Implementation of Inquiry–Based Science Education: Issues, Exemplars and Recommendations

Mazura Khalik[1], Corrienna Abdul Talib[1#] & Intan Bidayu bte Mohd Rafi[2#]

[1]Faculty of Social Sciences and Humanities, Universiti Teknologi Malaysia, Johor, MALAYSIA.
[2]SMK Taman Universiti, Johor, MALAYSIA.

[#]corresponding authors <corrienna@utm.my> and <intanbidayu@gmail.com>

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Abstract

The introduction of Inquiry-based Science Education (IBSE) in education field was inspired by constructivist learning theory. Constructivism refers to the idea that learners construct knowledge and concepts for themselves. IBSE provides some of the criteria required by the 21st century learning including creativity, critical thinking, communication and collaboration. This study reports the output through systematic review on some of the implementations of IBSE approaches that were familiar and effective to be used in Science education such as 5E Model, 7E Model and Process–Oriented Guided Inquiry Learning (POGIL). Some of the advantages and disadvantages of these approaches were determined. It was proven that the effect of these approaches influences the students' achievement, attitude and self - confidence towards Science subject. Many problems encountered by the Science instructors were detailed out so that a variety of modification methods could be highlighted. A great number of teachers explained that they did not have a higher self–efficacy to carry out the task based on IBSE principles. This was due to insufficient time, resource materials and incompetent teaching skills. The ZYL Triangle Model was recommended to be applied by the Science educators. It was an effective pedagogy approach whereby its objective was to assist and guide teachers to conduct the classroom and laboratory session systematically.

Keywords: Constructivist; Inquiry-based Science Education (IBSE); 5E/7E model; Process–Oriented Guided Inquiry Learning (POGIL); ZYL model; Self–efficacy

Introduction

Background and Overview

Education is the process of facilitating learning or acquisition of knowledge, skills, beliefs and habits. It is a dynamic process and it changes with changing times. Teaching Science concerns getting students ready to cope and adapt not only changes but also challenges in their lives. Many researchers have observed the problem of students becoming uninterested in and demotivated to learn science at a young age (Swarat, Ortony, & Revelle, 2012). The teaching and learning approaches used and the quality of teaching is a major determinant of student engagement with and success in school subjects (Tyler & Osborne 2012). Nearly 60 % of European students stated that science teaching is not interesting enough and only 15% of them were satisfied with the quality of science teaching in schools (MEYSCR, 2010).

Inquiry is a process that required students to understand the nature and properties of science where this purpose can be achieved through scientific experiments. The objective of inquiry – based science teaching is to improve students 'understanding of concepts and procedures (Minner, Levy & Century, 2010). It is also important for the development of scientifically literate citizens (Goodrum & Rennie, 2007). The stages of inquiry include orientation phase, conceptualization phase, investigation phase, conclusion phase and lastly discussion phase (Pedaste et al., 2015).

At the beginning of the twenty-first century, many countries are struggling to improve the equity and quality of education by launching various educational reforms and practices. In order to ensure all the students' understand the nature of science and possess a higher ability to learn scientific concepts, an educational practice known as Inquiry – based Science Education (IBSE) has been introduced all over the world and is viewed as an effective approach for learning scientific concepts and understanding the nature of science (NOS) in which the process of inquiry is key (Martina et al., 2016). Decision making, critical thinking, tolerance, adaptability and autonomy are the importance of competencies which are enhanced through IBSE (Aksela, 2010).

Spencer and Walker (2011) stated that young students nowadays tend to be motivated to learn and curious to know towards the subject. The gap between how science subjects are taught and how they are perceived in society nowadays become increase rapidly (Cakmakci et al. 2011, Osbone 2007). It is necessary to implement an effective teaching/learning method which can reduce the gap between the understanding of nature based on the knowledge taught in school and extracurricular knowledge obtained from different information sources (Ault & Dodick, 2010; Bianchini, 2008). Therefore, teachers have big responsibilities to increase student's interest in Science education especially at an early age. For this reason, IBSE is becoming a popular choice as a suitable educational method for the development of motivation, knowledge and right skills for the students to enjoy learning the science subject.

Rationale and Objectives

The traditional and directed – teaching approach has long been criticized because it makes students feel bored towards presentation, too much writing, less practical activity and students act only as recipients of information. Wang and Wen (2010) stated that the direct teaching has a tendency to restrict the development of students' skill and abilities to make judgement. The traditional model of teaching has been based on textbooks reading and lectures. This method of teaching is a one way communication that have more teacher's talking and students just listening to the input. In this situation, students who succeed can memorize information and algorithm but fail to understand the relevant concept and not a good problem–solver. For this reason, IBSE has been introduced so that the learning session could be improved effectively and innovatively.

This study reports the output of analysis through systematic review on some of the implementation of IBSE approaches that were familiar and effective to be used in science education such as 5E Model, 7E Model and Process–Oriented Guided Inquiry Learning (POGIL). Some of the advantages and disadvantages of these approaches were identified with discussion on issues and illustrations on exemplars, subsequently recommendations for the future research.

Literature Review

Inquiry-based Learning: Concepts, Issues and Factors Influencing Inquiry Process

Studies had shown that the anxiety of the students towards Chemistry subjects are due to their negative perception of this subject, lower interest and attitudes, wide range of syllabus to be covered, lack of information and awareness about the future career, students' background, the abstract nature of the subjects, teacher–centered applications and lack of resources or teaching aids in laboratory and traditional lecture session (Jegede, 2007; Kolomuc, Ozmen, Metin & Acisli, 2012; Nbina & Vico, 2010). Referring to an analysis made by two international assessments (i.e. TIMSS and PISA), the low scientific literacy level among Malaysian students was revealed to be influenced by incompetency of science teaching from the educators. According to the analysis made by TIMSS on 2007 and 2011, most of the Malaysian students' skills in conducting an experiment while doing an investigation.

