THE EFFECTIVENESS OF NANOSCIENCE ACTIVITIES IN IMPROVING SECONDARY SCHOOL STUDENTS' ATTITUDE, RELEVANCE, AND UNDERSTANDING OF CHEMISTRY CONCEPTS

CHUA KAH HENG

UNIVERSITI SAINS MALAYSIA

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by

CHUA KAH HENG

**Thesis submitted in fulfilment of the requirement
for the degree of
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CAT	Chemistry Achievement Test
CDC	Curriculum Development Centre
KBSM	*Kurikulum Bersepadu Sekolah Menengah* (Integrated Curriculum for Secondary School)
MMR	Mixed Method Research
MOE	Ministry of Education
PMR	*Penilaian Menengah Rendah* (Lower Secondary Examination)
SPSS	Statistical Packages for Social Sciences
ROSE	Relevant of Science Education
ROCES	Relevant of Chemistry Education Scale
STEM	Science, Technology, Engineering, and Mathematics
TIMSS	Trends in International Mathematics and Science Study
TOSRA	Test of Science-Related Attitudes

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ABSTRAK

Aktiviti makmal merupakan salah satu bahagian yang penting dalam pengajaran dan pembelajarn kimia. Dalam pembelajaran kimia, cikgu cuba menambahkan pengetahuan pelajar. Selain itu, sama cikgu juga membangunkan kefahaman pelajar dari segi idea, teori, serta model yang berguna untuk menerang dan meramal kelakuan yang berlaku dalam kimia. Pada masa yang sama, ini juga dapat memupuk sikap positif terhadap pembelajaran kimia dan meningkatkan kerelevanan pendidikan kimia. Penyelidikan ini bertujuan untuk memperkenalkan aktiviti-aktiviti nanosains serta mengkaji kesannya ke atas sikap pelajar terhadap pembelajaran kimia, persepsi terhdapa kerelevanan pendidikan kimia serta kefahaman konsep kimia. Soal selidik dan temubual telah digunakan bagi melihat perubahan pada pembolehubah bersandar. Soal selidik Sikap terhadap Pembelajaran Kimiatelah digunakan bagi mengukur perubahan dalam sikap. Skala Kerelevanan terhadap Pendidikan Kimia telah digunakan untuk mengukur persepsi pelajar terhadap kerelevanan pendidikan kimia dan Chemistry Achievement Test bagi mengukur kefahaman konsep-konsep kimia. Seramai 163 orang pelajar Tingkatan Empat terlibat dalam kajian ini. Sebanyak 8 aktiviti nanosains digunapakai sebagai manual aktiviti dalam makmal. MANCOVA, ANCOVA dan Bayesian analisis telah dijalankan untuk melihat perubahan pada variable bersandar. Bagi nilai sikap terhadap pembelajaran kimia, keputusan yang signifikan diperolehi untuk sikap secara keseluruhan dan keempat-empat konstruk. Perubahan yang signifikan juga diperolehi untuk kerelevenan terhadap pendidikan

kimia secara keselurahan dan keenam-enam konstruk. Untuk kefahaman konsep kimia, analisis ANCOVA menunukkan bahawa terdapat perbezaan yang signifikan di antara kumpulan kawalan dan kumpulan eksperimen. Dapatan temubual menyokong dapatan yang diperolehi daripada analisis kantitatif. Justeri, boleh disimpulkan bahawa aktiviti nanosains ialah salah satu pendekatan yang boleh digunakan untuk menyampai pengetahuan serta meningkatan sikap perlajar terhadap pembelajaran kimia dan pengubah persepsi perlajar terhadap kerelevanan pendidikan kimia.

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relevant of chemistry education and all the six constructs. For chemistry concepts, ANCOVA analysis indicate that the difference between control group and experimental group is significant. Interview responses further support the significant results obtained in the quantitative findings. As such, nanoscience activities are one approach that could be adopted to impart knowledge and enhance students' attitude towards chemistry lessons and change students' perception towards the relevance of chemistry education.

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CHAPTER ONE

INTRODUCTION

1.0 Introduction

One of the aims of modern education is to produce human capital need and development of the nation. According to the Malaysian National Philosophy of Education, education should be cultivated students who can contribute to the development of the society positively and constructively (Ministry of Education, 2001). Most importantly, education should assist the country to move forward in achieving status of developed and harmonious country. Therefore, schools and other educational institutions play a significant role in enabling the system in producing high quality human capital, hence fulfilling the need of the country as dictated in the Vision 2020 (Mohamad, 1991).

In order to realize the vision in making Malaysia as one of the developed nation by the year 2020, government has set a high priority for the advancement of science and technology. The importance of science and technology is stated as one of the vital agenda of Vision 2020. The agenda focuses in creating scientifically literate and innovative human capital, forward looking and able to contribute to the civilization of future scientific and technological world (Mohamad, 1991). In the nutshell, mastery of science and technology among the younger generation is important and crucial in order to achieve the agendas of Vision 2020.

