THE EFFECT OF PROCESS-ORIENTED GUIDED-INQUIRY LEARNING ON STUDENTS' SCIENTIFIC INQUIRY LITERACY SKILLS AND ACHIEVEMENT IN SECONDARY SCHOOL CHEMISTRY

BY

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LIST OF ABBREVIATION

POGIL	Process-Oriented Guided-Inquiry Learning
CM	Conventional Method
ZPD	Zone of Proximal Development
PTPL	Peer-led Team Learning
PLGI	Peer-led POGIL Learning
IPM	Information Processing Model
CLT	Cognitive Load Theory
SPM	Sijil Peperiksaan Malaysia
GPMP	Gred Purata Mata Pelajaran
KBSM	Kurikulum Kebangsaan Sekolah Menengah
ScInqLit	Scientific Inquiry Literacy Test
ABAT	Acids Bases Achievement Test
EGT	Experimental Group Teachers
CGT	Control Group Teachers
ANCOVA	Analysis of Covariance

LIST OF APPENDICES

LIST OF AWARD

1. Research University Postgraduate Research Grant Scheme Award (USM-RU-PRGS) by Institute of Postgraduate Studies, Universiti Sains Malaysia (1 July 2010- 30 Jun 2012).

LIST OF PUBLICATIONS & SEMINAR

Conference Papers

1 Corrienna Abdul Talib and Zurida Ismail (2011). The Effect of Translation on Students' Scientific Inquiry Literacy Test Scores, in Program Book and Abstract for the 4th International Conference on Measurement and Evaluation in Education (ICMEE), 9-12 October 2011, Universiti Sains Malaysia, Pulau Pinang.

2 Corrienna Abdul Talib and Zurida Ismail (2011). Scientific Inquiry Literacy of Malaysian High Schools Students, in Full and Brief Paper (Science) of the 4th International Conference on Science and Mathematics Education (CoSMEd 2011), 15-17 November 2011, SEAMEO RECSAM, Pulau Pinang.

Conference Abstracts

3 Corrienna Abdul Talib and Zurida Ismail (2011). The Effect of Process-Oriented Guided-Inquiry Learning on Students' Scientific Inquiry Literacy and Achievement in Chemistry. Paper presented in the 14th Asian Chemical Congress (14ACC), 5-8 September 2011, Queen Sirikit National Convention Center, Bangkok, Thailand.

4 Corrienna Abdul Talib and Zurida Ismail (2011). The Effect of Translation on Students' Scientific Inquiry Literacy Test Scores. Paper presented in the 4th International Conference on Measurement and Evaluation in Education (ICMEE), 9-12 October 2011, Universiti Sains Malaysia, Pulau Pinang.

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KESAN PEMBELAJARAN INKUIRI TERBIMBING BERORIENTASIKAN PROSES TERHADAP KEMAHIRAN LITERASI INKUIRI SAINTIFIK DAN PENCAPAIAN MURID DALAM KIMIA SEKOLAH MENENGAH

ABSTRAK

Kualiti pendidikan adalah sangat bergantung kepada apa yang guru lakukan di dalam kelas. Demi menyediakan murid-murid hari ini menjadi individu yang berjaya kelak, guru kimia perlu memastikan pengajaran adalah berkesan. Guru harus mempunyai pengetahuan bagaimana murid belajar dan cara terbaik untuk mengajar kimia. Menukar cara pengajaran dan pembelajaran kimia adalah satu kebimbangan profesional perguruan yang berterusan. Usaha harus diambil dari sekarang untuk berubah daripada kaedah konvensional kepada pendekatan berpusatkan murid. Kajian ini, memperkenalkan pengajaran berpusatkan murid sebagai pendekatan alternatif untuk mengajar di sekolah di Malaysia. Kajian ini bertujuan untuk mengkaji kesan relatif Pembelajaran Berorientasi Proses Inkuiri Terbimbing (POGIL) terhadap kemahiran literasi saintifik dan pencapaian murid dalam kimia khusus bagi topik Asid dan Bes. POGIL berfokuskan teknik dan menggunakan inkuiri terbimbing untuk membangunkan pemahaman. Kajian lepas mendapati persekitaran pembelajaran yang menarik membuatkan murid merasa selesa dan seronok serta pencapaian lebih baik. Persekitaran pembelajaran yang dianggap sebagai meyakinkan, menggalakkan dan memenuhi kehendak dapat meningkatkan pencapaian murid. Rekabentuk kuasi eksperimen telah digunakan dalam kajian ini. Instrumen yang digunakan ialah Ujian Literasi Inkuiri Saintifik (ScInqLiT) untuk mengukur kemahiran literasi inkuiri saintifik dan Ujian Pencapaian Asid Bes (ABAT) untuk mengukur pencapaian murid selepas mengikuti strategi pengajaran POGIL. Kajian melibatkan 128 orang murid tingkatan empat dari sekolah-sekolah luar bandar di Perak. Ujian-*t*, analisis kovarians dan ujian berulang ANOVA telah digunakan untuk mengkaji perubahan dalam pembolehubah bersandar. Bagi kaedah pengajaran POGIL terdapat perubahan yang ketara terhadap kemahiran literasi inkuiri saintifik dan pencapaian dalam asid dan bes. Keputusan ujian berulang ANOVA menunjukkan bahawa POGIL dan CM tidak memberikan kesan yang signifikan terhadap ketekalan pengetahuan murid. Walau bagaimanapun dapatan kajian mendapati bahawa penggunaan POGIL dapat meningkatkan kemahiran inkuri dan pencapaian dalam kimia berdasarkan peningkatan dalam pasca ujian. Kaedah ini sesuai dilaksanakan di peringkat sekolah di Malaysia jika diberi peluang dan masa yang mencukupi untuk menyesuaikan diri dengan pembelajaran inkuri. Oleh yang demikian, para guru perlu diberi latihan dalam pengendalian POGIL di dalam usaha meningkatkan kemahiran inkuiri dan pencapaian dalam mata pelajaran kimia dan juga mata pelajaran yang lain.