Researchers have suggested that students' learning should combined with an inquiry process similar to the way scientists work (Anderson, 2007; Lederman et al. 2014). The term "acting like a scientist" can be analogous to the procedural steps of "the scientific method" which required students to make observations, construct research questions and hypotheses, implement investigations, analyze data, develop conclusions and disseminate report findings with others. With regards to the integral part of acting like a scientist, Schwartz, Lederman and Lederman (2008) stated that extensive social interactions such as engaging in content specific discussions, defending arguments, reasoning for decision making, making research conclusions, as well as demonstrating perseverance are also included. Wong and Hodson (2008) determined that there are eight important factors which influence the inquiry process as outlined below:

(1) various methods of investigation;
(2) consideration of existing theories throughout inquiries;
(3) recognition of the tentativeness of theories;
(4) creativity;
(5) the importance of peer review;
(6) social, political and cultural influences;
(7) funding and ethical issues; and
(8) collaboration and competition with other researchers, including also social interaction.

According to Hazelkorn et al (2015), inquiry-based science education (IBSE) has impacted science curricula in a large number of European countries. This is because, most of the past research in more than a decade proved that students' motivation can be increased through by IBSE. For example, a study that was conducted by Berg, Bergendahl and Lundberg (2003) found that students who experienced IBSE opportunities lead to an increase in academic performance and motivation. A study by Gibson and Chase (2002) also proved that 77 % of students who had successful experiences with IBSE tend to show a positive interest in science subject. The pedagogy of IBSE allows pupils to develop their conceptual understanding of scientific phenomena (Minner et al., 2010). Thus, it can be seen that IBSE have positive impact on academic performance and motivation among students.

European Commission (EC) (2007) proposed the needs for teachers' professional development (TPD) to use variety of new teaching approaches which can stimulate students' interest towards science subjects. This new strategy focused more on student–centered education using inquiry and context – based approaches. According to Anderson (2007), inquiry–based learning helps the students to build their own knowledge through material that make up their world. The focus of inquiry –based activities mostly has been on laboratory works to strengthen learning of concept and contents (Hogstrom, Ottander & Benckert, 2006). This study was to detail out the limitation of implementing various method of inquiry – based learning in science subjects due to the insufficient time and incompetent of teaching skills by the chemistry instructor. A new approach of teaching skills will be recommended to enhance the inquiry – based learning process.

IBSE Levels in Science Education

IBSE is age - specific when it is being applied to science education. Young students in primary school are not able to conduct scientific research independently compared to secondary school and university students. Therefore, it is necessary for teachers to develop the students' skill gradually and systematically based on their abilities in IBSE. Students play an important role in inquiry-based science strategies that need to actively engage as to collect knowledge and develop their own skills. The most important factor in developing the understanding of the student is to make an observation and experience their own experiment. IBSE has been suggested to positively affect learning outcomes of students by means of enabling open inquiries (Liang & Richardson, 2009). In open IBSE, teachers encourage pupils to conduct a self-designed, interest-guided inquiry in order to answer their own research question (Martina et al., 2016). During this process, the important role of the teachers is directed towards facilitating, supporting and supervising their pupils (Zion et al., 2007).

According to Banchi and Bell (2008), there are four levels of inquiry which are confirmation, structured, guided and open inquiry. They also define that, these four IBSE levels depend on the degree of teacher's guidance. The following Table 1 shows the four levels of IBSE.

Table 1
Four IBSE Levels

IBSE Levels	Questions (defined by teacher)	Procedure (defined by teacher)	Solution (defined by teacher)
1) Confirmation	Yes	Yes	Yes
2) Structured	Yes	Yes	No
3) Guided	Yes	No	No
4) Open	No	No	No

Confirmation inquiry is necessary at the beginning of implementation where it involves the confirmation and verification of laws and theories. The aims of the teacher are to develop observational, experimental and analytical skills of the students. Student will follow the teacher's instruction when conducting the experiment.

For structured inquiry, teachers help students by asking questions and also provide the guidance. They control the lesson procedures which should be followed, questions to be asked and the making of the decision. The students are looking for solution using their inquiry and explain the answer based on the evidence obtained. The details of the experiment are prepared by teachers but they seek for the solution themselves. It is very important stage because it develops the potential of students to perform high–level of inquiry.

In the third level of inquiry, i.e. guided inquiry, teachers play less role to guide the students where they cooperate with students to define research questions and gives opinion on procedures to be implemented by the students themselves. This will increase the level of confidence of the students so that they can work independently to seek for the solutions. One of the study revealed that guided inquiry is more compatible with constructivist learning where it is believed to produce more effective learning output compared to other types of inquiry (Minner, et al., 2010).

During an open inquiry, a question to be asked, methods/procedures to be followed and decisions to be made are some of the processes that will be experienced by the students (Taraban et al., 2007). This highest level represents a real scientific research. A higher level of scientific thinking and higher cognitive are required in this level where only certain types of students can apply this stage. From the four levels of inquiry, it can be concluded that there was an increase in the level of student - generated inquiry and responsibility increase as students move along the continuum.

Methodology

This study aims at exploring issues related to Inquiry-Based Science Education (IBSE) with exemplars and recommendations based on the findings from systematic review on previous research conducted related to IBSE. Selection of suitable articles, documents, and journals were done through keyword searches across multiple databases of academic publications that provide information about IBSE in various peer-reviewed journal articles that were subscribed by the researcher's university.