School science curriculum plays an important role in helping the country to produce human capital trained in science and technology. As such it is imperative to promote school science as a favourable subject from early stage of schooling. This is a call for the teachers to employ an appropriate pedagogy to deliver the content effectively. Hence, suitable pedagogy ultimately reported to influence the learning outcome and learning experiences of the students (Mumba, Banda, Chabalengula, & Dolenc, 2015; Ochonogor, 2011).

Past studies reported that to sustain students' engagement in science, students need to have a positive attitude towards the subject matter (Anwar & Bhutta, 2014; Basu & Barton, 2007; Osborne, Simon, & Collins, 2003); able to see the relevance of the subject matter with their everyday routine (Childs, Hayes, & O'Dwyer, 2015; Sevian & Bulte, 2015) and possess a good grasp of knowledge about the subject matter (Kennedy, 1998). As mentioned previously, effective teaching approach is necessary in order to attain the aforementioned learning in science particularly in chemistry. Nanoscience can be integrated in the teaching and learning chemistry, since nanoscience is becoming one of the important aspects in the contemporary sciences which has numerous applications in everyday life (Ghattas & Carver, 2012; Santiago & Morell, 2006). In the current study, nanoscience activities were used to teach certain chemistry concepts and its effectiveness in promoting understanding of the chemistry concepts, students' perceptions towards the relevance of chemistry education and attitude towards chemistry lessons were measured.

1.1 Background of the Study

In order for the education system to produce the desired outcome successfully, the system must be guided by a well-defined philosophy (Frankena, Raybeck, & Burbules, 2002). In the Malaysia context, the education system is guided and supported by the National Philosophy of Education (Ministry of Education, 2001). According to the Malaysian National Philosophy of Education, education in Malaysia is an on-going effort in developing the potential of individuals in a holistic and integrated manner. In other words, education is designed to produce individuals who are intellectually, spiritually, emotionally and physically balanced and harmonious (Ministry of Education, 2001). Hence, curriculum and policies have been designed and introduced in line with the National Philosophy of Education.

The ideas and the essence of National Philosophy of Education have been transferred into the National Philosophy of Science Education. The National Philosophy of Science Education stated that, "In consonance with the National Education Philosophy, science education in Malaysia nurtures a science and technology culture by focusing on the development of individuals who are competitive, dynamic, robust and resilient, and able to master scientific knowledge and technological competency" (Curriculum Development Center, 2006, p. 4). At the same time, the National Philosophy of Science Education also addresses one of the main concerns of National Philosophy, which is building a modern science and technology oriented progressive society (Curriculum Development Center, 2006). In short, the secondary science education targets to produce all-rounded Malaysian citizens who are scientifically and technologically literate, instilled with scientific curiosity, dynamic efforts, and knowledge and intellectual to meet the current needs. Moreover, the citizens are expected to have high competency in scientific skills, capable to cope with tremendous changes in science and technology, alongside with noble values. On top of that, they ought to possess responsibility towards environment and nature for the betterment of mankind, future generation, society locally and globally.

The aims of the national science curriculum have been translated into the core science and four other elective sciences: biology, chemistry, physics and additional science which are offered at the upper secondary level. The major aims of the chemistry curriculum are to provide students with the knowledge and skills in chemistry and technology; enable students to solve daily life problems; and make decisions based on scientific attitudes and noble values (Curriculum Development Center, 2006).

The chemistry curriculum consists of 14 topics and these 14 topics are presented as four main themes in the Form Four and Form Five syllabus. The four themes are introductory chemistry, matter around us, interactions between chemicals, and production and management of manufactured chemicals. The 14 topics are introduction to chemistry, the structure of the atom, chemical formulae and equations, periodic tables of elements, chemical bonds, electrochemistry, acids and bases, salts, rate of reaction, carbon compounds, oxidation and reduction, thermochemistry, manufactured substances in industry, and chemicals for consumers (Curriculum Development Center, 2012, 2013). All the 14 topics aimed to equip students with fundamental knowledge in chemistry and technology and enhance students' scientific knowledge and technological competency to ensure they are scientifically and technologically literate individuals in line with the National Science Philosophy (Curriculum Development Center, 2012, 2013).

The pedagogical strategies employed by the teacher is an integral component of teaching and learning process particularly in imparting chemistry concepts as these approaches cultivate conducive learning environment which ultimately enhance the learning of chemistry (Curriculum Development Center, 2012, 2013). Ochonogor (2011) mentioned that ways and practices used by the educators might positively influence students' passing rate and quality of passes in the chemistry. For instance, according to Mumba et al. (2015), inquiry-based instruction in a chemistry class provided an impactful learning experience to the students. Likewise, other studies also have reported that the use of inquiry-based instruction had brought positive impact in achieving the goals of science teaching for students in elementary as well as in high schools (Mastropieri, Scruggs, & Graetz, 2005; Mastropieri et al., 2006; Wang, 2011).

