THE EFFECT OF GREEN CHEMISTRY EXPERIMENTS ON ENVIRONMENTAL VALUES AND KNOWLEDGE AND CHEMISTRY CONCEPTS AMONG PRE-SERVICE TEACHERS

by

MAGESWARY KARPUDEWAN

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LIST OF ABBREVIATION

SD	Sustainable Development
ESD	Education for Sustainable Development
DESD	Decade of Education for Sustainable Development
QEV	Questionnaire on Environmental Values
CAT	Chemistry Achievement Test
MANOVA	Multivariate Analysis of Variance with Repeated Measures and Within-Subjects Factors
IUCN	The International Union for Conservation of Nature and Natural Resources
UNEP	United Nations Environmental Program
UNESCO	United Nations Educational, Scientific and Cultural Organization
NGO	Non Governmental Organization
SDCs	Sustainable Development Concepts
TECs	Traditional Environmental Concepts

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LIST OF AWARDS

1 Award given by National Institute of Education, Singapore to attend and present paper at the International Organization of Science and Technology Education Symposium 2006. Organized by NIE, Nanyang Technological University, Singapore.

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LIST OF PUBLICATIONS & SEMINARS

Journal papers accepted for publication

1 *Impact of green chemistry experiments on pre-service teachers' environmental values* was submitted to Chemical Education Journal. Accepted for October 2008 publication.

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Kesan Eksperimen Kimia Lestari Ke atas Nilai dan Pengetahuan Alam Sekitar dan Pengetahuan Kimia dalam Kalangan Guru Pelatih

ABSTRAK

Proses pengajaran dan pembelajaran yang menekankan pembentukan nilai menghargai alam sekitar merupakan kriteria utama untuk mencapai status pendidikan untuk perkembangan lestari. Pengetahuan pedagogi memainkan peranan penting dalam proses memupuk nilai, kemahiran, gambaran dan kepercayaan secara bermakna. Justeru, guru-guru seharusnya diberi pendedahan tentang isu-isu alam sekitar semasa serta cara mengabungjalinkan isu-isu alam sekitar dalam proses pengajaran. Penyelidikan ini bertujuan untuk memperkenalkan eksperimen kimia lestari (green chemisry) serta kesannya ke atas nilai alam sekitar, pengetahuan alam sekitar dan penguasaan konsep kimia di kalangan guru-guru pelatih. Soal selidik, temubual dan teknik permerhatian telah digunakan bagi melihat perubahan pada variabel bersandar. Soal selidik *Questionnaire on Environmental Values* telah digunakan bagi mengukur perubahan pada nilai. Manakala *Test on Environmental Concepts* digunakan untuk mengukur kebolehan memahami konsep alam sekitar dan *Chemistry Achievement Test* bagi mengukur kefahaman konsep-konsep kimia. Seramai 110 orang guru pelatih yang sedang mengikuti kaedah pengajaran kimia terlibat dalam kajian ini. Sebanyak 10 eksperimen kimia lestari telah digubal untuk rujukan dan aktiviti tutorial. Analisis MANOVA Pengukuran Berulang, analisis *univariate* dan kesan interaksi ringkas telah dijalankan untuk melihat perubahan pada variabel bersandar. Bagi nilai alam sekitar terdapat perubahan yang signifikan bagi keseluruhan nilai, nilai egosentrik dan nilai ecosentrik. Walau bagaimanapun tidak terdapat perubahan yang signifikan bagi nilai homosentrik. Terdapat perubahan yang signifikan untuk *Traditional Environmental Concepts* dan *Sustainable Development Concepts*. Pengujian Ujian-t secara berpasangan menunjukkan terdapat perbezaan yang signifikan diantara nilai min ujian pra dan min ujian pos bagi kefahaman konsep kimia. Dapatan temubual menunjukkan guru-guru pelatih yang pada awalnya mempunyai nilai egosentrik, kini mempunyai nilai homosentrik and ekosentrik selepas menerima rawatan selama 10 minggu. Guru-guru pelatih juga telah menunjukkan kesedaran terhadap alam sekitar dan keinginan untuk

memelihara dan memuliharanya. Rawatan yang diberi juga berjaya dalam mengubah tingkah laku mereka dalam melindungi alam sekitar. Seterusnya guru-guru pelatih juga menyatakan rawatan yang dilalui adalah sangat menarik. Dapatan permerhatian adalah sejajar dengan dapatan temubual. Justeru, boleh disimpulkan bahawa kimia lestari ialah salah satu pendekatan yang boleh digunakan untuk menyampai pengetahuan dan memupuk nilai yang dapat membentuk tingkah laku seseorang individu.

The Effect of Green Chemistry Experiments on Environmental Values and Knowledge and Chemistry Knowledge among Pre-service Teachers

ABSTRACT

To achieve the status of education for sustainable development, the teaching and learning must accomplish in bringing changes in environmental values of the students. Pedagogical knowledge plays an important role in the process of conveying values, skills, perspectives and ethics meaningfully. Hence, teachers need to be educated with knowledge of environmental issues and ways it can be incorporated into their teaching. This study was conducted with the aim of introducing green chemistry experiments as a laboratory- based pedagogy as well as to evaluate the effect of these green chemistry experiments on the pre-service teachers' environmental values and knowledge and chemistry knowledge. Questionnaire survey, interviews and observation were conducted to measure the changes in the dependent variables. Questionnaire on Environmental Values was used to measure the environmental value change, Test on Environmental Knowledge to measure the acquisition of environmental concepts and Chemistry Achievement Test to measure the acquisition of chemistry concepts. Interviews and observations were conducted to get in-depth information on the outcome of the quantitative analysis. The study involved 110 pre-service teachers enrolled in a chemistry teaching methods course. A total of 10 green chemistry experiments were developed for use as reference and tutorial activities. Repeated measure MANOVA, Univariate Analysis of Variance and simple interaction analysis were used to look into the changes in the dependent variables. For environmental value, there are significant changes in the overall environmental, egocentric orientation and ecocentric orientation. However, for homocentric category the changes are not significant. For environmental concepts, both Traditional Environmental Concept and Sustainable Development Concepts scores improve significantly. For chemistry concepts, paired sample t-test indicate that the difference between mean score of test 1 and test 2 is significant. Interview responses indicate that firstly, environmental values of the pre-service teachers has changed significantly from initially being egocentric towards homocentric and ecocentric. Secondly, the course has influenced their environmental awareness and concern. Thirdly, the course also contributed to the behavioral changes. The pre-

services claimed that the course was interesting and have enlightened them. Observation confirmed the interview outcomes. As such, green chemistry is one approach that could be adapted to impart knowledge and inculcate values that would nurture sustainable behaviors.