Data Analysis and Discussions

This section discusses the findings through systematic review of literature related to the following features and important aspects of IBSE:

1. Inquiry-based learning is a possible solution to address various issues in education.
2. 5E Model, 7E Model and Process–Oriented Guided Inquiry Learning (POGIL) are approaches that were proven to have influenced students' achievement, attitude and self-confidence towards Science subject.
3. A great number of teachers explained that they did not have a higher self–efficacy to carry out the task based on IBSE principles due to insufficient time, resource materials and incompetent teaching skills. Hence the ZYL Triangle Model was recommended to be applied by the Science educators as it was an effective pedagogy approach whereby its objective was to assist and guide teachers to conduct the classroom and laboratory session systematically.

More elaborations will be made in the subsequent paragraphs.

Inquiry-based Learning as Possible Solutions to Address Various Issues

Inquiry-based learning is a possible solution to address the issue of students' low motivation for learning science subjects and is therefore included in several curriculum reforms in European countries (Kearney, 2016) as well as in Malaysian syllabus. The new Malaysian curriculum that have been used in 2017 which are Kurikulum Standard Sekolah Rendah (KSSR) and Kurikulum Standard Sekolah Menengah (KSSM) basically provided a reform and fresh syllabus that focus on inquiry learning which lead to higher order thinking skills. According to Capobianco and Feldman (2010), some examples of the changing landscape in science education are the role of scientific inquiry, scientific research practices and evidence–based claims in the science classroom. Inquiry– based science teaching method has three mediums namely inquiry, discovery and experiences. Inquiry involves testing and information searching which leads to discovery. After that, the discovery acts as a “tool” to gain knowledge, build a concepts and make a generalization. With the addition of experiences factor, the learning become easier to gather and collect the fact. Past research such as Lawson (1999) has showed that students who are actively engaged to construct their own knowledge lead to a positive academic achievement. According to Pedaste, Mäeots, Leijen, & Sarapuu (2012), inquiry also can be defined as a process of discovering new causal relations, with the learner formulating and testing hypotheses by conducting experiments and/or making observations. Through inquiry as a base of learning, there will be progressive development of students’ scientific and thinking skills such as logical thinking, rationale thinking, asking questions as well as problem-solving. Inquiry-based learning helps students to understand the concept of the nature of science, enhance the development of scientific skills as well as increase the students’ attitude and achievement towards science (Holloway, 2015).

The differences between traditional teaching method and inquiry–based teaching method as elaborated by Franklin (2002) (Cited in Nurshamshida Md Shamsudin, Nabilah & Nurlatifah, 2013) are shown in the following Table 2.

Table 2
Comparison between Inquiry–Based and Traditional Teaching Method

Characteristics	Inquiry-Based	Traditional
Principle learning theory	Constructivism	Behaviourism
Student participation	Active	Passive
Student involvement	Increased responsibilities	Decrease responsibilities
Outcomes		
Student role	Problem solver	Direction follower
Curriculum goals	Process oriented	Product oriented
Teachers role	Guide / facilitator	Director / transmitter

Implementation of IBSE and the Development of Models: Issues and Success Stories

Atkin and Karplus (1962) believed that textbook-based science teaching alone did not give students at any age the integration of conceptual understanding of the process skills that he called ‘scientific reasoning.’ Atkin and Karplus (1962) had introduced 3E Learning Cycle consists of exploration, concept invention and concept application stages. Many versions of learning cycles exist, ranging from 3E **(**Atkin & Karplus, 1967), 5E (Bybee, 1997) and 7E (Eisenkraft, 2003). 9E learning cycle is also proposed (Kaur & Gakhar, 2014). ‘E’ letters indicates the phases of learning process (Bybee et al., 2006). Each subsequent cycle of the model is an expansion starting from 3E Models.

I. 5E Model of Inquiry / 5E Learning Cycle

5E Model is one of many instructional approaches that supports the inquiry–based science learning which has five components (Bybee & Landes, 1990). The “Five Es” which is an instructional model for constructivism was developed by Roger Bybee, the innovators of Biological Science Curriculum Studies (BSCS). Students use their previous experience and the first–hand knowledge obtained from new explorations in trying to make sense of things (Newby, 2004). According to National Research Council (2000), the 5E Learning Cycle is not only an inquiry–based teaching approach but also constructivist–oriented strategy where the involvement of the students can be seen in experimenting, questioning and investigation of the problems. This model gives the student more opportunities to build their understanding of a concept during the teaching and learning process (Bybee, 2002). The phases involve in this learning cycle can be described as shown in the following Figure 1.

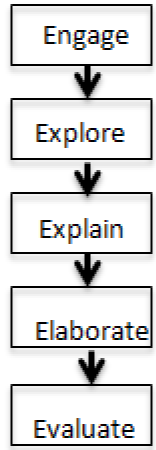

Figure 1. The 5E Learning Cycle Model.

In the engagement phase with 'inquiry minds', the attraction of students is initiated by the teachers to make them curious about the concept that will be learnt. Teachers have more opportunities to understand the knowledge and ideas possessed by the students that can be developed (Bybee, 2002). Teachers can invite students to construct their own questions about the process of scientific inquiry.

During the exploration phase involving 'working with questions', an interaction of the students with the materials and ideas through classroom as well as small group discussion is formed (Llewellyn, 2005). Students can construct their understanding by observing, recording, describing, comparing as well as sharing their experiences and ideas with others.

In the explanation phase involving 'conducting a scientific investigation', an opportunity is provided to the students to connect their previous experience with current learning. They can gain the main ideas of the module. The students can be involved in student – to – student discourse where they can explain their ideas before debating to others. Students' previous experience can be described easily by the introduction of formal language, terminology, scientific terms and content information.