THE EFFECT OF PROCESS-ORIENTED

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ABSTRACT

The quality of education that teachers provide to students is highly dependent upon what teachers do in the classroom. In preparing students of today to become successful individuals of tomorrow, chemistry teachers need to ensure that their teaching is effective. Teachers should have the knowledge of how students learn and how best to teach chemistry. Changing the way teachers teach and what to teach in chemistry is a continuing professional concern. Efforts should be taken now to direct the presentation of chemistry lessons away from the conventional methods to a more student centered approach. In the study, a student-centered learning style was introduced as an alternative approach to teaching in Malaysian schools. The paper aimed to examine the relative impacts of Process-Oriented Guided-Inquiry Learning (POGIL) on students' scientific literacy skills and achievement in chemistry specifically under the topic of Acids and Bases. POGIL is a technique-focused and uses guided-inquiry activities to develop understanding. Research studies reveal that the campus where the environment is fascinating for students and they feel ease and enjoyment, their achievement is good. Learning environment which students perceive as affirmative, favourable, and fulfilling tend to lead toward increasing students' achievement. A quasi-experimental design was used in the study. The instruments used were Scientific Inquiry Literacy Test (ScInqLiT) to measure the scientific inquiry literacy skills and the Acids Bases Achievement Test (ABAT) to measure the achievement of the students after being exposed to POGIL. The study involved 128 form four students from rural schools in Perak. The t-test, analysis of covariance and repeated-measures of ANOVA were used to look into the changes in the dependent variables. For POGIL teaching method there were significant changes on students scientific inquiry literacy test and achievement in acids and bases. Repeated measures ANOVA showed that POGIL and CM had no significant impact on students' knowledge retention. However, the findings of the study revealed that POGIL could enhance students' scientific inquiry literacy skills and achievements in chemistry based on the improvement showed in posttest. The method could be implemented in Malaysian schools if given the opportunity and sufficient time to adapt to learning by inquiry. Thus, teachers should be given training in handling POGIL in an effort to improve the skills of scientific inquiry literacy and achievement in chemistry and in other subjects as well.

CHAPTER ONE

INTRODUCTION

1.0 Introduction

The quality of education provided to students depends on teaching and learning processes in the classroom (Furner & Kumar, 2007). In an effort to respond to the challenge of Vision 2020, Malaysian education always encourages science teachers to use a variety of teaching methods to provide today's students with the success they deserve (Lay, 2009). Teachers need to be knowledgeable in engaging student interest and in science teaching approaches (Trout, Padwa, & Hanson, 2008). The pedagogic research states that classroom teacher can play an important role in influencing students' motivation (Palmer, 2009). Changing teaching methods in presenting science lessons should not be considered as a burden but as a continuing professional development, moving instruction that is the teaching-learning cycle, more towards student-centered (Effandi & Zanaton, 2007).

In preparing the students of today to become the successful individuals of tomorrow, science teachers need to ensure that their teaching is effective (Bunce, 2009). It is generally accepted that the classroom teacher can play a pivotal role in influencing student motivation, and a number of studies in science education have found this to be the case (Shymansky, Yore & Anderson, 2004). Changing the way we teach and what we teach in science is a continuing professional concern and efforts should be taken now to direct the presentation of science lessons away from the teacher and center more on the student (McKeachie, 2002).

The Integrated Curriculum Specifications of Chemistry for Secondary School have been designed to provide students with the knowledge and skills in science to develop in them thinking skills and strategies to enable them to solve problems and make decisions in everyday life (Malaysia, Curriculum Development Centre, 2005). The curriculum aims at producing active learners. To this end, students are given ample opportunities to engage in scientific investigations through hands-on activities and experimentations. Yet despite these good intentions and directions, teacher centered teaching practices still take center stage (Moog & Spencer, 2008).