CHAPTER ONE

INTRODUCTION

1.0 Introduction

One of the aims of modern education is to support students in developing a sense of responsibility towards their respective environment. According to Miranda, Alexandre and Ferreira (2004) it is possible by educational means to encourage the formation of positive environmental values, teach the skills and cognitive ability required for active participation as individuals or members of community in solving environmental problems. Miranda et al., (2004) further asserted schools and other educational institutions have significant roles to play as actors and sources of influence in society in the promotion of sustainable development and environmental conservation.

Yencken, Fien and Sykes (2000) and Fien, Sykes and Yencken (2002) argued that existing education failed to develop environmental knowledge, beliefs, values and behavior that are central to sustainable development. According to them, the education failed to develop knowledge, beliefs, values and behavior that would protect the environment from further destruction for the benefit of the present and future generations. Fundamentally, education system reflects on the 'reproductive' and 'constructing civil society' roles of the government. In terms of 'reproductive' roles education system educate citizens in ways that will enable them to contribute to the desired economic activities and goals. In terms of 'constructing civil society' education is a tool to maintain the national well-being by responding to the concerns about social problems such as racism, poverty, public safety and increasingly the environment. Unfortunately, the press of short-term political and economic priorities has given ascendancy to the reproductive roles of the education (Yencken et al., 2000). Accordingly, Yencken et al., (2000) and Fien et al., (2002) suggested that education be reformed in terms of the curriculum.

Additionally, the revised curriculum would make little contribution for reconstructing civil society unless the methods of teaching and learning (pedagogical

knowledge) that are used in secondary schools are also reformed. This is because pedagogical choices that a teacher makes are a significant determinant of the outcomes of learning experiences of students. The nature of a particular lesson whether or not it contributes to the empowerment for participation is essentially a matter of how they are worked on pedagogically and how they are articulated with other issues in and beyond the school (Alan, 1995). Issues of pedagogy are therefore vital in the reorientation of education towards sustainability. Orr (1991) draws attention to the overtly powerful influences of teaching methods in inculcating values of a sustainable society by asserting:

> Process is important for learning. Courses taught as lecture courses tend to induce passivity. Indoor classes create the illusion that learning only occurs inside four walls isolated from what the students call, without apparent irony, the 'real world'. Dissecting frogs in biology class teaches lessons about Nature that no one would verbally profess. (Orr, 1991. pg 101).

McKeown et al., (2002) suggested that learning for sustainability should be based on constructive approaches by integrating materials from a wide range of sources. As asserted by Roth (2006), learning and knowing means having and taking position emotionally in the world and not something to be kept in the memory. Kaivola (2004) asserted sustainability could be reached with a student-centred approach, whereby students seek meaning for themselves. This is called a 'deep approach' which generally leads to higher levels of academic understanding and greater likelihood of being able to transfer their knowledge and skill to similar real-world context.

Tanaka (2000) states that sustainability could and should be integrated with chemistry concepts. Tanaka (2000) further pointed out that green chemistry is one of the approaches of integrating sustainability while teaching chemistry. Green chemistry will seek for environmental friendly and responsible chemistry. Teaching these concepts would enable students to acquire content knowledge related to environmental problem as well as fostering students' ability and attitudes necessary for precise judgment to solve these problems. Tanaka (2000) proposed the following objectives for teaching:

- Awareness: to help students to acquire sensitivity to the environment and its attendant problems, develop the ability to perceive and discriminate

among stimuli: process: refine and extend these perceptions: and use this new ability in variety of contexts.

- Knowledge: to help students acquire a basic understanding of how the environment functions, how people interact with the environment, and how the problems/issues dealing with the environment arise and how they can be solved.
- Attitudes: to help students develop a set of values and feeling of concern for the environment and the motivation and commitment to participate actively in environmental protection and improvement.
- Skills: to help students acquire the skills to identify and investigate the environmental problems/issues and contribute to the resolution.
- Participation: to provide students with opportunities to be actively involve at all levels towards such resolution

According to Anastas and Wagner (2000) the implementation of green chemistry experiments as laboratory-based pedagogy and sustainable chemistry is congruent with Tanaka's (2000) suggestions.

Green chemistry represents a fundamental paradigm shift from existing chemistry which pollutes to pollution prevention (Hjerdsen, 2000). As such, the aims of green chemistry experiments are centred on pollution prevention. Green chemistry provides opportunities to reflect the effects of the chemicals to the environment and health compared to the conventional way of conducting experiments. Moreover, green chemistry laboratory provide a platform for the students and teachers to discuss the environmental issues. Haack et al., (2005) said green chemistry's role in pollution prevention provide educators with a variety of opportunities to integrate the environmental issues in chemistry curriculum. In addition educators and students at all the levels would feel empowered to explore the connection between green chemistry and local environment.

The concept of green chemistry that is commonly being used in industrial application is incorporated into education as laboratory-based pedagogy (Singh, Szafran & Pike, 1999; Giokas, 2003). Hutchison and Reed (2000) suggested that green chemistry also known as sustainable chemistry is the chemistry that integrates

environmental issues into laboratory sessions and provide a platform for discussion of the complexity of living system and the interdependence of human being to the nature. In addition green chemistry can be also used as a tool to deliver the concepts central to sustainable development (Collins, 2001). As such green chemistry represents a shift from scientific literacy towards sustainable literacy.

