AN EXPLORATORY STUDY ON TEACHERS' KNOWLEDGE AND APPLICATION ABOUT THE PRACTICE OF SCIENCE

by

OOI HEAN BENG

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OOI HEAN BENG
School of Educational Studies
Universiti Sains Malaysia

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LIST OF ABBREVIATION

CUDOS	Communalism, Universality, Disinterestedness, Objectiveness and Skepticism
NOS	Nature of Science
PEKA	Pentaksiran Kerja Amali (Assessment of Practical Work)
POS	Practice of Science
T (number)	In-service teacher (1, 2, 3 etcetera)
TR (number)	Pre-service teacher (1, 2, 3 etcetera)

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SUATU KAJIAN EKSPLORASI MENGENAI PENGETAHUAN GURU TERHADAP AMALAN SAINS SERTA APLIKASI PENGETAHUAN MEREKA DI BILIK DARJAH

Abstrak

Kajian ini bertujuan meninjau pengetahuan guru dan guru pelatih mengenai amalan sains serta tahap pengetahuan ini dikongsi dengan pelajar-pelajar mereka. Soal selidik telah diedarkan kepada 139 guru dari negeri Perak, Kedan dan Pulau Pinang dan 110 guru pelatih dari satu universiti. Temubual dengan 13 orang guru dan 11 guru pelatih telah dijalankan, dirakam dan ditranskripkan. Dari respon soal selidik, pengetahuan guru tentang amalan sains diperolehi. Transkrip temubual membantu kajian ini memahami perkara yang diutamakan semasa pengajaran sains dan sama ada unsur-unsur amalan sains ditegaskan. Dapatan kajian menunjukkan guru-guru mempunyai pengetahuan berciri positivistik serta pos-moden mengenai amalan sains. Walaubagaimanapun, pengetahuan ini tidak dikongsi bersama pelajar secara eksplisit atau implisit. Guru-guru ini sedar amalan mereka di bilik darjah tidak memberikan gambaran yang tepat mengenai amalan sains tetapi merea berasa terikat kepada keperluan kurikulum sains serta penekenan kepada kecemerlangan akademik. Pelatih memberi lebih perhatian kepada konsep sains dan kemahiran pedagogi. Kajian ini mencadangkan bahawa kurikulum sains perlu juga memberi penekanan kepada elemen-elemen dan aktiviti-aktiviti yang menggalakkan kesedaran mengenai proses-proses yang terlibat sebelum ide-ide sains diterima dan diumumkan. Penekanan ini perlu dilakukan semasa latihan guru sains dan disokong secara berterusan oleh pihak-pihak yang ada kepentingan dalam pendidikan sains di Malaysia.

AN EXPLORATORY STUDY ON TEACHERS' KNOWLEDGE AND APPLICATION ABOUT THE PRACTICE OF SCIENCE

Abstract

This study explores the teachers' and trainees' knowledge about the practice of science and to what extent the said knowledge is shared with their students. Questionnaires were distributed to 139 teachers from Perak, Kedah and Penang and to 110 trainees from one university. Interviews with 13 teachers and 11 trainees were conducted, audio recorded and transcribed. The responses from the questionnaire provided information about the teachers' knowledge about the practice of science. The interview transcripts helped to determine whether the knowledge and activities that reflected the practice of science were part of their classroom teaching. The findings of this study indicated that the teachers and trainees have a mixture of positivistic and post-modern knowledge about the practice of science. However, this knowledge was not shared with their students explicitly or implicitly. The teachers were aware that their present practices do not reflect the actual practice of science but they felt that they have little control over the demands of the science curriculum and the emphasis for academic excellence. The trainees were more concerned about content and pedagogical skills. The findings of this study suggest that to promote science literacy, the science curriculum, besides the science content, must also include the emphasis the elements and activities that encourage the awareness about the processes involved before scientific ideas are accepted and published. This must be explicitly emphasized at pre-service levels and continually supported in schools by the stakeholders of Malaysian science education.