The Chemistry Curriculum Specifications for Form Four and Form Five (Malaysia, Curriculum Development Centre, 2005) also addresses the expectation that chemistry will be taught with an emphasis on learning through inquiry, while incorporating thinking skills and strategies, and thoughtful learning. Many if not most, high school teachers agree that inquiry and the use of materials based on the learning cycle are the best methods for teaching (Trout, Moog, & Rickey, 2008).

Students' acceptance of inquiry method is emphasized because this method is more suitable to be implemented if the student falls into the category of more intelligent and have good discipline. The process of teaching and learning of chemistry should be effective in order to enhance the students' ability to think and apply the learned chemistry concepts in real situations. Researchers have shown that thinking skills are related to the students' cognitive styles and thus, will affect their achievement in learning (Minderhoutt & Loertscher, 2007).

Chemistry and thinking practice cannot be separated. According to Carillo, Lee and Rickey (2005) the main goal is to promote rationality in chemistry among students because chemistry is a rational field of science education. Students need to learn to appreciate the high value of the process of thinking that tends to practice. In education, rationality is critical thinking.

Inquiry science lessons have been proposed as a best practice for teaching science and for assisting students to confront their misconception (Nadelson, 2009). Inquiry lessons require that students think and behave like scientists to develop and test their own hypotheses based on the evidence and data they generate. According to The National Science Education Standards (National Research Council [NRC], 1996), scientific inquiry involves the diverse ways scientists propose, explore, and test explanations for phenomena based on evidence produced by their work. Inquiry can simply be defined as a way of studying the world.

While it seems reasonable that science teaching should include methods that challenge students to think and behave like scientists, the results of inquiry learning, however, have not been what educators hoped. Although, the value of inquiry and learner centered methodology is officially recognized, many science teachers emphasize to finish the syllabus off rather than focus on procuring activities of science process skills in the teaching and learning process (Siti Musitah, 2007). In addition, a lack of appropriate materials often hinders local implementation of these methods (Che Ahmad et al., 2009). Even if teachers are knowledgeable about teaching with process-centered techniques, they often find that existing curriculum materials do not adequately support inquiry-based learning in their classes (Tsai et al., 2007).

Based on the findings of a study done by Syahruzaman (2010), teachers' understanding and the implementation of an inquiry approach is moderate while students' understanding towards inquiry approach is good. The main problems faced by teachers in implementing this approach in teaching and learning of a science subject are time constraints, higher tendency of misconception and also the large number of students in each class (Brown et al., 2006). Nadelson wrote concerning attempts to teach using inquiry, "The students responded that they did not know what to do" (2009, p. 48). He also stated the kind of inquiry teachers want for their students is a complex process and is beyond the skill set of high school students and students express frustration when involved in inquiry lessons (Bartley, 2007).

In order to deal with the problems inherent in inquiry lessons, science educators have turned to guided inquiry. In a guided inquiry lesson, students work in small cooperative learning groups using print materials that ask questions designed to guide students to develop their own understanding of the concepts (Bunce, 2009). The teacher's role in guided inquiry lessons is to facilitate and guide students to the knowledge the lesson is designed to teach (POGIL, 2010).

Guided inquiry offers a way for teachers to assist students as they develop accurate mental images of abstract chemistry phenomena. Guided inquiry also assists students to connect their understandings of macroscopic and submicroscopic chemical phenomena to their symbolic representations. In light of the difficulties many students face in high school chemistry classes; this type of pedagogy is needed to help students deal with the abstract concepts of chemistry by providing the necessary scaffolding. Students taught using a method that allows them to comprehend the three levels of representation in chemistry and how they are inter-connected should facilitate student understanding and improve achievement. Also, students holding misconceptions that hinder their understanding of chemistry can confront and expose their own misconception and replace them with a proper understanding of scientific phenomena.

Research on how students learn has been used to develop a new approach to teaching. There is general agreement that understanding is constructed dynamically and is facilitated by using active modes of learning (Mason, 2006). Learning is facilitated when students have a chance to think about difficult material with their peers in a guided small-group fromat. Process-Oriented Guided-Inquiry Learning (POGIL) is an alternative approach and relatively new tactic to teaching in Malaysia. POGIL was developed and has been used mostly in chemistry classrooms in the United States of America. Much of the research on cooperative group learning suggests that this model leads to improved student performance and increased higher-order thinking skills (Johnson & Johnson, 2000). POGIL is an instructional method that aims to actively engage students in learning content, while at the same time fostering development of the essential problem solving, analytical, critical thinking skills required in scientific careers which may enhanced the transformation of the educational curriculum in the Malaysia Education Blueprint 2013-2025 (Malaysia, Ministry of Education, 2012) which focuses on the concept of higher order thinking skills (HOTS).