1.1 Background of the Study

Fundamentally, Education for Sustainable Development (ESD) is about values and empowerment which seeks respect. This involves respecting others, those of present and future generations, respecting difference and diversity, respecting the environment as the resource provider of our planet (World Commission on Environment and Development, 1987). The underlying principle of ESD is that people of all ages and from all walks of life must be empowered to choose and appreciate environmental issues by providing value-driven learning. As such ESD aims to move the people to adopt behaviours and practises that will enable all to live a full life without being deprived of the basics such as clean drinking water and pollution free air to breathe (UNESCO, 2006). These behaviours and practices will help to ensure an environmentally sound and economically prosperous society.

According to McKeown, Hopkins, Rizzi and Chrystalbridge (2002), Sustainable Development (SD) involves a combination of three areas: environment sustainability, economic sustainability and social sustainability with culture as the underlying dimension. Sustainable development strives for a balanced development of these three areas. However, Philippou and Christou (2000) pointed out that in most peoples' minds economic growth plays a predominant role as it is associated with high income, luxury and comfortable living. Philippou and Christou (2000) further argued that social development normally follows economic prosperity. Cultural development, the most desirable characteristics or dimension of growth, frequently falls at the bottom of the priorities. Cultural development is just expected as a result or by product of economic growth. In a sustainable world, environmental protection, economic objectives and social justice should be linked in harmony. Downes (2004) pointed out that only through education can the combination of these three areas be experienced. Thus,

education is the most appropriate tool to visualize the combination of these three areas.

The aim of ESD is not to create an abstract concept but rather to cultivate a form of good citizenship applied to our daily behaviour (Hopkins, et al., 2005). Osler (1997) and Nakayama (2006) said that ESD should encourage young people to take action on what they have learned rather than simply absorbing information for the purpose of examinations. Additionally, Moore and Herb (1997) stresses that ESD must make the students understand sustainability as an aspect of their social and ethical responsibility in order to become citizens who see themselves as connected to the natural world and to other humans.

Kelly (1997) argued that in order to achieve the above mentioned desire, a holistic and integrated approach is required. Cox, Fein and White (1997) suggested ESD must be infused through the learning experiences in all subject areas. Hicks and Bord (2001) and Hopkins and McKeown (2001) argued that the status of ESD can also be achieved through the integration of sustainability concepts through particular subjects or disciplines. Fien and Tillbury (2002) claimed that any learning context should provide opportunity for the student to develop the critical thinking skill, problem solving skill and values required to understand the complex interdependence of social, cultural and economic activities. Korthagen (2004) noted these can be done by introducing relevant issues and examples that will enable students to critically examine the linkage between every day processes, events and environment and development issues. Korthagen (2004) further said real world problem solving skill will train students to become effective practitioners.

Hopkins and McKeown (2001) noted for ESD to be successfully implemented, responsible and accountable leadership is required. Consequently, the World Commission on Environment and Development (1987) asserts teachers will have a central role in delivering the message of sustainable development. Therefore, ESD should begin with the education of teachers' through teacher education programme and extended through primary and secondary schools. Fien and Tilbury (1996) asserted that in the light of ESD, teachers should be provided with substantial background and expertise, along with necessary resources to impart skills and attitudes effectively. This aspect is lacking in the pre-service teacher training curriculum. Powers (2004),

McKeown-Ice (2000) and Scott (1996) stressed the power of pre-service curriculum by saying it possess multiplier effect. They said one teacher has the potential to impact many students throughout her carrier. A teaching method course has the potential to impact many future teachers and ultimately far grater number of students.

1.2 Statement of the Problem

The National Philosophy of Education states that “Education in Malaysia is an on-going effort towards further developing the potential of individuals in a holistic and integrated manner, so as to produce individuals who are intellectually, spiritually, emotionally and physically balanced and harmonious based on a firm belief in and devotion to God” (CDC, 2006). As articulated in the National Education Philosophy, the primary and secondary school science curriculum is developed with the aim of producing such individuals. The aims of the science curriculum for secondary schools are to provide students with the knowledge and skills in science and technology to enable them to solve problems and make decisions in everyday life based on scientific attitudes and noble values. The curriculum also aims to develop a concerned, dynamic and progressive society with a science and technology culture that values nature and works towards the preservation and conservation of the environment. Hence, as stated in The National Report of Malaysia on Development of Education (MoE, 2004), ESD, in particular the concepts and components of environmental education is being implemented across the curriculum at all levels of schooling.

According to Daniel et al., (2008), the Ministry has used the infusion and integration approach, whereby environmental issues were infused and integrated into subjects such as Man and Environment in the primary level and through geography and the sciences at the secondary level. The teaching of environmental education is closely related to the nation’s aim of developing a society that is sensitive and possesses appropriate knowledge, skills and values towards environmental issues and able to contribute to the solutions of the environmental problem. However, a study by Mageswary, Zurida and Norita (2006) on attitude and action of Malaysian students towards environmental problems indicated that students were not very enthusiastic in solving environmental problems. They were more concerned about the economic

development of the nation. Environmental destructions were readily accepted as consequences resulting from economic development.

A descriptive study by Lim Siaw Fong (2005) in two schools in Selangor as well as Sharifah, Laily and Nurizan's (2005) study showed that students' and teachers' general knowledge about the environment was high. However, their understanding of environmental issues and recognition of environmental problems was only at the surface level. The findings also indicated that awareness and sensitivity towards environmental issues were very low. Aini, Fakhrul, Lily and Jariah (2003) reported that although Malaysian in-service teachers possessed a considerable level of environmental knowledge, they lacked a general understanding of the underlying causes of environmental problems. They also reported that the practices of environmental behavior among teachers were not in concert with the level of environmental concern and knowledge. This is probably due to the fact that the framework for implementation of environmental education is uncoordinated and not structured towards effectiveness within the National Education System (NES) (Daniel et al., 2008; Nadeson et al., 2005).

