaching and traditional teaching methods.

1.8 Hypothesis

Ho1a: There is no significant difference between the pre-test and post-test mean scores thinking skills of the students in the S-IBT (experimental) group.

Ho1b: There is no significant difference between the pre-test and post-test mean scores thinking skills of the students in the Con-T (control) group.

Ho2: There is no significant difference between the post-test mean scores thinking skills of students in the S-IBT and Con-T groups.

Ho3a: There is no significant difference between the pre-test and post-test mean LOTS scores of the students in the S-IBT group.

Ho3b: There is no significant difference between the pre-test and post-test mean HOTS scores of the students in the S-IBT group.

Ho4a: There is no significant difference between the pre-test and post-test mean LOTS scores of the students in the Con-T group.

Ho4b: There is no significant difference between the pre-test and post-test mean HOTS scores of the students in the Con-T group.

Ho5a: There is no significant difference between LOTS post-test scores of students in S-IBT and Con-T groups.

Ho5b: There is no significant difference between HOTS post-test scores of students in S-IBT and Con-T groups.

Ho6: There is no significant difference between in the knowledge retention scores of students in the S-IBT and Con-T groups, after controlling for pretest mean scores.

Ho7a: There is no difference between the mean of total pre-test, post-test thinking's skills scores and knowledge retention test scores of students in the S-IBT.

Ho7b: There is no difference between the mean of total pre-test, post-test thinking's skills scores and knowledge retention test scores of students in the Con-T.

Ho8a: There is no significant difference between the mean of LOTS knowledge retention test scores of students in the S-IBT and Con-T.

Ho8b: There is no significant difference between the mean of HOTS knowledge retention test scores of students in the S-IBT and Con-T.

Ho9: There is no significant between interaction between the two types of instructional approaches and also across time (Post-test and Knowledge Retention test)

Ho10a: There is no significant difference between the post-test Construct Table & Graph item (HOTS) scores of students in the S-IBT and Con-T groups.

Ho10b: There is no significant difference between the knowledge retention test Construct Table & Graph item (HOTS) scores of students in the S-IBT and Con-T groups.

Ho11a: There is no significant difference between the post-test Planning-Experiment item (HOTS) scores of students in the S-IBT and Con-T groups.

Ho11b: There is no significant difference between the knowledge retention test Planning-Experiment item (HOTS) scores of students in the S-IBT and Con-T groups.

Ho12: There is no significant difference between the gain ratio for the biology two sub-chapters of students in the S-IBT and Con-T groups.

Ho13: There is no significant difference between the curiosity index of students in the S-IBT and Con-T groups.

1.9 Significance of the study

This study is important for researchers to explore how structured inquiry-based teaching (S-IBT) approaches affecting students' LOTS, HOTS, knowledge retention (retention test) and gain ratio when there is little research done based on inquiry and it is still relatively new and at the stage of infancy in Malaysia. In the end, researchers hope to gather in-depth knowledge and alternative approaches based on inquiry to help teachers recognize the important relationship between inquiry-based teaching as an instructional tool and the promising outcomes that can motivate students in learning science, especially in Biology.

By promoting teacher-centered learning to student-centered learning, it is hoped that students will progress from lower to higher order thinking skills in contemporary science education. An array of appropriate and effective teaching methods in inquiry-based teaching lesson plans, strategies, activities, and materials can be realised to enhance students' higher order thinking skills which can ultimately prove beneficial in helping them achieve better academic results. Effective instructional teaching is useful to avoid unnecessary waste of schools' human resources and reduce frustrations faced by teachers and students during lessons.

This study not only provides empirical evidence supporting inquiry-based curriculum reform to policy makers, but also provides them with the justifiable assurance upon successful application of these strategies. Thus this study strives to build confidence among teachers when preparing their curriculum and instruction using inquiry-based teaching. Hence students will be motivated with sustainable knowledge and skills in order to produce quality science graduates to meet 2020 human capital targets and help the country sustaining talent recruitment in the future.

1.10 Limitation of the study

This study is to test how effective a treatment (or an intervention) is on an outcome by controlling all other factors that might influence that outcome instead of generalising or drawing inferences to the population. This study is limited to national secondary schools or sekolah menengah kebangsaan (SMK) in Kuala Lumpur. The samples are selected from Form 4 students who have taken Biology as one of their science subjects, co-ed schools and Form 4 Biology instruction based on Secondary Curriculum or Kurikulum Bersepadu Sekolah Menengah (KBSM) are used for this study.

This study will be conducted using a quasi-experimental research approach with an intact group that the samples will be selected from to make an equivalent group. The instruments used included thinking skills test, pre-test, post-test, knowledge retention test, and gain ratio measurement.