Nanoscience is one of the most contemporary scientific innovations of the 21st century and as the newest and most current field in science, and is noted as one of the widely researched area (Ghattas & Carver, 2012; Hingant & Albeb, 2010). Nanoscience requires to look into atoms and molecules at the microscopic level (Laherto, 2010) and influences human's daily life in many ways (Ho, Scheufele, & Corley, 2010). For example, nanoscience technology is utilised in the production of anti-aging cosmetic products, DVD's and CD's, antibacterial coating, telecommunication products such as mobile phones, Bluetooth, signal transmitters, stain resistance coating for furniture and textiles, sportswear and equipment. Ghattas and Carver (2012); Santiago and Morell (2006) reported that nanoscience had the capacity to narrow the gap between real science and textbook science. For this reason, nanoscience has been infused into the teaching and learning of chemistry in various contexts. For instance, in Europe, countries such as Italy, UK and Slovenia, have infused nanoscience into the high school curriculum (Ban & Kocijancic, 2011; Goldoni, Lisotti, & Renzi, 2013). Besides, countries such as Israel also infused the nanoscience into the curriculum for teaching and learning of secondary level chemistry (Blonder & Mamlok-Naaman, 2016; Blonder & Sakhnini, 2012) .

Attitude is one of the constructs that has been researched for more than 40 years (Aiken & Aiken, 1969; Can, 2012; Cheung, 2009a, 2009b, 2011; Koballa, 1988; Koballa & Crawley, 1985; Otor & Achor, 2013; Xu, Villafane, & Lewis, 2013) and is a well-established hypothetical construct that predict humans' behaviours (Can, 2012; Cheung, 2009b, 2011; Eagly & Chaiken, 1993; Glasman & Albarracin, 2006; Kelly, 1988; Koballa, 1988; Osborne et al., 2003). Attitude still stays relevant in today's context because not only is it able to predict students' achievement in class (Lang, Wong, & Fraser, 2005), but it also covers a wider niche area inclusive of human's behaviour towards a subject or any object. Attitude towards a subject matter is defined in various ways and various methods and different instruments were used to measure attitude. For instance, in an early study conducted by (Fraser, 1978) in the Test of Science-Related Attitudes (TOSRA) students' attitude towards science was defined using seven different constructs: social implications of science, normality of scientists, attitude to scientific inquiry, adoption of scientific attitudes, enjoyment of science lessons, leisure interest in science, and career interest in science. TOSRA is widely adopted by many researchers in science education research and used in various contexts (Chua & Karpudewan, 2016; Joyce & Farenga, 1999; Lang et al., 2005). However, the multidimensionality of the TOSRA items has not been confirmed by any empirical research. After performing the factor analysis, many researchers were in the opinion that the 70 items do not fit well into the seven scales (Khalili, 1987; Schibeci & McGaw, 1981; Smist, Archambault, & Owen, 1994).

Kind, Jones, and Barmby (2007) presented attitude towards science as learning science in school, practical work in science, science outside of school, importance of science, self-concept in science, and future participation in science. On the contrary, Salta and Tzougraki (2004) in their work defined attitude as students' views on the difficulty, interest, usefulness of chemistry course, and importance of chemistry. In another study, Tapia and Marsh (2004) emphasized that 'Attitude scales must withstand factor analysis, tapping the important dimensions of attitudes, and require a minimum amount of time for administration' (p. 17). Moreover, researchers such as Breckler (1984), Krosnick, Judd, and Wittenbrink (2005), and Munby (1997) emphasized the importance of a confirmatory approach to test the construct validity of attitudinal data, which can be accomplished with confirmatory factor analysis (Byrne, 1998). Unfortunately, most science educators used an exploratory approach rather than confirmatory approach to perform validation of their attitude scales (refer to Kind, Jones, and Barmby, 2007 and Salta and Tzougraki, 2004).

Considering all the weaknesses of the earlier proposed attitude scales and validation processes of the scales, Cheung (2009a) proposed a new dimension of attitudes towards chemistry based on the latent process viewpoint consist of "liking for chemistry theory lessons", "liking for chemistry laboratory work", "evaluative beliefs about school chemistry" and "behavioural tendencies to learn chemistry". The Attitude Towards Chemistry Lessons Scale (ATCLS) with these four scales was later validated using confirmatory factor analysis method. Compare to other attitude dimensions, the dimensions proposed in the ATCLS by Cheung is reported to be comprehensive, holistic and covers all the aspects of teaching and learning chemistry

(Cheung, 2007, 2009a, 2009b). As such, attitude towards chemistry lessons in this study is defined according to Cheung's dimensions.