Sharifah and Hashimah (2006) reported that there is a huge lack of concern among Malaysians in engaging in environmental issues and portraying responsible environmental behaviours and sensitivities. A study by Aini and Roslina (2002) showed that about 1.0kg/day of waste is generated per person and despite rigorous campaigns for recycling and the attainment of recycling rate has increased from 1-2 percent in 1997 to merely 5 percent in 2001. According to Pudin (2006) "*The root cause of environmental problems in Malaysia today is none other than the very low environmental awareness within the society*". Among the reasons for the very low environmental awareness among Malaysians could be due to the lack of emphasis on Environmental Education (EE) since it is not an examination subject (Sharifah and Hashimah, 2006).

Tikka, Kuitunen and Tynys (2000) asserted knowledge will ultimately determine the nature related behaviour. However, Ponniah (1996) pointed out that most new teacher from teacher preparation institutions, graduated with a limited knowledge of environmental issues and ways it can be incorporated into their teaching. The majority of teachers felt that they are not prepared for conveying the broad spectrum of issues

and content related to the environment, as needed in the teaching of sustainable development (Miranda et al., 2004; Gan Siowck Lee, 1987). The minimal offering of environmental education in Teacher Education Programme also indicates that pre-service teacher training in environmental curricula should be overemphasized (Teoh, 1996). Teoh's (1996) finding as well as studies conducted by Sharifah (1998), Devasara (2000) and Nur Akmal (2004) indicated that the trainee teachers' understanding and awareness of environmental issues was very minimal.

Mohamed Zohir and Sharifah (2005) reported that 51% of in-service teachers in their study claimed to have 'only a little knowledge' or No knowledge at all' when asked "How much do you think you know about Education for Sustainable Development'. A total of 28% of the pre-service teachers responded that they did not know anything while 15% indicated that they knew something about Education for Sustainable Development. Findings from the study by Yencken et al., (2000) in Young People's Environmental Knowledge and Attitudes among Asia Pacific Countries indicated that students are not aware of the concept central to sustainable development. Students are more familiar with traditional environmental concepts such greenhouse effects, ozone depletion and global warming. In a study conducted by Aini et al., (2007), the concept of sustainable development was noted as alien by most of the students and only 3% could define it in ways that accorded with the definition of the Bruntland report (World Commission on Economic and Development, 1987).

There is widespread opinion that teachers' conceptions of pedagogy play a crucial role in their effectiveness as primary mediators between the subject and the learner (Kyridis, Mavriki & Tsakridou, 2005). This was further highlighted by Finger (1994) in her study explaining the relationship between environmental knowledge and action. Finger (1994) suggested that the major challenge for educators stems from the fact that individuals are already highly aware and concerned when it comes to environmental issues and problems, yet do not display the corresponding environmental behavior. Finger (1994) as well as Fien (2007) asserted that the fall in developing appropriate behaviors is due to the ineffective teaching strategies used to deliver the environmental education.

Zeeda (2001) noted that the failure of the Malaysian education in addressing the

environmental issues effectively could be attributed to the pedagogy used to deliver the knowledge. She suggested that the pedagogical techniques should encourage deep learning in which students take more responsibility for their own learning. The Malaysian Syndicate of Examination (2003) reported the inability of students to analyze, synthesize, evaluate and extrapolate the learned concept could be due partly to the teacher-centered pedagogy used to deliver the concepts. The majority of teachers still continue to use didactic approach which is teacher-centered instead of the inquiry approach (Sharifah & Lewin 1993; Ministry of Education, 1997). The TETSDAIS Project (2003) which was implemented to train the European Teachers on Sustainable Development and Intercultural Sensitivity also reported that most new teachers graduate from teacher preparation institutions with limited knowledge of education for sustainability and ways that it can be incorporated into their teaching. The lack of attention in preparing for teaching environmental literacy and sustainability results in missed opportunities to incorporate these basics into the curricula of education programs.

Icamina (1993) proposed sustainable development can be addressed by incorporating traditional knowledge and scientific knowledge. Fien et al., (2002) claimed that integration of concepts central to sustainable development in teaching and learning process portrays the phenomena of integrating scientific and traditional knowledge. The rising interest in environmental literacy and education for sustainability has created expectations that timely, accurate content should be taught to the primary, secondary curriculum as well as teacher education curriculum. Rahman (2000) suggested the content of science need to be reoriented to develop better understanding and knowledge to support for more sustainable decision making. As suggested by Roth and Barton (2004)

> In the everyday world of a community, science emerges not as a coherent, objective and unproblematic body of knowledge and practices, rather, science often turns out to be uncertain and contentious and unable to answer important questions pertaining to specific (local issues) at hand (Roth & Barton, 2004, pg. 159)

Green chemistry an environmental responsible manner of teaching and learning science is an alternative approach to make the science taught in the classroom to be very

much relevant to the everyday living of the learners. Green chemistry possesses properties of enhancing high quality education and students' capability of higher order cognitive skills such as question-asking, critical thinking, decision-making and problem solving.

1.3 Purpose of the Study

This study aims to investigate the effects of green chemistry experiments on chemistry pre-service teachers' environmental values and knowledge. The specific aims of this study include:

a. To investigate the effect of green chemistry experiments in changing pre-service teachers' environmental values over time.
b. To investigate the effect of green chemistry experiments on pre-service teachers' knowledge of
    i. chemistry
    ii. traditional environmental concepts and
    iii. sustainable development concepts

1.4 Research Questions

The research questions are as follows:

a) Is there any significant change in pre-service teachers' environmental values before and after completing the green chemistry experiments?
b) Is there any significant difference in pre-service teachers' acquisition traditional environmental concepts and sustainable development concepts before and after completing the green chemistry experiments?
c) Is there any significant difference in pre-service teachers' scores in chemistry achievement test before and after completing the green chemistry experiments?

1.5 Hypothesis

Based on the research question the following hypotheses were formulated:-

$H_0$1: There is no significant difference in the pre test, post test1 and post test2 mean values of environmental value subscales of pre-service teachers after conducting a series of green chemistry experiments in the manual. Specifically:

- there is no significant main effect of the value subscales
- there is no significant main effect of the test time.
- there is no significant interaction effect of value subscales X test time.