The elaboration phase involving 'extension of conducting a scientific investigation', an opportunity is provided for the students to apply introduced concepts to new experiences (Llewellyn, 2005). It enhances the use of scientific terms and descriptions of the students. They can draw or make a conclusion from evidence and data obtained. Not only they can deepen their understandings of concepts and processes but also can interact with others by discussing their understanding of the problems. One example of the lesson plan is shown in Appendix A.

During the evaluation phase, the process of 'pulling it all together' is placed centrally in the model where it provides a summative assessment of what students know and can do (Bybee, 2002). Students can access their progress by comparing their current understanding with previous knowledge. Rubrics (quantified and prioritized outcome expectations) determined hand-in-hand with the lesson design, teacher observation structured by checklists, student interviews, portfolios designed with specific purposes, project and problem-based learning products, and embedded assessments are some of the tools that assist in diagnostic process.

Zaitoun and Zaitoun (2003) as well as Ahmed (2006) revealed that there are many advantages by using 5E Models. It considers an individual differences, motivates the students to use their mental process, show much attention to focus on the development of multiple thinking skills, discussion and collaborative learning, helps to build an accurate understanding, provides the students with various ways of evaluation, depends on the expansionist thinking as well as introduce progress in knowledge and science as a way of research where the student follows the learning from micro to macro, and based on an excitement to attract attention. Each phase of 5E Models has a certain function where it can help formulating a better understanding of scientific and technological knowledge, skills and attitudes of the learners, as well as to the teacher's coherent instruction (Bybee et al., 2006). By using the 5E Models, students could easily accessible to connect the new knowledge with the existing prior knowledge.

One of the study conducted to investigate the effects of 5E Model on undergraduate students' achievement and on their attitudes towards Chemistry subject found that, the achievement of the students is higher when implementing the 5E Model as compared with traditional lecture–based. This finding is consistent with the study conducted by Hwang, Wu, Zhuang and Huang (2013) where students who experienced this model were quite successful and had less cognitive load as compared to the students who experienced traditional teaching method. Koksal and Berberoglu (2014) found that there is an increase towards students' achievement and attitudes when implementing this model. The achievement of students in electrochemistry course using this model is higher than using the traditional method (Sen, 2015). It stated that attitude of the students can be developed in a positive ways through inquiry–based learning (Gibson & Chase, 2002; Koksal & Berberoglu, 2014). The learning motivation of the university students also increased when implementing 5E mobile inquiry learning approach (Cheng, Yang, Chang & Kuo, 2016). The improvement of primary school students' achievement and attitudes towards science course in terms of the subjects of reproduction, growth and living organics can be observed when implementing the inquiry–based (Celik & Cavas, 2012).

A study was conducted by Sen and Ozyalcin Oskay (2017) on 34 undergraduate students in Turki using 5E Learning Cycle to determine the effects of implementing this model towards chemical equilibrium concept. The respondents were divided into two groups; [18 respondents = experimental group (abbreviated as EG), 16 respondents = control group (abbreviated as CG)]. EG was exposed to 5E learning methods and CG remained in a traditional teaching method for almost 5 weeks' learning session. It was found that the achievement of the EG towards chemical equilibrium concept was higher than CG. This finding gained through this experiment was parallel to the previous study carried out by past researcher (Çelik & Çavaş, 2012; Nwagbo, 2006). The result that there was no significant difference on cognitive and affective attitudes towards science was contrast with findings obtained in previous studies in the literature.

The effectiveness of instruction based on 5E Learning Cycle Model towards the Biology subject was revealed by many researchers where students gain better understanding about the concepts (Balci, 2005; Garcia, 2005). Lee (2003) stated that students could understand about plant in daily life better when taught by using this model. However there are no differences in academic performances found when students were taught using this model (Poderoso, 2013; Greenmiller, 2014). There is also no significant difference on achievement and attitudes of the students (Gonen, Kocakaya & Inan, 2006; Koseoglu & Tumay, 2010; Nuhoglu & Yalcin, 2006).

Some teachers said that 5E Model does not have any negative effects but they encounter many problems when implementing this model in a classroom due to insufficient learning material and equipment. All these materials are necessary for application of 5E Model where it could not be conducted effectively due to the lack of these materials. Insufficient time for teaching sessions also become part of the constraints. Teachers claimed that the application of this model was quite tiring. Balci (2005) suggested that to ensure the successful implementation of this 5E Model, the teachers should know how to construct and manage the classroom activities.

II. 7E Learning Cycle

7E Learning Cycle is an extension of 5E Model where its objective is to ensure teachers do not leave out any important instructional components. Eisenkraft (2003) proposed elicit, engage, explore, explain, elaborate, evaluate, and extend that makes up the 7E components. The main aim of this model is to highlight the importance of previous understandings and transfer it into a new concept. Ozemen (2004) emphasizes that the 7E Model was considered to be effective and could encourage students to participate in learning session actively, assist them to conduct research properly, encourage the exchange of ideas or communications and also enhance the problem–solving skills. This model also able to give an opportunity for teachers to easily evaluate their students. The 7E Model (Figure 2) allows the use of technology and become easier for educators to implement this model in school (Ozemen, 2004). In 7E Model, the 'engage' phase in 5E Model is extended into 'elicit' and 'engage' phase.