Studies reported that students with favourable attitude to learn sciences show a good prediction for them to learn advance sciences (Kelly, 1988) and predicts their future preference and behaviours (Glasman & Albarracin, 2006). Therefore, attitude is one of the important outcomes of chemistry education in secondary schools besides academic achievement. It is evident from the literature that teaching approach employed by the teacher determines the students' attitude towards chemistry (Blonder, 2010; Blonder & Dinur, 2012; Blonder & Mamlok-Naaman, 2016; Blonder & Sakhnini, 2012). Particularly, it was noticed in a study involving 20 teachers from Australia, focusing on a relationship between teaching approaches with students' attitude in learning, an impactful and meaningful teaching approach was believed to foster a positive attitude among the students (Mackenzie, Hemmings, & Kay, 2011). Meanwhile, Hains-Wesson (2011) asserted that different teaching technique applied during the teaching and learning can attract students, improve students' engagement, and subsequently enhance students' attitudes as well as learning experience.

Knowledge on chemistry has a close connection with human's daily life. In order to make the chemistry content which are taught in the classroom to be relevant with students' everyday living, the teaching approach employed by teacher should be able to narrow the gap between students' wishes and teachers teaching (Hofstein, Carmi, & Ben-Zvi, 2003; Yager & Weld, 2000). These happen when the approach allows students to immediately connect school chemistry with their daily life occurring (Blonder & Dinur, 2012; Blonder & Sakhnini, 2012; Laherto, 2012; Schank, Wise, Stanford, & Rosenquist, 2009). One possible way is by having nanoscience in the curriculum as it is noted that nanoscience act as a bridge which links the chemistry concepts with daily life application (Varadan, Pillai, Mukherji, Dwivedi, & Chen, 2010).

According to Stuckey, Hofstein, Mamlok-Naaman, and Eilks (2013) relevance in the context of chemistry education is manifested in three dimensions: individual relevance, societal relevance, and vocational relevance. The relevance of chemistry education based on these three dimensions covers both intrinsic and extrinsic components, as well as the present and future aspects. The individual relevance of chemistry education refers to the matching of students' curiosity and interest, providing students with requisite and useful skills for coping with their everyday lives. The relevance of chemistry education from societal viewpoint is about preparing students to be self-determined and responsible to lead lives in society by understanding the interdependence and interaction of chemistry and society. Meanwhile, the relevance of chemistry education from the vocational dimensions is about offering future professions and career opportunities, preparing for further academic endeavours which will inform the students about future career undertakings related to chemistry. In this study, relevance of chemistry education was measured in terms of what I want to learn about, my future job, me and the environment, my chemistry classes, my opinion about chemistry and technology and my out-of-school experience (Sjoberg & Schreiner, 2010). These six constructs of relevance fit into three dimensions of individual, society and vocational relevance (Stuckey et al., 2013). The items from I want to learn about, my chemistry classes, my opinion about chemistry, and my out-of-school experience fits to the individual dimension; meanwhile items from me and the environment goes well with the societal dimension and my future job fits into the vocational dimension.

Chemistry, by nature is highly conceptual. Therefore, students' conceptual understanding of chemistry concepts is an important area of research in chemistry education (Ben-Zvi, Eylon, & Silberstein, 1988; Gabel, 1988). In school, chemistry concepts such as the structure of the atom, state of matter, salts, acids and bases are the fundamental concepts of chemistry that have to be mastered by students at the early stage of learning chemistry (Kirbulut & Beeth, 2013; Levy Nahum, Mamlok-Naaman, Hofstein, & Taber, 2010; McWeeny, 2007). Understanding these concepts are important in the learning curve (Wu, Krajcik, & Soloway, 2001), as it has a close connection in explaining everyday phenomena in a scientific manner (Kirbulut & Beeth, 2013). Research has shown that many students do not understand fundamental chemistry concepts correctly (Osman & Sukor, 2013), and unfortunately still struggling to learn these basic concepts (Aydeniz & Kotowski, 2012; Canpolat, 2006).

One possible reason why the students are facing difficulty in understanding the concepts taught in classroom is due to the poor teaching approach and pedagogies used by the teacher during the teaching and learning process (Levy Nahum, Mamlok-Naaman, Hofstein, & Krajcik, 2007; Weerawardhana, 2006). Various researchers have asserted that through effective and students-centred teaching approach, it is possible for students to better improve their understanding on the chemistry concepts (Ozmen, Demircioglu, Burhan, Naseriazar, & Demircioglu, 2012; Park, Light, Swarat, & Denise, 2009; Yakmaci-Guzel & Adadan, 2013). Nanoscience itself is interdisciplinary in nature (Chari, Howard, & Bowe, 2012; Hey, Joyce, Jennings, Kalil,

& Grossman, 2009; Tegart, 2003) and the implementation of nanoscience in the curriculum enhances the constructivist approach of learning (Allamel-Raffin, 2011; Mehraban, 2016). Students learned about the real-world circumstances in the nanoscience curriculum (Blonder & Sakhnini, 2012; Bradley, Castle, & Chaudhry, 2011; Feather & Aznar, 2011). The student-centred nanoscience curriculum permitted the students to construct the knowledge based on their individual and collective experiences of handling nano level activities (Blonder & Dinur, 2012; Blonder & Sakhnini, 2012).