H_0 2: There is no significant difference in the pre test, post test1 and post test2 mean scores of knowledge subscales of pre-service teachers after conducting a series of green chemistry experiments in the manual. Specifically:

- there is no significant main effect of the knowledge subscales
- there is no significant main effect of the test time.
- there is no significant interaction effect of knowledge subscales X test time.

H_0 3: There is no significant difference in the pre test and post test mean scores of the Chemistry Achievement Test (CAT) of pre-service teachers after conducting a series of green chemistry experiments in the manual.

1.6 Rationale of the Study

Hart (2005) reported that only one percent of the survey related to environmental studies listed endangered species as a serious problem and only one in five had heard of biodiversity. Similarly, Roper Organization (2005) testing on green point average reported the average adult and teenager were able to answer fewer than four out of ten questions correctly. The respondents in the study by Aini, Fakhrul and Suan (2001) regarded the main cause for the water crisis is due to the attitude of people towards the value of water and non-adaptation of water saving practices in their daily life. These surveys revealed an important need for a citizenry with knowledge of environmental and integrative skills needed for understanding the interdependent relationships between

the environment, economy and society. Education is a key in responding to this need.

Green chemistry is proposed to be an effective laboratory-based pedagogy in delivering environmental issues to students. Green chemistry experiments or sustainable chemistry are developed with the aim of preventing and reducing pollution of the environment and risk to human health. These experiments were developed based on real world and real time scenario. The interdisciplinary nature of green chemistry would require students to use their critical thinking and communication skills to address the complex problems.

This study looked into values and knowledge that could be inculcated and imparted through the implementation of green chemistry experiments among pre-service teachers. It is significantly important to inculcate the appropriate values to the students, since values form the individuals' general beliefs and world view (Stern, Dietz & Guagnano, 1995). General beliefs and world view determined their specific beliefs and attitudes which in turn will determine their behaviour. From the perspective of environmental education it is significantly important to transform the students' value from egocentric towards egocentric. The students' values tend to evolve from their action concerning themselves towards concern for the whole biosphere.

In addition to value, knowledge imparted is also equally important to bring about behavioural changes among the students. According to Ajzen and Fishbein (1985) knowledge will determine the attitude and attitude in turn will determine the behaviour. Finding from Aini et al's (2001) study indicated that the traditional environmental knowledge could only enhance the concern towards environment. According to them, students taught with the traditional environmental knowledge perform significantly lower on environmental behaviour. Therefore, it is imperative to impart knowledge such as concepts central to sustainable development to bring the intended behaviour change.

In order to deliver appropriate values and knowledge to the students, it is important for teachers to attain these values and knowledge. As McKeown (2006), stressed the importance of teachers in delivering value centred education.

> Teachers influence the lives of children who are fortunate enough to go to school. The cumulative effects this daily contact has on the

> lives of pupils—either as children or later as adults—is enormous. While other professionals may have contact with a child during critical moments (e.g., a physician administering an antibiotic), it is the teacher's daily contact with a child that has a much greater influence. Teachers help shape each pupil's worldview, economic potential, attitude toward others in the community, participation in community decision-making, and interactions with the environment. Teachers educate future leaders, professionals, laborers, parents, and citizens of the world. Although teachers are often unseen heroes in our communities, they are our hope for creating more sustainable societies. (McKeown & Hopkins, 2002, pg. 252)

1.7 Significance of the Study

The experiments and finding obtained through this study is resourceful for the curriculum planners and policy makers. The experiments introduced in this study portray the greener version of the experiments currently exist in KBSM chemistry curriculum and pre-service teachers' curriculum. As such this study represents one way of greening the KBSM chemistry curriculum and chemistry teaching methods course. Besides the experiments being benign, these experiments make way for opportunities to integrate environmental issues as well. Thus, implementation of green chemistry experiments as in this study is one of the approaches to reform existing education to address ESD which could be replicated by curriculum planners.

Findings obtained from this study provided further insight on the impact of green chemistry on environmental values and knowledge. Values inculcated and knowledge imparted is significantly important as values and knowledge noted to be the determinant of behavioural change. Finding of this study indicated the knowledge imparted through green chemistry and consequently the values inculcated had successfully developed sustainable behaviours. As such green chemistry as implemented in this study is an approach to develop behavioural change in line with UNESCO's Decade of Education for Sustainable Development which centred on man and asking human to change their behaviours in order to lead sustainable lifestyles.

1.8 Limitation of the Study

The aim of ESD is to integrate environmental issues across the curriculum. This study was conducted in teaching of chemistry, thus the findings of this study are limited and centred on chemistry. However, incorporation of environmental issues in a particular discipline is also accepted as an approach of implementing ESD (Cox et al., 1997).

The duration of the study is only 14 weeks. If the duration of the study is prolonged there would be a higher probability to produce a clearer and more accurate result. Rokeach (1973) claimed significant value change can be detected between 3-5 weeks of the treatment. According to him continuous exposure enhances the value formation.

This research used a case study approach which limits the generalization of the study. However, according to Gay and Airasian (2000) by applying the same treatment, using repeated measure design and when the different students respond similarly to the treatment, generalizability of the study will increase.

This study used a one group pre-post design. Since there wasn't any control group, changes in the dependent variable could be caused by other external factors such as previous knowledge. However, according to Howell (2007) when samples are repeatedly exposed to the treatment and measured, the samples serve as their own controls because the characteristics of individual subjects remain constant under different treatment time and changes in dependent variable could be due to the treatment. Additionally, when the sample serves as their own control Hawthorne effects could also be controlled.

1.9 Operational Definitions

1. *Chemistry Achievement Test* refers to a set of questions that evaluates the ability of pre-service teachers applying chemistry concepts in solving environmental problems. It will be measured using five semi

structured questions.