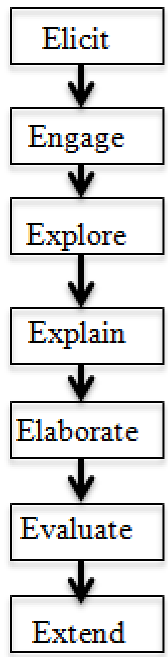

Figure 2. Eisenkraft's 7E Instructional Model.

Each explanation of every phase in 7E Model are described below (Kanli, 2009):

a) Engage phase - is a stage where motivation and interest of the students being developed. This helps the students to focus on a problem and current situation properly.

b) Explore – this phase required some skills of scientific research where students are given time to conduct experiment and opportunity for skills development.

c) Explain – students needed to collaborate with others for acceptance or rejection of hypothesis they suggested. To consider whether the models should be accepted or not, teachers need to provide specific explanation for the students to understand.

d) Elaborate – students need to conduct an experiment to test their new concept. Therefore students can develop their knowledge and skills of the concept before application takes place.

e) Extend – this stage needs the students to relate the existing concepts with real life so that they can transfer their knowledge and skills obtained confidently.

f) Exchange – the presentation of data and graph are necessary for the students so that they can form a discussion group to share their new findings.

g) Evaluate – students try to find answers from the data and evidence they obtained. The evaluation by the teachers takes place formally and it is very important to give feedback to the students' performance.

According to the result of study conducted by Francis Adewunmi Adesoji and Mabel Ihuoma Idika (2015), 7E Learning Cycle and case based-learning strategies have an effective effect towards achievement and attitude of senior secondary schools' students towards Chemistry subject as compared to the traditional teaching method. Student who learned with 7E Learning Cycle obtained a higher grade on Acid–Base course due to the existence of each phase of 7E that required the students to check their own knowledge that can be used in further study (Eisenkraft, 2003). An instructional material for chemistry, physics as well as biology topics based on 7E Model was developed by Cepni, San, Gökdere and Küçük (2001) and the results revealed that students were able to learn through this model. But teachers stated that too much time is required to use such materials and schools encounter an insufficient of necessary physical condition.

On the other hand, some of challenges to implement this model is the competency of the teachers to conduct this model which has different approaches compared to direct instruction (Krajcik, et al., 1998). Past researches also had showed that teachers experienced difficulties in developing learning activities based on 7E Model including how to relate the materials into real life. At stage one of 7E Model (elicit), teachers required much time thinking about the concept, finding an idea to relate this concept into real life as well as making relation and connection with new circumstances. Another obstacles encountered by the group of chemistry teachers in this study were they did not understand constructivist learning clearly, lack of skills to help learners to discover the concepts, difficult to conduct experiment for classroom practice especially for organic chemistry subject which originally has been taught without having lab experiments, teachers' limited experience to apply 7E Model and time allocation issues.

III. Process Oriented Guided Inquiry Learning (POGIL)

Process –Oriented Guided–Inquiry Learning (POGIL) is one of inquiry–oriented approach which is promising and is better approach for university–level Chemistry courses. POGIL is an educational philosophy and one of a classroom technique. A teaching strategy and a philosophy of learning are part of elements of POGIL which aim to change from a 'model of transmitting knowledge from teacher to student' to 'a developmental model of student-centered instruction' (Geiger, 2010). The National Science Foundation (NSF) awarded large Systematic Change Initiative grants for the reform of Chemistry Education in 1994 and 1995. The initiatives are Peer Led Team Learning (PLTL, 2007), Molecular Science, which includes Calibrated Peer Review (CPR, 2001), ChemConnections Project (2004), and Process Oriented Guided Inquiry Learning (POGIL). Through this grant, there was greater success of the students in Chemistry course as a result of the understanding on how people learn has been recognized.

As an instructional model, POGIL has been introduced to fulfill the goal of improving student learning. POGIL is based on constructivist theory of learning in which the students work in a small group and they are fully engaged in the learning session. The guided inquiry used becomes the basis of designed materials which purpose is to guide the students to develop new knowledge (Farrell, Moog & Spencer, 1999). The unique process of POGIL compared to Problem–Based Learning and Peer–Led Team Learning are the use of the learning cycle to promote inquiry and also focus more on students' process skills to be developed through the use of defined team roles (Eberlein, et al., 2008).

Major principles of POGIL are students actively engaged in learning session, thinking, analysing data, drawing conclusions, and constructing their own knowledge rather than depend on the teachers information, and interacting with peers by discussing their ideas together (Piaget, 1985). There are three stages learning cycle of POGIL which are exploration, concept invention, and application. These three stages were developed by Karplus in 1960s. This teaching method was developed for elementary school sciences (Karplus, 1977).

According to Bobrowski (2007) through the 'teacher–centered' mode, an introductory courses objectives remain at Level 1 of Bloom's Taxonomy, the knowledge level achieved by memorization with limited comprehension. The result is the students cannot explain the concept correctly although they can be able solve the problems algorithmically (Pickering, 1990). On the other hands, the study indicates that POGIL project has improved collaborative learning environments for Chemistry courses. A small group learning activities is one of POGIL instructional material which is suitable from introductory Chemistry to upper Chemistry such as Physical Chemistry (Moog, 2006 & Spencer et al., 2003). It provides instructor support and develops instructional materials since 2003 (Moog, 2006; Process Oriented Guided Inquiry Learning, 2012; Spencer et al., 2003). Several challenges are faced by the students in Biochemistry where it is built on fundamental of Biology and Chemistry subject. To solve unfamiliar problems in Biochemistry subject, higher cognitive skills are required where it can be developed by implementing POGIL (Zoller, 1993; Nygren in Beyerlein & Apple, 2005). The implementation of POGIL in Organic Chemistry at seven institutions indicates that the percentages of the examination score of the student in POGIL section are higher than the students in traditional lecture section (Lewis & Lewis, 2005; Perry & Wight, 2008). There is also a positive achievement in cognitive and affective skills when lecture session was replaced into small group active learning approach (Baepler, Walker & Driessen, 2014). The students show a better attitude and self–efficacy during the first time implementation of POGIL in general and organic chemistry courses (Chase, Pakhira, & Stains, 2013).