CHAPTER ONE

OVERVIEW

1.0 Introduction

The development of science and technology epitomizes progress. It is an indicator of having achieved first world status. In relation to this, a progressive country requires her to have citizens that are generally science literate. Malaysia aspires to be a fully developed nation and has put into action plans to achieve her goals. One area of concern is the development of the nation's school science education. However, the enrolment of students pursuing the sciences at higher levels of education is dwindling (Lee et.al., 1996; Ministry of Education, 2004). What is more worrying is that the report of a fairly recent study (Ratnawati, 2005) indicated that over the years, we have not progressed but deteriorated slightly in the number of people who have knowledge beyond the most basic that they have learned in schools. For example, 55.2% of the respondents in the study answered correctly to the statement, "The center of the Earth is very hot (True/False)". However, only 11.8% answered the statement, "All radioactivity is man-made (True/False)" correctly. This level of knowledge is definitely not enough for our population to make sound and wise decisions where science and technology have impacts on our lives. This is especially so since we are living in the world where there are a growing number of scientific claims and counterclaims (O'Neill & Polman, 2004).

According to a newspaper report on 16 August 2009, Professor Emeritus Datuk Mohamed Abdul Majid was quoted saying that Malaysia still lags behind in science and technology compared to developed countries (The Star (a), 2009). In his opinion, the education system is not supporting the development of science and technology. If this were true, then it is only natural that the students will not be encouraged to further their studies in the sciences. Lee et. al. (1996) suggested that the lack of interest and perceived lack of ability to do science as reasons for the decline in the number of students pursuing the sciences but the study did not provide much insights to the actual problems. The other two studies (Ministry of Education, 2004; Ratnawati, 2005) were too general and superficial to offer ideas and suggestions that would help improve the implementation of the science education in Malaysian schools.

There have been changes have been made in the science curriculum since after Malaysia gained independence. In 1968, the Schools Division initiated what was termed as Special Project (Projek Khas) to raise the teaching standard of science and mathematics. From 1985 until 1993, the New Curriculum for Primary School (Kurikulum Baru Sekolah Rendah – KBSR) which was followed by New Curriculum for Secondary School (Kurikulum Baru Sekolah Menengah – KBSM) were introduced, where the theme was on Man and His Environment (Alam dan Manusia). In 1994 (until now), the Integrated Curriculum for Primary and Secondary Schools were introduced. Finally, in 2003, to raise our competitiveness in the global arena, the medium of instruction for teaching science and mathematics was changed to English (Poh, 2005). Although it is still a controversy to some concerned parties, the medium of instructions will be reverted to the Malay Language by 2012. The changes made focused more on the teaching and learning strategies – Special Project, the scientific method; KBSR/KBSM, the inquiry-discovery approach and the Integrated Curriculum, the constructivist approach. There were of course some changes in the content. The teachers' roles were in the implementation of the changes introduced by the Ministry of Education. Subahan (1999) found that the teachers felt they lack knowledge and skills required to implement successfully what was required in the new curriculum and pedagogies. The findings in his study suggested that the pre-service and in-service training only prepared teachers and trainees to have more content knowledge and to give them the confidence to "face" their students. Most of these teachers have little opportunities to keep abreast with the latest development in science and science education, especially when they are already posted to schools.

Teachers are the agents of change. The success of these changes depends in part on the abilities of the teachers, in this case the science teachers, to impart the necessary knowledge about science to their students. Thus, teachers must have the correct knowledge about science. In this time and era, it is not enough to merely teach science. It is that and more. O'Neill and Polman (2004) had shown the importance and benefits of getting the students to build a deeper understanding of how scientific knowledge claims and theories are constructed. This can be achieved through the knowledge about the practice of science. Based on the requirements of the Malaysian science curriculum (Ministry of Education, 2006; Ministry of Education, 2008), these aspects are missing in our science education.