2. *Values* are normative views about the world. There are three types of value concerning the environment: ecocentric, egocentric and homocentric. These values will be measured using questionnaire on environmental values (QEV) (Kempton, Boster & Hartley, 1995).
3. *Sustainable development concepts (SDCs)* refer to concepts such as biodiversity, carrying capacity, precautionary principle and intergenerational equity evaluated using Test on Environmental Concepts (Yencken et al., 2000).
4. *Traditional Environmental Concepts (TECs)* refer to concepts such as air pollution, water pollution, haze, global warming, solid waste and recycling evaluated using Test on Environmental Concepts (Yencken et al., 2000)

CHAPTER TWO

LITERATURE REVIEW

2.0 Introduction

The main aim of the study is to investigate the effect of green chemistry experiments as a laboratory-based pedagogy on pre-service teachers' environmental values and acquisition environmental knowledge and chemistry knowledge. This chapter begins with a discussion on education for sustainable development and review of literature on education for sustainable development in Malaysia. This will be followed by explanation of green chemistry as sustainable chemistry and the role of science laboratory work on imparting knowledge and development of values. The importance of environmental values and knowledge will be discussed as well. This chapter will end with illustrating the theoretical and conceptual framework that governs this study.

2.1 Education for Sustainable Development

Sustainable Development (SD) is a difficult concept to define (Hopkins et al., 2001). This is not surprising as there are hundreds of definitions for sustainable development and its conceptualization is complex and still evolving (Dale & Newman, 2005). However, World Commission on Environment and Development (1987) defined sustainable development as *development that meets the needs of present without compromising the ability of future generations to meet their own needs.*

SD reflects the relationship between the ecological environment and the economic development process (Barbier, 1987). Economic development is the process where the needs of the people in the country are fulfilled and sustained over time. SD according to McKeown et al. (2002) is a combination of three components: environment, economic and social. The well being of there areas is interwined and not separate (Figure 2.1). A healthy prosperous society for instance, relies on a healthy

environment to provide food and resources, safe drinking water and clean air for its citizen. Sustainability is a paradigm for thinking about the future, by considering the balance amount of economic, social and environmental factors in the process of seeking development and improvement quality of life.

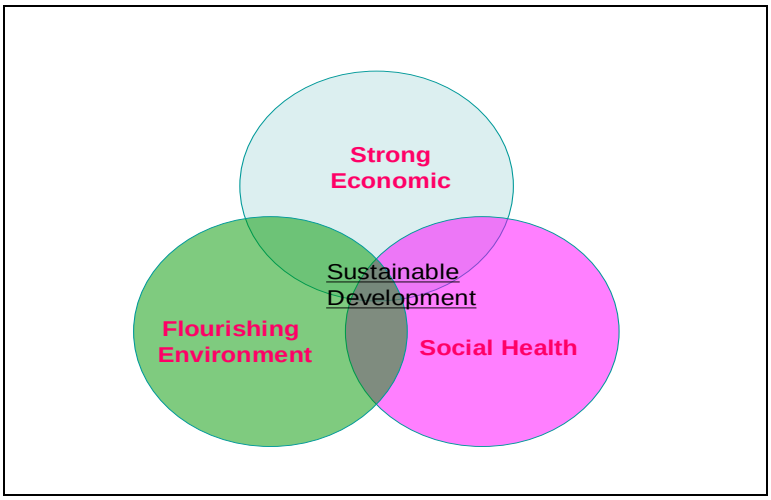

***Figure 2.1*. Sustainable Development (adapted from Dave, 2004)**

In 1987, the World Commission on Environment and Development report, "Our Common Future", indicated the importance of education especially because 'the changes in human attitude that we call for depend upon a vast campaign of education' (Filho, 1997). Again, during The Earth Summit, *Agenda 21 of Chapter 36*, reiterates the role of education in mobilizing the society towards a sustainable development. *Agenda 21* puts forward the role of education in pursuing development that respects and nurtures the natural environment and focuses on re-orienting the existing education framework to foster values and attitudes towards environment as well as, envisioning the ways and means of doing so. Accordingly, education that focuses on bringing SD into practice is ESD. ESD is a dynamic concept that utilizes all aspects of public awareness, education and training to create or enhance an understanding of the linkages among the issues of SD. ESD is a vision of education that seeks to balance human and economic well-being with cultural traditions and respect for the earth's natural resources.

Ahlberg (2004) proposed the first tentative theory of Education for Sustainable Development (Figure 2.2). The theory highlights ability, competence, expertise,

intelligence, creativity and wisdom for all aspects of sustainable development, and these are noted to be the core of sustainable development.