A study was conducted by Marazban Kotwal and Abilasha Jain (2015) on a group of 51 students of T.Y.B.Sc., majoring in Chemistry at St. Xavier's College in a course of on Spectroscopy (a subdiscipline of Physical Chemistry) defined that POGIL activities need more coordination and coordinating approach compared to traditional methods. About 59 % of these respondents strongly agreed and 26 % of them agreed that POGIL activities boost their level of self–confidence towards independent learning and found that peer–learning or cooperative learning which is an integrated part of POGIL are advantageous. About 89 % of the students strongly agreed and agreed that there is an improvement towards science concepts while 11 % of the students neither agreed nor disagreed about this opinion. An improvement of student retention and performance was shown by 80 % of the students which were strongly agreed and agreed while the remaining 20 % neither agreed nor disagreed giving an indifferent opinion. This result also revealed that there is an increase in level of challenge level with time in tandem with the students' adaptation to the POGIL methodology. There is a clear indication that POGIL has an ability to transform Chemistry education where the students' understanding is deepened the responsibility of the students for learning is enhanced.

According to Sander and Sanders (2005), academic confidence is part of the concept of self–efficacy. POGIL has shown its advantage to improve students' confidence (Straumanis, 2010). POGIL can increase the students' confidence to study organic chemistry. Academic confidence influences the studying, understanding, verbalizing, clarifying and attendance process (Sanders & Sanders, 2005). POGIL can promote self–efficacy when students are involved in concept of invention. Through this, they can discuss about their performances in task together with self–efficacy while pursuing their academic goals.

The expansion and flexibility of POGIL make it differ from other inquiry–learning models. At its first objective, POGIL was originally designed for general and organic Chemistry. Then, its use was expanded into physical, analytical and biochemistry. Recently this approach was implemented in biology, inorganic chemistry and in graduate level instruction. POGIL not only can be carried out at university level but also at high school for chemistry subject (Trout, Padwa, & Hanson (2008). POGIL can be adopted at any institution. It can be conducted based on the instructor's personality and style of teaching. POGIL was originally implemented at small classroom but nowadays it can also be suited and modified for a large classroom (Yezierski, et al., 2008). The use of technology such as tablet P-Cs (Mewhinney & Zuckerman, 2008), computer–based assignments (Hanson & Apple, 2004) and classroom personal response clickers (Ruder & Hunnicutt, 2008) can be applied together in POGIL classroom. There is also a shift from 'technique introduction' and 'concept verification' to 'concept development' and scientific processes in POGIL laboratories activities (Creegan, 2003; Kerner & Lamba, 2008). POGIL also can be combined with other student–centered approaches such as problem–based learning (PBL) (Lees, 2008) and peer–led learning (Lewis & Lewis, 2005).

As a new approach to chemistry education, some teachers claimed that they are not familiar with the POGIL's technique. The level of challenges using the Accelerator Model shows that students were also not happy due to insufficient of their cognitive and affective skills to maintain an effective learning (Morgan & Apple, 2007). To increase an effectiveness of POGIL approach, the size of the group should be limited only to three or four members including of higher and lower performances of the students, different races and gender (Shatila, 2007). The differences of the gender should be considered during the selection (Hanson, 2006). Therefore, the larger number of groups will increase a greater intervention of teachers.

IV. ZYL Triangle Model

Most of the study strongly recommended that IBSE is one of effective way to implement at various level of education. Learning at the 21st centuries should focus more on the activity of the students rather than the presentation of the instructor. To enhance and develop the teachers' competency in teaching session, the ZYL Triangle would provide lots of benefits to the teacher when conducting their science classroom or lab session. This model can be implemented together with another inquiry–learning approaches. ZYL Model is one of pedagogical approach which describes each phase for experiment, demonstration and simulation purposes (Nurshamshida Md Shamsudin et al., 2013). It starts by reading the number sequences exits at the edge of the triangle (Figure 3). Below is the detail about the ZYL Model:

a) Figure 3 shows ZYL Triangle Model on Experiment Pedagogy that is suggested to be implemented before and during the experiment where it starts with explanation of the steps, introduction by teachers on safety rules, discussion with the students about misconception and explanation on the steps before conducting an experiment to ensure the experiment can be performed systematically as well as finally discussion and finding steps together with the students. By using this pedagogical approach, it helps the teachers to minimize mistakes and also time consuming if they combine inquiry–learning along with this mode.

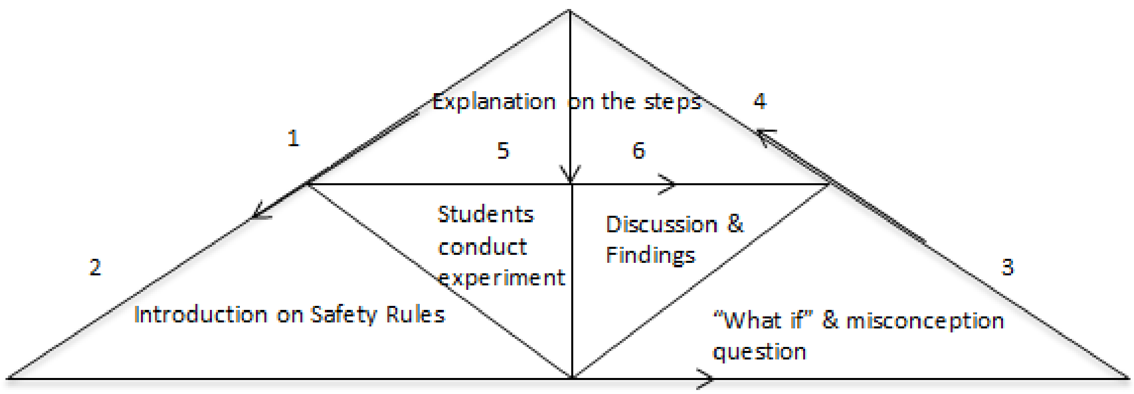

Figure 3. ZYL Triangle Model on experiment pedagogy.