1.1 The background of this study

What views do students have about scientists? Regardless of cultural backgrounds or gender, studies over the years have shown that students have a skewed and narrow portrayal about science and its practice (Fort & Varney, 1989; Song & Kim, 1999; Rubin & Cohen, 2003). Scientists were mostly seen as males, bearded and bespectacled. Samples of drawings showed that most scientists worked with test tubes, conical flasks and beakers neatly arranged – images of chemists. Strangely, when they were asked to name famous scientists, they named mostly physicists. These views could have come from many sources – films, the print or electronic media, and the teachers. Studies have shown that the television is the most popular source of science information for Malaysians. Other popular source include the newspapers, the radio and magazines (Ratnawati, 2005). During a course conducted for the Science and Mathematics Department for an Institute of Teacher Education in August 2009, where about 30 lecturers participated and the researcher was a participant, it was seen that even the lecturers drew similar pictures in their portrayals of the scientists. Only one drawing was of a female scientist, drawn only because that group of lecturers wanted to be “different”. Although this may an isolated case, we have to bear in mind that these lecturers will be training future science teachers for our Malaysian schools! If these were their images about scientists, what would their knowledge about the practice of science be? Could they have some impact and influence on the future science teachers that they are training, which will in turn influence the school children’s knowledge about the practice of science? The implications of such possibilities cannot be ignored if we desire our students to have correct knowledge about the practice of science.

This study is focused on in-service teachers and pre-service (will be written as teachers and trainees respectively in this study) science teachers as the source of knowledge. This study proposes that what our teachers know about the practice of science, how they teach science and the knowledge their students have about science are closely related. In part, many Malaysian students may not see science as an attractive option at higher levels of education or as a career. A possible cause could be the lack the correct knowledge about science and the practice of science (Ratnawati, 2005). Where can they get the correct views then? One very important source is the science teachers in schools. What if the teachers really do not have the knowledge, as suggested by Subahan (1999)? Whatever changes that take place to improve the science education will not have much impact unless and until the teachers have the necessary knowledge. A list of studies posted by the Bahagian Perancangan dan Penyelidikan Dasar Pendidikan from 2003-2008 at doctoral level have focused more on the efficacies of programs and approaches in teaching and learning science (Ministry of Education, undated). Bartholomew, Osborne and Ratcliffe (2004) found that teachers' knowledge and understanding are two dimensions that will determine a teacher's ability and confidence to teach about science effectively. What knowledge do our teachers have about the practice of science? It is the intent of this study to find out, and with good reasons, as will be presented in the course of this thesis.

1.1.1 Issues in Science Education

There is a growing awareness that there is a need to re-assess the effectiveness of today's science education in schools (Sadler & Zeidler, 2003; Duggan & Gott, 2002; Barab & Hay, 2001; McComas, Almazroa & Clough, 1998; Nott & Smith, 1995; Shamos, 1995; Costa, 1993; AAAS, 1990; Driver, 1985). There was even a proposal to teach "bad science", that is, scientific projects that had gone awry (Sadler & Zeidler, 2003) so that students are better prepared to make critical evaluations of the social and ethical ramifications of science. A commonly included feature in all the science Curriculum Specifications provided by the Curriculum Development Centre (Ministry of Education, 2005; Poh, 2003) is a list of desired skills and a brief description of each skill. They include science process skills, science manipulative skills and thinking skills. Although these skills are important and have to be taught and practiced, they do not and cannot reflect the practice of science.

How much do Malaysian students know about science and its practice? When does learning about science occur? In Malaysia, it was found that students are exposed to the practice of science only when they are undergoing their post-degree courses (Tan, 2003). Assessment of Science Process Skills (Penilaian Kemahiran Amali), usually known by its acronym PEKA, is a program initiated to improve science learning. In practice, it is basically used to evaluate students' science process and manipulative skills. Although a study (Sharifah & Rohaida, 2005) showed that there were improvements in the intended skills, it did not indicate how this program had contributed to the students knowledge about the practice of science.

Malaysian students need to be exposed to the practice of science in schools, at least early in secondary school levels. With the curriculum changes mentioned earlier, the emphasis on the science curriculum was the science process and manipulative skills, scientific attitude and noble values (Subahan, 1999). The attainment of these skills, attitude and values may be the ideals in the practice of science but they are not, by themselves, the practice of science. The scientific method as practiced in Malaysian schools, which incorporates a series of steps like observing, formulation of hypothesis, testing the hypothesis, testing the hypothesis through experiments and the assessment of the experimental results represents a ritual of procedures rather reflecting the practice of science (Morris, 1999).