1.1 Background of the Study

Chemistry is offered at the upper secondary level as an elective subject. It is a two-year program involving form four and form five students. The elective science subjects prepare students who are more scientifically inclined to pursue the study of science at the post secondary level. This group of students takes up careers in the field of science and technology and plays a leading role in this field for national development. The aims of the chemistry curriculum for secondary school are to provide students with the knowledge and skills in chemistry and technology and enable them to solve problems and make decisions in everyday life based on scientific attitudes and noble values.

The Chemistry syllabus for form four is based on four themes (Malaysia, Curriculum Development Center, 2005):

- Introduction to chemistry
- Matter around us
- Interaction between chemicals
- Production and management of manufactured chemicals

The themes provide an understanding of chemistry as a field of study. In the first theme students are introduced to matter and the method of acquiring science knowledge in a scientific manner through scientific investigation. Second theme introduces chemistry as a study of matter. The theme provides basic concepts in chemistry, a prerequisite to the learning of chemistry, and mastery of these concepts is important to understanding the subject. The third theme provides understanding of chemical reactions, the cause of chemical changes in substances. The theme also investigates the idea that matter interacts to produce new substances and causes energy changes. The application of chemical reactions in industries is also covered in this theme. The fourth theme enables the student to understand the manufacturing of chemicals for daily and social needs. Students relate knowledge and skills that they have learned in chemistry lessons to experiences in daily life. The importance of responsible ways of managing and handling manufactured chemicals is also highlighted in the fourth theme.

Much has been written and said about teaching and learning strategies in the chemistry curriculum emphasizing thoughtful learning that helps students acquire knowledge and master skills to develop their mind to an optimum level. Research in chemistry education has shown that students often have difficulty in understanding chemistry concepts due to their abstract nature. Many attempts have been made by researchers to assist students' learning by identifying the difficulties experienced by students and advancing possible solutions to overcome this problem (Ozkaya et al., 2006). According to the literature, many students have problems in chemistry and do not successfully master the underlying concepts (Rusmawati, 2005). Some students do not understand the basic concepts (Gilbert, Reiner & Nakhleh, 2008). Many students have trouble comprehending concepts when the principles behind them are abstract or difficult to observe directly (Condry & Spelke, 2008). Students in various stages of studies have negative attitudes towards chemistry (Coll, Dalgety & Salter, 2002). Students assume chemistry is a difficult subject and overcame the subject by memorization alone (de Jong, 2000). Chemistry is a subject that is full of abstract ideas, and many require an understanding of complex concepts (Dori & Hameiri, 2003). Due to the negative attitudes of students toward chemistry, the number of students taking chemistry courses at universities in western countries has decreased (Breuer, 2002).

A study conducted by Faiza (2005) in secondary school science stream students showed that students had no interest on this subject and many of them did not have the skills to answer the questions that shaped a concept. They did not see the importance of concepts or ideas they had learned. If given a choice, most students of the science stream were more than willing to change into non science classes, if they were eligible to continue in school majoring in science. However, if these same students were made creative participants in the learning process, in ways where they were able to share their ideas, they felt motivated to continue. It is this "generation of motivation" amongst the students which is the real challenge to us – the teachers.

Difficulties facing students exist not only at the secondary schools but also at higher levels. Zurida and Norita (2000) based on their study on students learning in a higher learning institution found that students who failed to resolve the question of stoichiometric problems did so because they:

- Were unable to explain the chemical reaction
- Could not write the response equations
- Were unclear regarding the types of problems
- Did not know the objectives of what to look for
- Had no procedural knowledge
- Had difficulty to understand the term
- Neglected the calculation of mathematical and chemical formulae

Teaching chemistry is not just a series of scientific principles and theories to be pounded into the heads of students (Sharma, 2007). Science is dynamic and should not be taught as if it was conclusive information (Sharifah Norhaidah, 2002). It requires the development of concepts underlying the principles of chemistry and students learn to enjoy the development and then appreciate the subject. The conventional method of teaching mostly focuses on completion of course curriculum and in the process students often become passive listeners. Once this stage is reached, they develop phobia and ultimately lose interest in the subject. Thus, teaching and learning strategies that keeps them interested need to be emphasized by the chemistry teachers. It is important to help students to master the concepts and effectively support the learning process of chemistry (Reid, 2008).

Keeping this in mind, an approach to learning based on guiding students through a process of inquiry until the students “discover” the concept of interest need to be formalized. Inquiry type of learning is best accomplished using more student-centered active-learning strategies (Smith et al., 2009). The inquiry teaching of science across the secondary levels is a goal to which Malaysia’s education aspires, as documented by the Chemistry Curriculum Specifications (Malaysia, Curriculum Development Centre, 2005).