b) Figure 4 describes about the ZYL Triangle Model on Demonstration Pedagogy Development which begins by preparing materials, contents or aids that will be used in demonstration process in the classroom. The focus point will be highlighted by the teachers so that student will know what is going to be focused. Their knowledge and curiosity about the subject will be developed later. Then teacher will respond about the students' misconception before the actual demonstration of the students starts. The discussion on the lesson which focus on the contents of the topic will start so that teachers can evaluate about their understandings and can make a suitable conclusion to foster the learning session.

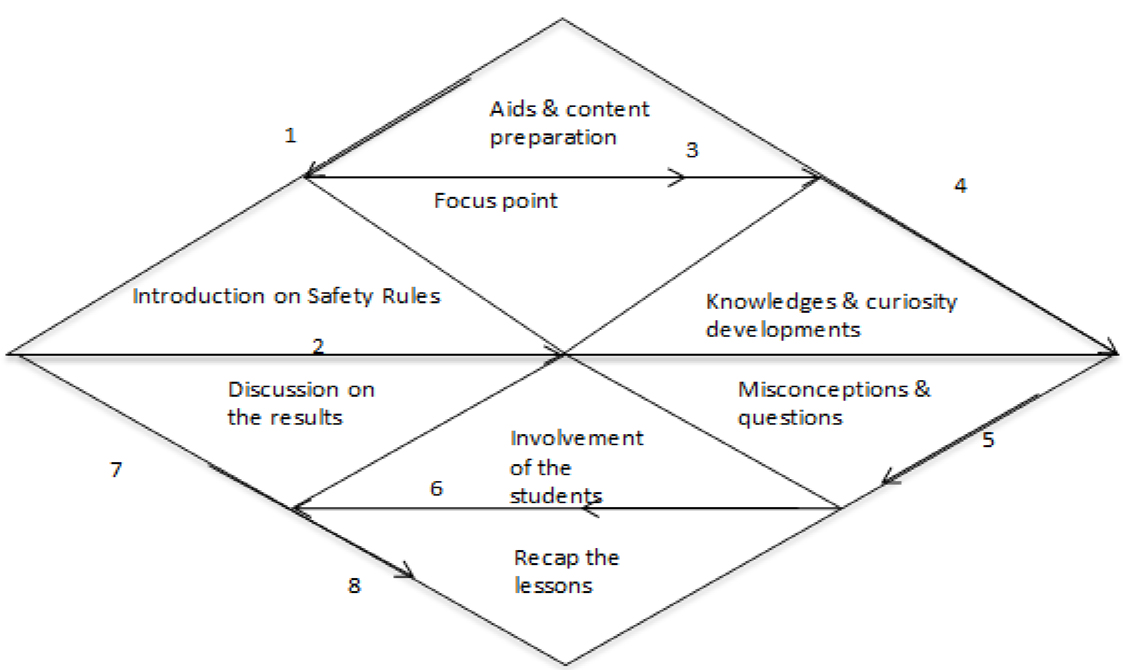

Figure 4. ZYL Triangle Model on demonstration pedagogy development.

c) Figure 5 details out the ZYL Triangle Model on Simulation Pedagogy Development where it required the creativity of teachers to prepare video, model or diagram to stimulate the response of the students. The simulation process will start by explanation of the concept or process where its aim is to construct the knowledge and curiosity of the students. The discussion of misconception will be held and the teachers are encouraged to initiate the questions to determine the students' understanding. The last step is to analyze the experience gained through this simulation.

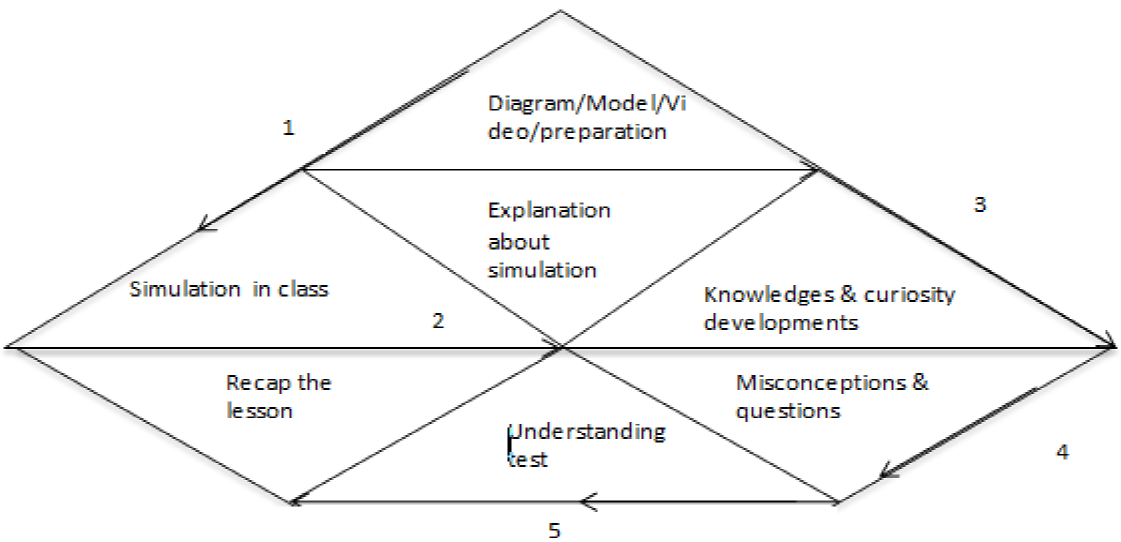

Figure 5. ZYL Triangle Model on simulation pedagogy development.