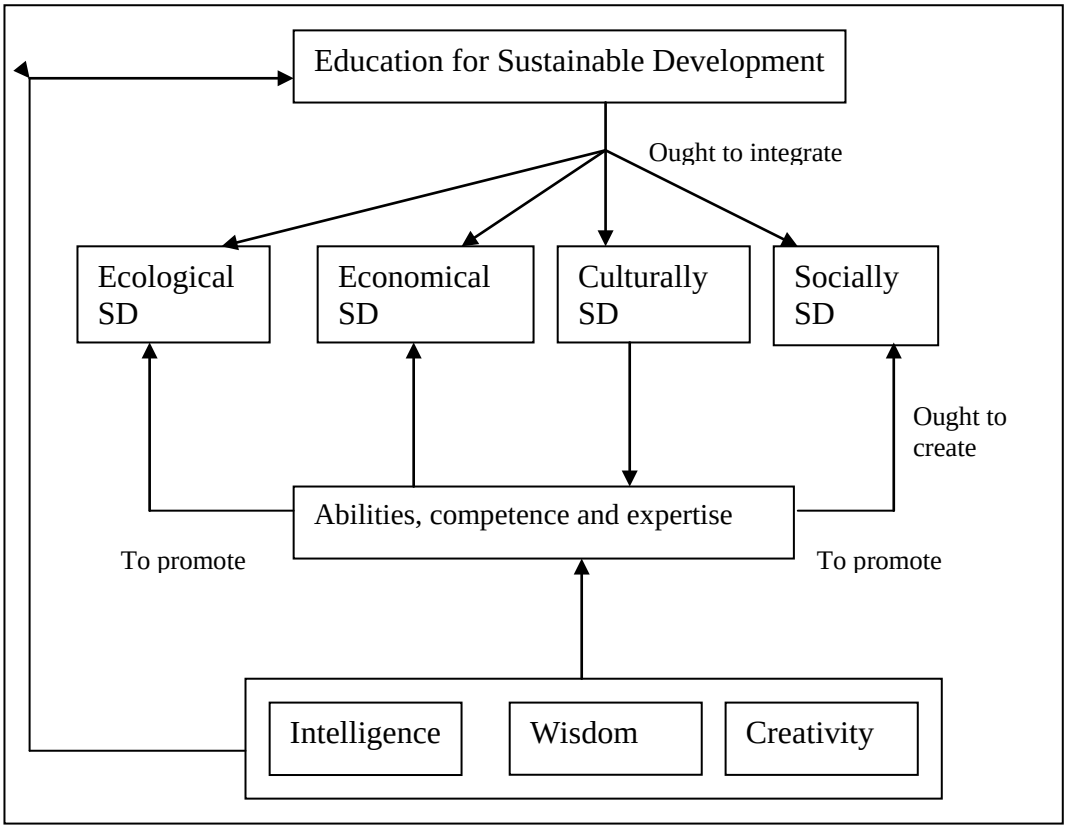

Figure 2.2. **Tentative theory Education for Sustainable Development (adapted from Ahlberg, 2004)**

According to Zoller (2004), sustainable development requires a radical change in the environmental behavior and thinking. Therefore, there is an urgent requirement for a paradigm shift from algorithmic/imparting knowledge type teaching to higher-order cognitive skills learning (Table 2.1). The ultimate target of education is to produce environmentally literate graduate, who is capable of evaluating thinking, making decision, solving problems and taking a responsible action accordingly. The teaching should move away from knowing facts and algorithmic solving exercises/tasks towards conceptual learning from problem solving. The process of education should be student-centred and related to real world issues rather then teacher-centred. Additionally, Kaivola (2004) suggested that Education for Sustainable Development

(ESD) should be based on a student-centred approach with focus on improving academic, higher order thinking skills, foster teaching and learning in meaningful ways.

Table 2.1
Paradigm shifts in education (adapted from Zooler, 2004)

From	To
Technological, economical and social growth	Sustainable development
Corrective	Preventive
In-vitro isolated and highly controlled	In-vivo complex systems
Disciplinarily	Transdisiplinary
Scientific enquiry	Socially accountable and responsible and environmentally sound
Algorithmic lower-order skills (LOCS) teaching	Higher Order Cognitive skill learning (HOCS)
Reductionist thinking	System thinking
Dealing with topics in isolation or closed systems	Dealing with complex, open system
Knowing/recognising/applying of facts and algorithms for solving tasks	Conceptual learning for problem solving and transfer.
Teacher-centered	Student-centered, real world, research oriented learning.

Pedagogical knowledge plays an important role in the process of conveying values, skills, perspectives and ethics meaningfully (Fien, 2002). In order to attain sustainability, pedagogy must be viewed as a process of encouraging students to explore questions, issues and problems, especially in content relevant to them and their communities. The pedagogy used must involve in the development of student-centred approaches in teaching and learning. This does not mean teacher centred method such as exposition, narration and demonstration is totally excluded in teaching and learning process (Kaivola, 2004). Student centred approach should be used whenever is possible. In this context, learning should be based in the community and use the environment and community as resource for learning. It should involve activities such as problem solving, debating over controversial issues, role-play, simulation games, values clarification and as well as a range of creative and experiential activities. Hence, teachers should adopt the pedagogy of learning though thinking. Learning through thinking is a process of learning in which learners construct their own knowledge by asking questions, problem solving and taking decision based on their own judgment. Student centred learning, innovative methods of teaching problem based learning, and

various applications of information technology encourage students to seek meaningful learning. This the so-called ‘deep approach’ and ‘strategy approach’ by students generally lead to higher levels of academic understanding. Students are likely to transfer their knowledge and skills to other context and also enhance the live long learning, even after they leave school.

Maheshwari (2004) proposed that ESD should be research-based and focus on issues of promoting good life for us and the future generations. Learning of topics such as natural world, effects of human activities on environment and trends in population growth should not be taught as knowledge needed to pass examination. Instead, through understanding of these topics, children should internalise the concern for adoption of a sustainable future. Bandhu (1990) further enhance the fact that to achieve the status of education for sustainable development, the teaching and learning must accomplish in bringing changes in environmental values of the students.

Fien (2000) illustrates ways in which education for a sustainable future can be integrated into and across twelve different school subjects or areas of the curriculum. The first approach is interdisciplinary approach. In this approach, students need to integrate ideas from many different perspectives rather than compartmentalize what they learn into discrete 'boxes' of knowledge. In order for successful implementation of this approach, teachers need to be flexible and skilled in accessing and integrating knowledge from different sources and disciplines.

The second approach is integrating ESD through educational objectives. Many educational objectives, especially in the areas of attitudes and skills, are common across most subjects in the curriculum. Teaching about sustainability emphasizes critical and creative thinking, problem solving, decision-making, analysis, cooperative learning, leadership, and communication skills. Consequently, it is a very good way of integrating sustainability into educational objectives without the problem of curriculum overload.

The third approach is infusing through learning experiences in all subject area. Ideally, education for a sustainable future should permeate the entire school curriculum, with every subject area, at every year level, dealing with aspects of sustainability in some way. Some subjects, by their very nature, present greater opportunities for such

infusion than others do, but all subjects have a very important role to play. For example in science teaching sustainability can be integrated through:-

- investigating chemical changes to the atmosphere caused by human and industrial activity
- water quality monitoring and studying the effects of oxygen levels on life forms
- seed collecting, planting and propagating
- investigating the physics of energy production from renewable and nonrenewable resources and their
- environmental impact
- studying food webs and ecosystems and the impact of inorganic fertilizers, pesticides and waste products
- investigating the science of global warming
- inviting community resource people to talk about science issues

Dawe (2004) has developed eleven potential approaches to teach ESD among pre-service teachers (Table 2.2). They are categorised under three headings: Personal, Re-connecting to reality and Holistic Thinking. Miranda et al., (2004) proposed two approaches in educating teachers in education for sustainable development. One of it is the teacher as a reflective practitioner approach. According to this approach teachers' actions do not follow the instrumental logic of technical rationality but their actions are based on practical and tacit knowledge activated during the action process. The second approach is the teacher as a socio-critical agent. According to this approach, the teachers should have sufficient autonomy for critical reflection on daily teaching activities and the context in which these activities occur.