POGIL is a relatively new student-centered teaching style to science disciplines especially in chemistry. Students work in small groups on especially designed activities that follow the learning cycle and are intended to develop mastery of both course content and key process skills. The POGIL pedagogy is based on scientific process, constructivism and the use of cooperative group learning, and guided inquiry (POGIL, 2009). It is coupled with a three-step learning cycle consisting of hands on exploration of data followed by series of questions designed to guide the student to the development of a concept and finally an application of the understanding of the concept. POGIL is actually a perfect fit for use in high schools (Moog & Spencer, 2008). The fundamental tenets of this approach are:

- What goes on in the learner's head is dramatically influenced by what is already there.
- The instructor needs to know what the students already know and what is going on in their minds.
- Students construct their own knowledge.

1.2 Statement of the Problem

How do students learn chemistry? How should chemistry be taught in schools? Two pedagogical limitations have been identified as the major shortcomings in conventional secondary education: lecture-based and teacher-centered instruction (Effandi & Zanaton, 2007). In such an environment, students become passive recipients of knowledge and resort to rote learning. The majority of work involves teacher-talk using either a lecture or a simple question and answer techniques that demand basic recall of knowledge from the learners. Lecture based instruction dominates classroom activity with the teacher delivering well over 80 percent of the talk (Effandi & Zanaton, 2007). Generally, only correct answers are accepted by the teacher and incorrect answers are simply ignored. Students seldom ask questions or exchange thought with other students in the class.

The conventional classroom is also characterized by directed demonstrations and activities to verify previously introduced concepts. Instruction is therefore not for conceptual understanding but rather for memorizing and recalling of facts with the help of demonstrations. It is generally recognized that the chemistry education process has two components, content and process. Content deals with the structure of knowledge while process is the skills needed for acquiring, applying and generating knowledge (Apple, Beyerlein & Leise, 2005). A keen emphasis on public examinations by teachers has led to teaching being mainly geared towards passing these examinations. According to Ling (2000) Malaysian schools still embraces the notion that memorization is learning: Being able to repeat or recall something in an examination is the evidence of understanding.

Thus, teaching and learning in the classroom in some context becomes largely teacher-centred as required by the curriculum, thereby ignoring the development and mastery of scientific and thinking skills among students (Sharifah Maimunah, 2003). Using the didactic approach has been the practice of chemistry teaching (Anida, 2008). In most cases, content is taught didactically through lecture and scientific practices through structured laboratory experiments. Studies of students' understanding of science ideas after instruction provide clear evidence that conventional, didactic teaching methods are not very successful in bringing about productive changes in students' conceptions (Nakhleh, 2004). Although didactic styles of instruction can be reasonably successful in imparting the facts, rules, procedures, and algorithms of a domain, they are not effective for helping students refine and build their own ideas about science concepts, in part, because they neither require nor encourage high levels of metacognition (thinking about their own thinking) on the part of the students (Rickey & Stacy, 2000). Conventionally the attention has been on the content, leaving the process emphasis for higher-level training (Abu Hassan, 2003). Typically, students are simply told the "correct" scientific ideas and are expected to understand them, despite the fact that they are given few opportunities and little guidance to develop such an understanding. This often makes the study of chemistry dry and a necessary evil needing a passing grade (Zawadzki, 2010).

As already indicated above, the Malaysian education system orients itself toward the exam instead of the acquisition of knowledge. This leads to the negative attitude of students towards chemistry because they are forced to memorize facts, or remember formulas and symbols and should follow the teaching and learning programs that merely to finish the syllabus (Sharifah Maimunah, 2003). Teachers teach chemistry by emphasizing simplified and memorized facts so students can score high on the exam. Students only learn to pass exams and get certificates by remembering facts and problem-solving algorithms without understanding the concepts and principles in depth. They flounder when they need to apply these principles. Also, faulty theoretical understanding can lead to students' misconception of chemistry concepts. In the workplace this can have dire consequences, as evidenced by many man-made chemical disasters.

Strategies for the development of thinking and analytical skills are reduced or do not happen at all. The teachers have no time to design a creative teaching method palatable to students. Science teachers leave the difficulty of teaching abstract topics, difficult to understand by students, to statements that most often they themselves possibly memorized but do not understand. Consequently, students fail to master the basic reasoning behind the concepts and face the difficulties of memorizing too many facts and formulas in science-related subjects. This finding parallels the results of a study done by Salta and Tzougraki (2004), who found that science teaching methods were not effective and caused students to think that science subjects are prosaic, hard, too much memorization, and difficult to associate with daily life. Consequently, the questions asked in typical science classroom instructions are not directed to the stage of development of students thinking ability of maturity (Ling, 2000) and certainly students are not exposed to the kinds of questions used in international standard tests. Alarmingly, questions that avoid the processes of inquiry will also delay the cognitive development (Abrams, Southerland & Silva, 2008). The barrier to the inquiry process is the inability and ignorance of teachers of the proper method and process of successful learning through inquiry. The findings also suggest that the vast majority of teachers themselves do not understand the nature of the subject, especially chemistry (Abd-El-Khalick & Lederman, 2000) and that this deficit is a critical factor in students low achievement in developing an understanding of the nature of the scientific enterprise (Slater, Slater & Shaner, 2008).