Due to the insufficient time and incompetency to conduct IBSE approaches faced by the teachers, this new pedagogical model is strongly suggested to be implemented together with another inquiry learning approaches because it provides better guideline for the teachers to conduct the classroom and laboratory. A few programs explaining and demonstrating the application of ZYL Model should be organized to assist the teaching skills among the chemistry instructors. ZYL Model when combining with another inquiry learning approaches should be slightly different among primary, secondary and higher level of education.

Conclusion

The results of this systematic review show that IBSE is one of an inspiring instructional approach to foster the science education in every level of education. Therefore, it is essential for teachers to enhance their teaching skills so that the learning sessions can be conducted in a systematic process. Teachers should notice about the presence and use of specific domains of knowledge which are the conceptual domain, epistemic domain, social domain and procedural domain. The difference of the specific domain in each stage of learning cycle should be addressed by the teachers. This is not only to develop an excellent academic science-based knowledge of the students but also the capability to conduct an experiment scientifically and to build their interest towards science subject.

Teachers need to transform their attitudes and competency teaching skills towards IBSE by applying the inquiry–learning cycles with another relevant method such as ZYL Model or PBL method. The inquiry learning cycles (5E and 7E Learning Cycles) are age–specific approaches. It can be applied at each level of education by modifying certain elements present in every stage. For primary school students, the teachers need to make their presentation in every step with interesting and exciting introduction which can attract the children's attention about the subject. It is very important for young children undergo an enjoyable Science lesson so that they can understand the concept of the subject and relate their understanding with the surroundings.

In many studies conducted, it was shown that IBSE has a potential to transform a formal Science lesson to an enjoyable Science lesson for the primary school level students who can be exposed to simple inquiry and fun hands–on activities. The curricula in school need to be redesigned so that IBSE can be conducted efficiently. The school administration should pay attention on insufficient time and resource materials that are parts of IBSE constraints. It is believed that IBSE can enhance academic performance, attitudes, cognitive and affective domains of the students. By implementing IBSE in science education, it is believed that there will be a great transformation of every aspect of students' development.

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Appendix A

Example of Lesson Plan by Using 5E Model

Theme : **Maintenance and Continuity of Life**
Topic: Cell as the basic unit of life

Objective Understanding cell in term of cell structure, function and organization.

Learning Standard : 2.1.1
Explain that living things are made up of cells that carry out life's functions and undergo cell division

2.1.2
Demonstrate the preparation of slides of animal cells and plant cells using the correct procedures

2.1.3
Communicate about each structures in cells with their functions as well as compare and contrast animal cells with plant cells.

Learning Development	Activity in class	Notes
Before start the class, teacher need to **clarify** with students the objective learning of today's class. Learning Objective: Understanding cell in term of cell structure, function and organization		
Engage	**Identify the prior knowledge through context.** 1. Uncover the prior knowledge of students' with analogy such as building structure. Relate the basic unit to build a house or building is by using bricks with the basic unit of life.	Teacher's exploit students thinking skill to understand the concept of cell as the basic unit of life.
	2. Ask question as follow: • What is the most basic thing for every living things?	Teachers are encouraged to ask a question and brainstorming with the students to uncover student ideas about one science concept

	3. Students are encourage to build a questions for the next investigation: • Are all living things built from cells? • Can cells reproduce? • How does animal cell look like? • How does plant cell look like? • Does animal cell and plant cell have the same shape? • What are the difference between animal cell and plant cell?	Teacher need to stimulate students to raise a questions about the topic that will be learn.
Explore	4. Conducting scientific investigations about animal cell and plant cell through microscope. **The questions that can be raised during the exploration activity are as follows:** • How can a student study the appearance of a cell? • What are the investigation steps needed for students to study abut cell? • What are the structure that students might found in during the exploration?	Students plan and conduct the exploration activity based on questions raised in a group. As students carry out the activities, the teacher need to raise a questions as a guidance for students to lead for next focus which is the structure of animal and plant cell.
	5. Draw animal cell and plant cell that have been observed under microscope.	Students record the findings in an individual practice report books notes.
	6. Teacher exhibit a diagram of animal cell and plant cell while guiding students towards the function of the cell structure	Teacher can use cards that are labeled with component functions to be matched to the cell diagram.
Explain	**7.** Students communicate the exploration findings with the multimedia. **Question that can be ask to students:** • What are the findings that can be share about cell structure and function of the cell that be seen under the microscope?	Students present the findings as a group. Teacher reviews the findings and solidifies the understanding of science concepts from student presentations.

Elaborate	**Develop the idea in new situation.** 8. Teacher guide students to understand the concepts of cell also carry out some process to live and ask students to make the comparison of healthy cell and the cancer cell.	Teacher can use multimedia to show to students about cancer cell.
Evaluate	Teacher can use some worksheet or module to evaluate students understanding.	
Important: Teacher must make a summary together with the students about what have they learned for today class.		