The control group (Traditional Teaching) and the treatment groups (Structured-based inquiry-based teaching) went through the same Biology topics. These two groups came from different schools, so naturally their classes were conducted by different teachers from their own respective schools. Both teachers have over 10 years of teaching experience. Only two chapters from their syllabus are used, which were: A. Movement of substances across the plasma membrane and B. Chemical composition of the cell. The treatment group had to go through two experiments selected from each chapter for the treatment, making a total four of experiments as shown below:

A1-Movement of substances across a semi-permeable plasma membrane

A2- Concentration of an external solution which is isotonic to the cell sap of plant

B1- Effect of temperature on enzymatic reaction

B2- Effect of enzyme concentration of biochemical reaction

1.11 Definition of Conceptual terms

The following are conceptual definition of terms in this study:

Inquiry	A question which a person asks in order to get news or data**.** For science students, it refers to the involvement of students in scientifically oriented questions, collecting evidence, generating explanations from evidence, evaluating explanations and justifying explanations (Raychowdhury & Sterling, 2013).
Traditional teaching	Steps or protocols well-planned by a teacher that are often used in class to plan and control students' activities, assuming the students will attend, listen and memorize what is presented by the teacher (Kamei et al., 2012; Khalid & Azeem, 2012).
Laboratory	A place or room filled with benches, students' workstations, where students experience scientific experiments or science teaching (Singer & Hilton, 2006).
Higher order thinking skills (HOTS)	One of the thinking strategies that involves conceptualizing, making decisions, and problem solving. HOTS enable students to use their prior knowledge to solve routine problems and teachers are able to create an environment for students to use what they have learned to explore their understanding. HOTS are the skills, activities and questions developed from Bloom's Taxonomy (Danny & Weil, 2004). The higher the level (Bloom's), the more complex the functional cognition, and the more complex the questions; and creating, would be the most complex cognitive domain (Lord, French, & Crow, 2009).
Lower order thinking skills (LOTS)	Consists of questions focusing on the methods of recalling processes, structures, and settings (Freahat, 2014). Remembering, understanding and applying are the three level of LOTS in Bloom's Taxonomy (Anderson & Krathwohl, 2002). It applies to reviewing basic knowledge and skills, memorizing facts, and lower critical thinking (Edwards & Briers, 2000; Freahat, 2014).

Knowledge retention Can include knowledge evaluation, knowledge development and knowledge reposition (Wamundila & Ngulube, 2006). It can act as an indicator to predict how well a learner perform in the first place (Dominowski, 2012).

Gain ratio Enables a researcher to estimate whether a learner has the sufficient amount of learning through the treatment (McGuigan, 1971). Learners' prior knowledge and skills need to be taken into consideration in gain ratio to measure the real gain received due to an experimental treatment (Chopra, 2008). In other words, the effectiveness of a treatment also can be measured through the gain ratio. According to McGuigan & Peters (1965) gain ratio can be used to measure the student's overall learning, and the amount that a student could possibly learn from the treatment given to them.

1.12 Definition of Operational terms

The following are operational definition of terms in this study:

Inquiry Is a way of defining phenomena, enquiring, explaining constructivism, making arguments, and sharing their thoughts or ideas with others.

Structured inquiry based teaching Is an approach to teach biology where students need to do hands-on activities in a group at a laboratory. The teacher provides research problems and procedures but instruct the students to generate the hypothesis, execute the working plan of the experiment, gather data, analyze the data, make conclusions and discussion. Students do hands-on/ practical activities in groups with the time given in the laboratory before the subject concepts are taught in classroom.

Traditional teaching Is an approach to teach biology that is teacher centered. There is no laboratory class; lessons are fully based on theory and explanations from the teacher. There is no group activities. The teacher involved uses a projector and a laptop to teach the syllabus in a classroom.

Duration of teaching The control and treatment groups were exposed to 8 weeks of teaching; a 35 minutes duration represents a period, 4 periods per week were used to teach Biology.

Laboratory Is a place where students can find an answer to a scientific research problem by using apparatus and materials prepared at the lab. It allows students to do hands-on activities (wet or dry) with their teacher monitoring them at the lab. The students are allowed to talk or discuss with each other, or walk around to get the apparatus and materials.

Cooperative Learning This only applies to the treatment group at the laboratory. Students choose from their own classmates and form a group which consists of four persons sitting at the same laboratory bench. The group will have the same experiment to execute. They then collect the data and make a conclusion about the result. Even in group work, each member needs to execute the experiment once and

	collect data individually (rotate) with the help or guidance of other members. All members will need to share their data with their group members and generate the mean result for the experiment (replication). During the practical, members need to talk with each other, share their ideas, and critique the ideas or the way the members execute their experiment. Lastly, all members will have a discussion and conclude with a statement which is later shared with other classmates.
Practical/Hands-on	Each student needs to handle the apparatus and materials, execute the experiment (at least once) according to the procedures given by their teacher and collect the data from the experiment in a laboratory setting.
Lower Order Thinking Skill	Include the cognitive domains that categorized at the lower level of the Revised Bloom's Taxonomy: Remembering and Understanding.
Higher Order Thinking Skill	Include the cognitive domains that categorized at the upper level of the Revised Bloom's Taxonomy: Applying, Analysing, Evaluating and Creating.
Knowledge retention	Test scores taken from samples after three weeks upon finishing their post-test.
Gain Ratio	Is the ratio obtained by minusing the pre-test from the post-test, over the maximum score minus pre-test.
Secondary science students	In this study secondary students refers to the learner taking Biology in Form Four.

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