Previous research indicates that Malaysian students, including those who have completed upper secondary school and continued their education in college or university do not demonstrate sufficient higher-level cognitive abilities (Mushita & Sharifah Norhaidah, 2003). The target of 60:40 ratios of science to non science students is still far from being achieved. This can be proved by the total number of candidates who apply for admission to public universities. Total applications received in 2004 were 39,724 for science courses and 46,242 for arts courses (Morshidi, 2005). Loo (2003) stated that the strategies of a pure science curriculum may not take into account individual differences such as cognitive styles, which can contribute to the achievement of science.

A strictly lecture-based presentation of facts and concepts, on the other hand, may lead students to believe that everything has been figured our already and that the study of science is an exercise in memorization rather than investigation. The present teaching practice, however stresses the mastery of content rules and formulas, and memorized procedures rather than meaningful inquiry-based activities to foster scientific curiosity (Syed Anwar Aly & Merza, 2000). Learning tasks are often entirely textbook-driven, with little opportunity for students to raise questions through conceptual conflict or to attain an understanding of scientific inquiry (Ling, 2000). A similar scenario also happens in matriculation chemistry courses where lectures make up the core of chemistry teaching and learning (Dani & Kamisah, 2011).

Teachers who engage in the conventional method will inform, verify and start their lessons with explanations and follow them with examples and observations. Although there are times where this approach is preferable, even necessary, the problems with it are that not only do teachers attempt to communicate knowledge instead of giving students the opportunity to construct it through direct experience, but that the transmission approach does not take into account the diversity of capacities and needs that exist in different students (Ling, 2000). Mazur (2009) suggested that one possible explanation for the survival of these techniques is that even experienced teachers may be misled as to whether students are truly learning concepts rather than memorizing algorithms.

Negative effects of chemistry students in Malaysia particularly in the District of Larut, Matang and Selama, might be viewed in terms of the less promising achievement. This situation can be seen based on the analysis of SPM results for the subjects of chemistry for 2009 and 2010 in the District of Larut, Matang and Selama as in Appendix 1. About 57 percent of schools in this district show that more than 50 percent of the total students that took Chemistry in SPM, obtained Grade 7 D to 9 G in year 2010 compared to only 44.8 percent in 2009. Students who are weak in science subjects are not willing to think critically, creatively and are not able to reach higher order thinking skills (Abd. Rafie, 2002). A study on scientific reasoning among students that took the Malaysia Certificate of Education [*Sijil Pelajaran Malaysia* (SPM)] examination showed that only 25 percent of science students were able to think up to the required reasoning level for entrance into the Institute of Higher Education (Hamidah, 2004).

An analysis of the report on the Chemistry SPM questions by Malaysia Examination Board [*Lembaga Peperiksaan Malaysia* (LPM)] for 2002 to 2003 (LPM, 2004) concluded that;

1. Medium and weak students still could not master the basic concepts of certain topics in chemistry, especially chemical formulas and equations.
2. Medium and weak students still could not solve problems involving the calculation and the concept of mole
3. Medium and weak students still could not state the number of mole in the form of a ratio.

Teaching and learning process involves understanding, construction and mastering concepts in students. The basic concept that has dominated encourages students to learn new concepts more easily (Abu Hassan, 2003). Unfortunately, several studies showed that students had difficulties understanding the concepts, thus failed to apply these concepts in daily life (Yakubu, 1992). There are several factors that can disrupt a meaningful learning, such as learning approach the teacher used. Many studies showed more teachers encourage students to memorize facts without understanding the concept (Yakubu, 1992). Students were unable to develop new knowledge due to this phenomenon, thus failing to apply the concepts learnt in the classroom into daily life. In the United Kingdom, a study done by Ramsden (1992) found that many students were only able to state the definition of a concept without the ability to associate the concept with the world outside the classroom. As a result, students were unable to apply science concepts learned when solving problems in daily life. The same problem also occurs in the United States and Japan (Kumano, 1997). In the U.S. for example, there were students who felt that their learning does not bring any meaning, and could not be used to solve everyday problems. However, in Japan only a small number of students who aware of the importance of science knowledge in solving everyday problems (Bond, 2004).

1.3 Purpose of the Study

The purpose of the study is to investigate the effectiveness of POGIL as an intervention intended to enable students to become more scientifically inquiry literate and help students learn chemistry more effectively. The specific aims of the study include:

a. To investigate the effect on student's scientific inquiry literacy skills of the POGIL approach compared to the conventional approach.
b. To investigate the effect on students' chemistry achievements test of the POGIL approach compared to the conventional approach.
c. To investigate the effect of students' knowledge retention between students taught through POGIL and those taught conventionally.