Table 2.2.
Potential approaches to teach ESD (adapted from Dawe, 2004)

The personal	
1. Educators as role model	Tutors themselves must change their lifestyles to be the role models for the students and their communities in order for the transformation towards sustainability to take place.
2.Learners as teachers and teachers as learners	Teacher's role is to act as catalyst for the discussion and re-evaluation of human values rather then delivering knowledge. Student's should be given opportunity to participate in construction and transformation of the study material that are meaningful in the context of their live and work
3.Lifelong learning	The purpose of education is to develop informed citizens that are capable of interacting positively and solving the problems of the community.
Reconnecting to reality	
4. Relationship with local community	Changes will never happen if we continue to dream about the future. Changes happen by being fully in touch with problems of their society.
5. Real life problems and experiences	Education has become ever more specialised and theoretical, far removed from the messiness of life. ESD will therefore have to try to find real life problems and actual experiences as learning situation.
6. Reconnecting people to people and to nature.	Environmental education shows that lecturing to pupils does increase environmental awareness, but does not automatically translate into sustainable action. Only if you know something, love it, have interest in it and develop responsibility towards it, you will care for it. Teachers should think about direct contact with nature.
7. Developing capacity for enacting changes	We need to move towards sustainability and acknowledge that our current situation is less sustainable, any learning which does not enhance the individual behaviour and will not lead to social change. ESD should develop the capacity for change in behaviour, rather than imposing a particular type of knowledge on pupils.
8.Reconnecting to reality	University's Sustainability Management systems provide opportunities for students to engage with the environmental management. This shows a direct links between ESD and practical issues such as safe disposal of waste and links to pesticides.
Holistic thinking	
9. Interdisciplinary and critical thinking	This is an important 'meta-skill': students need to be able to think critically about the nature of knowledge and what knowledge is produced and validated.
10. System thinking	ESD should be learned by seeing things differently as a whole system and develop enough reflective to understand how the whole system works.
11. Sensitivity for all the subjects.	ESD student will need to be able to recognise the contributions of all disciplines. ESD students must be sensitive to interaction between subjects.

Drake (2006) in his study used the Living Values Educational Program (LVEP) as a tool to teach ESD. The Living Values Educational Program is based on holistic thinking and life long learning approach. Drake (2006) reported that this program developed the positive social skills of students' while aggressive behavior declined. Drake (2006) also noted an increase in respect, caring, cooperation, motivation and the ability to solve problems.

Additionally Fien and Tilbury (1996) used an interdisciplinary, experiential, holistic, locally relevant, approach that emphasizes value, learner-centered and problem solving methods to teach ESD. Fien et al. (1996) asserted that these methods would enhance the effectiveness of teaching sustainability. Rowe (2000) claimed, at Northern Arizona University the approaches proposed by Fien et al. (1996) have been successfully implemented across the curriculum. Rowe (2000) reported that interdisciplinary approach increased the students' concern towards future society, increased the belief that the students can make a difference and increased the students' willingness to participate in solving societal and environmental problems.

The effectiveness of problem based learning to teach about sustainability is reported by Steinemaan (2003). According to Steinemaan (2003), students regarded problem based learning as an effective tool to learn about sustainability. Problem based learning also inspired broader thinking about sustainability. The students also appreciate the opportunity to work on real-world problem and saying one of the students quoted as:-

> I think the most successful curriculum is the ones that give the opportunity to put into practices the concepts learned in the classroom.

Zimmermam (1996) reported the effectiveness of using interdisciplinary, cross curriculum and holistic approach. By working together as teams in the classroom and by sharing experiences, the students can use their knowledge from local examples on a global scale. By focusing on the local environment, conflicts from the three faculties (environment, economic and social) at the same time the students gained action competence that enabled them to suggest needed changes or come up with innovative ideas for solving the problems.

Agashe (2000), in her action research case study infused cooperative learning approach into science teaching to address sustainable development. Agashe (2000) reported that cooperative learning could enhance the achievement of positive individual and social skills in cognitive, affective and psychomotor. These three areas significantly related to important aspects of ESD.

2.2 Education for Sustainable Development in Malaysia

Since the Sixth Malaysian Plan (1991-1995), (Economic Planning Unit, 1991) the Malaysian Government has integrated environmental considerations into the formulation of projects and programs. This was further strengthened in the Seventh Malaysia Plan (2996-2000), the Eighth Malaysia Plan (2001-2005) and in the Ninth Malaysian Plan (2006-2010). Each plan's requirements are intended to ensure efficient management of the environment and its natural resources in order to attain sustainable development. Among the key strategies taken by the Government in environmental education are (Seventh Malaysia Plan, Economic Planning Unit, 1996):

- broad-based campaigns through the mass media to encourage the life-long process of environmental education;
- infusing formal environmental education in the school curriculum;
- incorporating an environmental education subject in teacher training;
- establishment of Research Centre for Environmental Health; and
- active participations of private and public sectors including non-governmental organizations in promoting environmentally responsible behaviors.

The Economic Planning Unit of the Prime Minister's Department, as the country's implementer of *Agenda 21* indicates that Ministry of Education has actively advocated for the development of a curriculum that has elements of environmental education. The National Report of Malaysia on Development of Education prepared by the Ministry of Education (2004) stated that education for sustainable development, in particular the concept and components of environmental education should be implemented across curriculum at all levels of schooling. The elements of