1.2 Statement of the Problem

The knowledge of chemistry has a close connection with human's daily life. The air we breathe, the food we eat, the water we drink, the fuel we use for transportation and cooking are some of the examples that involve chemistry in human's daily life. However, the integral part of chemistry in human's daily living is not reflected in the school chemistry (Childs et al., 2015). This situation occurs due to the view that school chemistry should focus on delivering fundamental chemistry concepts with the goal of preparing students for understanding chemistry concepts and to perform for examination rather than educating them chemistry (Jong & Talanquer, 2015).

Study carried out by Sjoberg and Schreiner (2010) involving 40 countries revealed that school science fails to serve its purpose as less than 50% of the students from the participating countries felt that science and technology is relevant to their daily living (Sjoberg & Schreiner, 2010). In a different study conducted by OECD indicated that 75% of the students said that science helped them to understand things around them, however only 57% of them said that science is very relevant (OECD, 2007). Various studies have been conducted and all highlighted that science education, particularly chemistry remains unpopular among many students and one of the factors which contribute to this issue was the irrelevant of chemistry (Dillon, 2009; Gilbert, 2006; Hofstein, Eilks, & Bybee, 2011; Holbrook, 2008; Osborne & Dillon, 2008). Holbrook (2003, 2005) suggested that chemistry teachers should make chemistry education "more relevant" in order to better motivate their students and interest in learning chemistry. This situation has taken place since the 1980s (Newton, 1988a, 1988b) and it is yet to be solved until today (Eilks & Hofstein, 2015).

Chemistry is an important subject, however, this subject consists of abstract and complex ideas (Dori & Hameiri, 2003; Regis & Albertazzi, 1996). Due to this factor, according to O'Dwyer and Childs (2011); Reid (2008) many students frequently think that chemistry concepts are difficult to understand and master. Johnstone (2010) listed nine areas of chemistry which have been identified as too difficult for students to master. The areas are stoichiometry and the mole, balancing equations, ion-electronic equations, bonding, equilibrium, electrochemistry, reactions of carbonyl compounds, hydrolysis, condensation and esters, and radiochemistry. Many other studies also have made similar remarks on the same topics which are difficult to learn (Childs & Sheehan, 2009; Jimoh, 2005; Johnstone, 2006; Ratcliffe, 2002). In a research conducted in Ireland involving 276 students, it was reported that 165 students or 59.7% claimed that organic chemistry is one of the topics which students were unable to master and difficult to understand (O'Dwyer & Childs, 2011). Specifically, students had difficulty in differentiating the functional group, naming and drawing the compounds, organic formulae, laboratory classes and the organic reaction and mechanisms. Similar results were also reported by Bhattacharyya and Bodner (2005); Childs and Sheehan (2009); Ferguson and Bodner (2008); Johnstone (2006); Rushton, Hardy, Gwaltney, and Lewis (2008); Schroeder and Greenbowe (2008).

In a study conducted by Levy Nahum, Hofstein, Mamlok-Naaman, and Bar-Dov (2004), it was reported that high school students face difficulties in understanding chemical structure and bonding such as molecules, ions, hydrogen bonds, and giant lattices. Besides, acids and bases also posed many problems among high school students (Burns, 1982). Studies have shown that the understanding of acids and bases is weak among students (Artdej, Ratanaroutai, Coll, & Thongpanchang, 2010; Chiu, 2004, 2007; Kala, Yaman, & Ayas, 2013). In a study conducted by Chiu (2004), 34% of senior high school students considered weak electrolytes as consisting of molecules but changed into ions when an electric current passed through the electrolytes. Similarly, nearly 25% of high school students agreed that when solutions with equal concentrations of a weak acid such as ethanoic acid (CH_3COOH) and a strong alkali such as sodium hydroxide ($NaOH$) were mixed together, the solution which was formed was neutral because the two substances were completely reacted.

A poor understanding indicated that students are still not able to master the chemistry concepts well. This implicates that, the teaching process in the class does not benefits students. One of the contributing factors might be the teaching approach used by the chemistry teachers. Several studies conducted by different researchers shown that pedagogical approach influenced students' understanding in chemistry concepts (Dai, 2004; Gou, 2003). Another study conducted by Levy Nahum et al.

(2007) asserted that systemic and proper teaching approach that developed in the study have significantly increase students' understanding in the chemical bonding as compared to the traditional pedagogical approach.