1.4 Research Questions

Based on the purpose of the study to examine the effect of using POGIL on the students' scientific inquiry literacy skills and achievements in learning chemistry, the study addressed the following questions that guided the research:

a. Is there a significant difference in scientific inquiry literacy skills between students' taught with POGIL and those taught conventionally?
b. Is there a significant difference in students' scores in chemistry achievement tests before and after completing the POGIL activities as opposed to conventional teaching?
c. Is there a significant difference in terms of students' concept retention between students taught conventionally and those taught through POGIL?

1.5 Hypotheses

The following null hypotheses were investigated in the study:

H_{01}: There is no statistically significant difference between students taught by POGIL and those taught conventionally on the scientific inquiry literacy skills.

H_{02}: There is no statistically significant difference between students taught by POGIL and those taught conventionally on the chemistry achievement test.

H_{03}: There is no significant difference in terms of students' knowledge retention between students taught conventionally and those taught through POGIL.

1.6 Rationale for the Study

An effective learning environment is one in which students can actively engage, an environment in which there is something for students to do. A common finding in research on how people learn is not telling, which is not teaching: An idea cannot be transferred intact from the head of the instructor to the head of the student. In order to help students develop appropriate understanding of anything, it is necessary to know what is going on in the student's mind. Thus, instructors need to put themselves in a position to be so informed. This perspective suggests that the instructional focus should be on the activity of the students rather than the presentation by the instructor. This is the essence of a student-centered classroom. The role of the instructor is one of a facilitator of learning, asking probing questions to help guide the students to develop understanding, and addressing misconceptions or misunderstanding.

Malaysia's vision to become a developed nation by the year 2020 has placed science and technology as important subjects to excel in (Othman et al., 2009). Science and technology are often perceived as fundamental forces behind economic development in industrialized countries. The growth in science and technology is overwhelming. These forces are impossible to avert and they provide challenges and opportunities for people in science education. Education today must enable students to meet the challenges ahead, the demands of the work environment and of daily living. Thus, students not only need knowledge but also communication skills, problem solving skills, and creative and critical thinking skills in the years ahead. The Malaysia, Curriculum Development Centre (2005) stated:

> As a nation that is progressing towards a developed nation status, Malaysia needs to create a society that is scientifically oriented, progressive, knowledgeable, having a high capacity for change, forward-looking, innovative and a contributor to scientific and technological developments in the future. In line with this, there is a need to produce citizens who are creative, critical, inquisitive, open-minded and competent in science and technology.
>
> (Malaysia, Curriculum Development Centre, 2005, p.1)

Reports on performance in science learning, especially those that highlighted students' lack of interest as well as declining ability to do science (Lee, 2001), sparked much concern about the ability to achieve the targeted goals.

A look at the performance of Malaysian students in comparison to students from 49 countries participating in the TIMSS assessment (Gonzales et al., 2008) shows that Malaysia had lower average achievement in 2007 (471 scores) than in 2003 (510 scores). Malaysian Form Two students scored 471 in science. This is below the international average of 500 (Gonzales et al., 2008). Besides, in comparison to other countries, Malaysia was out performed by 21 of the 49 participating countries. The activities in TIMSS 2007 were similar to the ones of TIMSS 2003 in that they are commonly found in science classroom. As for the instruction, science teachers reported the following activities, teacher lecture (25 percent), teacher-guided student practice (17 percent), students working on problems on their own (13 percent) and homework review (13 percent) (Gonzales et al., 2008). Other activities were reviewing homework, re-teaching and clarifying content, taking tests and quizzes and participating in classroom management tasks that are not related to the lesson content (Gonzales et al., 2008).

Chemistry is a key, enabling science, and is a subject that is considered by many to be difficult for secondary school students (Lorenzo, 2005). A variety of reasons for this have been advanced. Taber and Coll (2002) noted that the chemistry concepts are abstract in nature and require students to construct mental images of things they cannot see, and thereby find chemistry hard to relate to. A further complication in the learning of chemistry (and other sciences) noted in the literature concerns the medium of instruction. The literature on students with problems of scientific language literacy, points to confusion between scientific terminology and similar sounding or the same words in common language usage. This suggests that this may result in students not understanding the meaning of scientific terms (Johnstone & Selepeng, 2001). Students for whom English is not their first language suffer more from such confusion if chemistry instruction occurs in English and it is probably due to lesser skills in English speaking, listening or reading (Coll et al., 2002). In some cases differences in world views result from cultural differences (Pakua, Treagust & Waldrip, 2005). These and some of earlier statements are reasons why students find chemistry study challenging, and correspondingly teachers find some chemistry topics difficult to teach (Ozmen, Demircioglu & Coll 2007).