Students' attitude plays an essential role in students' decision to study chemistry (Abulude, 2009). Abulude (2009) observed that attitude of students in secondary schools towards chemistry is not at a healthy level. Research conducted by Osborne and Collins (2000) involving 16 years old students indicated that these students' attitude towards chemistry is the most unfavourable among other science subjects. Bennett (2001) in the study has found out that in general, South African students have the least positive attitude towards chemistry. In Hong Kong, student only shows marginally positive attitude towards chemistry across secondary 4 – 7 (Cheung, 2009b). The same situation also happened in Turkey where Can and Boz (2012) found out that high school students' attitude towards chemistry dropped significantly. In another related study by Najdi (2012) which involved 103 grade-10 students showed an existence of correlation between attitude and teaching approach. The study reported that students' negative attitude towards chemistry was due to ineffective teaching approach used. Another study conducted by Yunus and Ali (2013) with 100 Form Four (Grade 10) students revealed that most of Malaysian students' negative attitude towards chemistry is due to the syllabus itself. In addition, the study also revealed that laboratory experiments manage to improve Malaysian students' attitude towards the chemistry lessons (Yunus & Ali, 2013). Therefore, teaching approach is recognized as one of the important factors that directly influence students' attitude in learning chemistry.

Studies have shown that the use of nanoscience activities in teaching and learning have created various positive outcomes. Study by Blonder and Sakhnini (2012) showed that nanoscience activities developed a positive impact to the 9th grade students' learning of chemistry and it is an effective approach in supporting students' understanding. In another study, a constructivist pedagogy integrated with the nanoscience activities was conducted with high school students. This teaching approach of moving from a teacher-centred pedagogy to a student-centred pedagogy motivated the participating students to learn more about chemistry (Blonder & Dinur, 2012). In a research carried out by Ibrahim and Karpudewan (2013), nanoscience-based constructivist teaching approach managed to increase secondary school students' attitude towards learning biology. Despite the reported positive outcomes, study on integration of nanoscience activities particularly in chemistry at the secondary level in not prevalence. Hence, through this study an attempt was made to employ nanoscience activities to teach the students on several chemistry concepts. The current study also determines the effectiveness of nanoscience activities in improving students' understanding of these concepts, students' attitude towards learning chemistry and students' perceptions about the relevance of chemistry education.

1.3 Purpose of the Study

This study aimed to investigate the effectiveness of nanoscience activities on students' attitude towards chemistry lessons, perception towards the relevance of chemistry education, and understanding of chemistry concepts.

1.4 Research Objectives

The objectives of this research are:

a) To identify the effectiveness of nanoscience activities on secondary school students' attitude towards chemistry lessons.

b) To identify the effectiveness of nanoscience activity on secondary school students' perceptions towards the relevance of chemistry education.

c) To identify the effectiveness of nanoscience activity on secondary school students' understanding of chemistry concepts.

1.5 Research Questions

The research questions are as follows:

Attitude Towards Chemistry Lessons

1.1 Is there any statistically significant difference in the linear combination between control and experimental group's attitude towards chemistry lessons post-test mean scores after controlling the pre-test score? (Quantitative finding)

a) Is there any statistically significant difference between the experimental and control group's liking for chemistry theory lessons post-test mean scores after controlling the pre-test scores?

b) Is there any statistically significant difference between the experimental and control group's liking for chemistry laboratory work post-test mean scores after controlling the pre-test scores?

c) Is there any statistically significant difference between the experimental and control group's evaluative belief about school chemistry post-test mean scores after controlling the pre-test scores?

d) Is there any statistically significant difference between the experimental and control group's behavioural tendencies to learn chemistry post-test mean scores after controlling the pre-test scores?

1.2 How the changes in students' attitude towards chemistry lessons supports the quantitative findings? (Qualitative finding)

Perception Towards the Relevance of Chemistry Education

2.1 Is there any statistically significant difference in the linear combination between control and experimental group's perceptions towards relevance of chemistry education post-test mean scores after controlling the pre-test score? (Quantitative finding)

a) Is there any statistically significant difference between the experimental and control group's "what I want to learn about" post-test mean scores after controlling the pre-test scores?

b) Is there any statistically significant difference between the experimental and control group's "my future job" post-test mean scores after controlling the pre-test scores?

c) Is there any statistically significant difference between the experimental and control group's "me and the environment" post-test mean scores after controlling the pre-test scores?

d) Is there any statistically significant difference between the experimental and control group's "my chemistry classes" post-test mean scores after controlling the pre-test scores?

e) Is there any statistically significant difference between the experimental and control group's "my opinion about chemistry and technology" post-test mean scores after controlling the pre-test scores?

f) Is there any statistically significant difference between the experimental and control group's "my out-of-school experience" post-test mean scores after controlling the pre-test scores?

2.2 How the changes in students' perceptions towards the relevance of chemistry education support the quantitative findings? (Qualitative finding)

Understanding of Chemistry Concepts

3.1 Is there any statistically significant difference between the experimental and control group's chemistry achievement test post-test mean scores after controlling the pre-test scores? (Quantitative finding)

3.2 How the changes in understanding of chemistry concepts support the quantitative findings? (Qualitative finding)

1.6 Hypothesis

Based on the research question, the following hypotheses were formulated.

Attitude towards Chemistry Lessons

$H_0$1: There is no significant difference in the linear combination between control and experimental group's attitude towards chemistry lessons post-test mean scores after controlling the pre-test score.

$H_0$1a: There is no significant difference between the control and experimental group's liking for chemistry theory lessons post-test mean scores after controlling the pre-test scores.

H_01b: There is no significant difference between the control and experimental group's liking for chemistry laboratory work post-test mean scores after controlling the pre-test scores.

H_01c: There is no significant difference between the control and experimental group's evaluative belief about school chemistry post-test mean scores after controlling the pre-test scores.

H_01d: There is no significant difference between the control and experimental group's behavioural tendencies to learn chemistry post-test mean scores after controlling the pre-test scores.

Perception towards the Relevance of Chemistry Education

H_02: There is no significant difference in the linear combination between control and experimental group's perceptions towards relevance of chemistry education post-test mean scores after controlling the pre-test score.

H_02a: There is no significant difference between control and experimental group's "what I want to learn about" post-test mean scores after controlling the pre-test scores.

H_02b: There is no significant difference between control and experimental group's "my future job" post-test mean scores after controlling the pre-test scores.

H_02c: There is no significant difference between control and experimental group's "me and the environment" post-test mean scores after controlling the pre-test scores.

H_02d: There is no significant difference between control and experimental group's "my chemistry classes" post-test mean scores after controlling the pre-test scores.

H_02e: There is no significant difference between control and experimental group's "my opinion about chemistry and technology" post-test mean scores after controlling the pre-test scores.

H_02f: There is no significant difference between control and experimental group's "my out-of-school experience" post-test mean scores after controlling the pre-test scores.

Understanding of Chemistry Concepts

H_03: There is no significant difference between control and experimental group's chemistry achievement test post-test mean scores after controlling the pre-test score.

1.7 Significant of the Study

This study provides a wider knowledge for teachers in applying nanoscience activities to the related topics in chemistry. In addition, not all the students who take up science will end up in a science related career. The main purpose of school science is to produce a scientifically literate society. Therefore, the exposure of 21st century science such as nanoscience to the students will not only embed students' interest in learning science, it also introduces early exposure to science in the real world. Students will become major consumer of the scientific product in years to come. It is crucial for them to make judgement of the products they consume based on the scientific facts.

In the attempt to employ more contemporary pedagogical approaches to deliver science concepts, particularly in chemistry, various 21st century strategies have been suggested (Eilks, Rauch, Ralle, & Hofstein, 2013; Roehrig, Michlin, Schmitt, Macnabb, & Dubinsky, 2012; Scott, 2015; Shwartz, Dori, & Treagust, 2013). The nanoscience activities as proposed through this study is a type of 21st century pedagogy because of its nature which is interdisciplinary that promotes student-centred learning.

Nanoscience is a new area in Malaysia particularly the integration of nanoscience activities in the educational context which is relatively contemporary. The manual on nanoscience activities used in current study provide detail description on how nanoscience could be implemented in chemistry curriculum, which would be very informative to the curriculum planners. The manual could be used as a guide in planning and integrating the 21st century science into chemistry curriculum. This could be exemplary for the planners to develop more explicit manual to be implemented at a larger scale. The findings of this study could be used to advice the policy developers on the effectiveness of the nanoscience activities in the chemistry curriculum and the students' experiences while engaging in the curriculum would also be useful to advice the policy makers on the urgency in implementing 21st century sciences.

Furthermore, students' knowledge in nanoscience can help to protect our environment from serious pollution as nanotechnology produces environmental friendly products. Therefore, we need to have experts and professionals in this field by helping to develop our country in terms of science, technology, and society. At the same time, it will assist in protecting our environment to ensure that we have a more sustainable future. Sooner or later nanoscience will become one of the major economic sectors in the global market, hence it is critical for Malaysia education system to start infusing more efforts in this area. Insufficient human capital in this area will impede the development and source of economic for the country.

On top of that, this research also adds value to the theories used in framing this research. It fills the gaps and provides evidence that nanoscience activities can be framed and explained using Activity Theory, i.e. Activity Theory explains the whole process of nanoscience activity that is conducted in the secondary chemistry laboratory setting. The nanoscience activities link all the six entities in Activity Theory and provide students a meaningful learning experiences in chemistry lessons. This provides an informative evidence to support the feasibility of conducting nanoscience activity by using this framework. Such information would be helpful for future researchers to frame their science laboratory activities generally and chemistry laboratory activities practically.