Most non-science majors have negative impressions of science subjects and dread taking them. In addition, because of the perceived difficulty in science courses, most non-majors assume they will do poorly in science classes. This is compounded further by pervasive lecturing in most college classrooms that does not engage students in the process of teaching and learning (Powell, 2003). The hope then is that active learning would alter negative student perceptions that interfere with the learning process while creating excitement in the classroom (Lujan & DeCarlo, 2006). In the past decade interest in using more active methods to enhance the learning of chemistry has grown (Eybe & Schmidt, 2004). Active learning is a student-centered approach based on engaging students in activities and creating classroom environments that permit student ownership of the learning process (Mohamed, 2008). Moreover, because active learning strategies incorporate multiple learning styles, such strategies are consistent with educational models based on theories of learning and motivation and promote deep scientific understanding in chemistry.

According to Staver (2007) an effective science teacher uses the following techniques to promote deep scientific understanding:

- Determine if tasks are problems or exercises for students; ask all students if they have a good-to-excellent idea or little-to-no idea of how to do specific tasks.
- Organize cooperative student groups that reflect intellectual, gender, and cultural diversity; have members of the group share and discuss their representations of the gap and proposed solution strategies.

- Use guided-inquiry teaching strategies (e.g., Learning Cycle, 5-E Instructional Model) that lead learners to continue developing and modifying their knowledge.
- Aim problem-solving instruction slightly beyond what students can do alone but within the boundaries of what they can do with assistance from others.
- Use science concepts and processes as contexts for students to write persuasive essays, engage in oral discussions, connect data with scientific theories, and solve problems requiring mathematical reasoning.
- Design discussions and negotiations among students as on-going learning experiences.
- Provide opportunities for students to claim ownership of their learning.

Looking at the students perspective, Bransford, Brown and Cocking (2000) stated that students learn by constructing their own understanding based on their prior knowledge, experiences, skills, attitudes, and beliefs, following a learning cycle of exploration, concept formation, and application, connecting and visualizing concepts and multiple representations, discussing and interacting with others and reflecting on progress and assessing performance. All of these ideas are incorporated into the design of POGIL in order to help students learn both discipline content and key process skills simultaneously (Hanson, 2006). POGIL enhance the teaching and learning process when students actively engaged and thinking in the classroom and laboratory, drawing conclusions by analyzing data, models, or examples and by discussing ideas, working together in self-managed teams to understand concepts and to solve problems, reflecting on what they have learned and on improving their performance as well as interacting with teacher as a facilitator of learning.

The POGIL approach has been shown to significantly increase student comprehension of difficult-to-understand concepts (Lewis & Lewis, 2005) and is designed to support guided inquiry in chemistry learning (Al-Doori, 2007). Hence, the study used POGIL as an intervention intended to help students learn acids and bases more effectively as well as to improve teaching methods besides, there are no published reports that explore if POGIL is effective in Malaysia.

1.7 Significance of the Study

This study is significant as a resource for students, teachers, researchers, curriculum planners and policy makers. The alternative teaching method introduced could help administrators and school teachers to improve students' performance of chemistry, scientific inquiry skills and reasoning skills that are needed in the present era of science and technology.

The results will encourage and help teachers that are always looking for the best and innovative way to convey their subject matter to their students. Since POGIL is rooted in the scientific process, guided inquiry and constructivism, it is actually a perfect fit for use in high school. POGIL materials provide students with a solid foundation of scientific thought processes and content. The POGIL method can be expected to facilitate learning and enhance understanding of each student regardless of ability level. This approach will indirectly facilitate teachers achieve the learning objectives. The study is expected to help students not only to remember the chemical concept but also to improve the candidates' achievement in *Sijil Pelajaran Malaysia* (SPM [Malaysian Certificate of Examination]). More students will be expected to get excellent grades and qualify to enter the field of science and technology. It will do its part in realizing the objectives of the government to move towards a knowledge-based economy.

The study will show the effectiveness of POGIL measured by changes in inquiry skills and achievement in chemistry of ordinary students. The study will also be able to convince teachers that academic achievement alone is not the only goal in education. This study satisfies the teachers training and curriculum development requirements of the Ministry of Education in Malaysia, and can be a resource for students and lecturers in public higher education institutions in their efforts to review and develop teaching strategies and learning more effectively. Construction of inquiry learning modules that include guidelines, preparation and implementation methods can certainly help any teacher wanting to try this method in her/his classrooms.

The study also provides information to curriculum planners and policy makers for identifying weaknesses in student understanding, improving instructional practice and determining program effectiveness in relation to teaching scientific inquiry skills. Furthermore, the study can serve as a resource for educational research or for professional development workshops for both elementary and secondary level teachers, because it shows learning gains among participants.