Output from this research also provides an empirical evidence to support other theories used in the research such as the Latent Process Viewpoint Model, Three-Dimensional Relevant Model, and Conceptual Change Model. The findings of the research have added an empirical evidence to the questionnaire constructed based on the Latent Process Viewpoint. The data had proven that, the questionnaire was applicable not only in Hong Kong and Turkey context, but it also manages to generate a positive output in Malaysia context. On the other hand, Relevant of Chemistry Education questionnaire used in this study verified that constructs used in ROCES manage to link and address all the three dimensions proposed in the Three-Dimensional Relevant Model. Such result had put forward a strong believe that ROCES questionnaire is suitable to be used to evaluate students' perception towards the relevant of chemistry education based on the Three-Dimensional Relevant Model.

1.8 Limitation of the Study

In this study, nanoscience activities were introduced as one of the approach to teach chemistry concepts (structure of the atom and acids and bases). One of the limitations that this study exhibit was that the study only focusing on certain concepts within the subject of chemistry. According to Blonder and Dinur (2012), the implementation of nanoscience activities in a single discipline is still applicable and manage to provide a significant result. Nanoscience is a versatile concept, perhaps it is also possible to implement in other chemistry concepts or science subjects such as biology and physics (Blonder, 2010, 2011; Blonder & Dinur, 2012; Drane, Swarat, Light, Hersam, & Mason, 2009).

For the purpose of the study, students from one school participated. This creates limitation in terms of generalising the finding. However, according to Grove, Gray, and Burns (2015) and Gay, Mills, and Airasian (2009), a minimum sample size of 30 is noted to be appropriated for experimental research. As such involvement of 163 samples in this study is appropriate. Due to the nature of this setting, the intact group selection method was used during the sampling period. Intact group sampling reduces disruption to the sample. To have a better control of the external variables and to improve the internal validity, it is advisable to include more schools and more students with diverse background (Institute for Work & Health, 2008) to yield the same results.

In this study, only eight nanoscience activities were used. According to Hasni, Roy, and Dumais (2016) and Holt (1988), eight activities is sufficient to measure the changes in students' attitude towards chemistry lessons, perception of relevance towards chemistry lessons and understanding of chemistry concepts. However, it is advisable to use more activities to have a greater impact. Therefore, in future study it is suggested to use more activities to measure the effectiveness of nanoscience activities as a teaching approach.

Shadish, Cook, and Campbell (2002) asserted that quasi experimental with experimental and control group design is one of best design to be used to measure effectiveness of any treatment. In this study both the control and experimental groups were in the same school. Having both groups in same school permits the groups to be taught by same teacher. With this teacher effect have been nested or controlled. Additionally, the having both groups in same school also controls other external variables such as climate, learning environment, and laboratory facilitates available which might contribute to the results as well. On the contrary having both groups in same school creates diffusion effect as there are possibilities for the students from the groups to interact. The diffusion effect is controlled in this study by keeping the two groups of students as separate as possible during the treatment period (Creswell, 2014, p. 175) and deemphasizing the fact that there is an experiment in progress and by encouraging teachers to avoid accentuating the differences between two groups (Vockell & Asher, 1995).

1.9 Operational Definition

Nanoscience – Nanoscience involves research to discover new behaviours and properties of materials with dimensions at the nanoscale, which ranges roughly from 1 to 100 nanometers (nm) (National Nanotechnology Initiative, 2008). In this study, nanoscience refers to the scale that falls under the range between 1 to 100 nm and it can be observed through human's five senses that were expressed through the eight nanoscience activities.

Nanoscience activities – Nanoscience activities are a series of activities designed to help students increase their conceptual understanding of chemistry, to improve their attitude towards chemistry lessons and perception towards the relevance of chemistry education. Nanoscience activities can be understood as an alternative teaching approach used for laboratory activities. It consists of hands-on nanoscience activities based on the chemistry concepts. For example, the serial dilution activity. In this activity students are requested to dilute 1 mL concentrated scented food colouring into 9 mL of distilled water until the 9^{th} test tube. At the end of the dilution process, the particles are in the size of nanoscale. At the end of the activity, students were requested to detect the colour changes and the smell of the scented food colouring.

Attitude towards chemistry lessons – attitude is a hypothetical construct used by social physiologist to understand and predict the behaviours of students (Eagly & Chaiken, 1993).

Students' attitudes toward chemistry lessons refer to the lessons taught in both theory and laboratory setting. The attitude towards chemistry lessons are reflected as liking for chemistry theory lessons, liking for chemistry laboratory, evaluative belief about school chemistry, and behavioural tendencies to learn chemistry work. Liking for chemistry theory lesson and chemistry laboratory is the feeling a student has towards the chemistry theory lessons and laboratory practical work. Belief about school chemistry is how students hold the importance and usefulness of school