Studies have shown that the present science education system is giving students the wrong impressions about the practice of science. Science is viewed as a body of facts, accepted theories and algorithms for solving problems (O'Neill & Polman, 2004). The rigidity of the scientific method gives students and the general public a distorted view of scientific enquiry (Morris, 1999; Lederman, 1998). It is true that changes have been made to make science learning more meaningful and relevant to today's contexts. However, these changes are at best cosmetic. Students are still regarded as recipients of knowledge. Hence, the teaching of science remains in its traditional form (Hurd, 1998). Wellington (1998) proposed that although we have shifted from a 'content-led' to a 'process-led' science education, we may actually be giving our students the wrong account about the processes and practice of science. The science process skills that are currently being taught in Malaysian schools may impress our students that scientific methods are guided by a set of discrete and rigid processes (Millar, 1989). This is further aggravated by the manner science laboratory activities are conducted in schools (Barab & Hay, 2001; McComas, Almazroa & Clough, 1998; Nott & Smith, 1995; Costa, 1993; Driver, 1985). As a secondary school science teacher for 18 years, the researcher must say that Malaysian school science is faced with very similar predicaments.

Practice-based scientific literacy will better prepare our children in the present world of constant claims and counter-claims. However, the present science education places more emphasis on the content of science (O'Neill & Polman, 2004). To meet the demands of 21st century living, this study believes that we need to review our focus and emphasis in science education. Based on the review, and if there is a need to make changes in the science curriculum, then it is only logical that we need to seriously consider the readiness and willingness of our science teachers to be agents of these changes (Subahan, 1999).

Whatever the curricular changes, teachers will be the prime movers. Thus, these changes can only be effective if the teachers' views and knowledge about science, the practice of science and science education concur with the intended programs and changes. This is important because the teachers' conceptual views and knowledge in these areas affect their teaching and their students' learning (Lidar, Lundqvist & Östman, 2006; Martin-Diaz, 2006). However, it cannot be assumed that the teachers will act in accordance with the views and knowledge that they have about science. There may be other factors, needs and demands that influence what the teachers do in their classes. They may have to face the pressures of external demands, the need for the students to get the “right” answers and having to cope with the demands of the examinations (Waters-Adams, 2006; Nott & Smith, 1995; Driver, 1985). The teachers may also be subjected to curriculum constraints and administrative policies (Lederman & Zeidler, 1987). Hence, there exist a conflict of doing what is epistemologically correct against what is currently practised.

For any curricular changes in the Malaysian science education to be successful, this study proposes that the teachers must have the necessary knowledge and skills. The knowledge should include the knowledge about the practice of science. Teachers need to be able to communicate this knowledge to their students, in word and in action, through their classroom teaching and practices. They would also need the ability to assess their students’ learning in theses aspects. . Hence, the need for the teachers to be competent in structuring school based assessment as part of the teaching and learning activities need to be seriously looked into (Tan, 2010). However, these skills and knowledge will only be translated into classroom practices when the changes required are carefully planned and wholly supported by all the stakeholders in the system.

1.1.2 What about science that educators are actually concerned in science education?

Why teach science? What is science? I think that science educators have to be clear about the ‘what’ before attempting to answer the ‘why’. Once this is accomplished, the ‘why’ will be easier to answer. So again, what is science? There is no straightforward description or definition of science.

Abruscato (2000) categorized science as processes that lead to discovery. It is also knowledge that is governed by a set of rules that include freedom, scepticism, order and originality. Ziman (1988) forwarded the idea that the answer to ‘What is science’ would depend on the aspect of science we want to define. The aspects that Ziman considered were:

a. the instrumental aspect where science is defined as ‘a means to solving problems’
b. the archival aspect where science is defined as ‘organised knowledge’
c. the methodological aspect where procedures such as experimentation, observation and theorizing are considered.
d. the vocational aspect that defines science as ‘whatever is discovered by people with a special gift for research’.

The descriptions above have encompassed the many facets of science. The researcher would like to suggest that science can also be considered as having two components – the nature of science and the practice of science. From the perspective of this study, the nature of science is akin to describing the ideals of science whereas the practice of science describes the realities of science.

1.1.3 The nature of science

Table 2.1 in Chapter 2 gives a very clear overview of the nature of science. Based on the list of item in Table 2.1 from McComas, Almazroa & Clough (1998), the nature of science can be said to encompass three aspects. First, it describes the characteristics of scientific knowledge. It then attempts to state how science should be practised. Finally, it is about the role of science in our society and culture, and, vice-versa (McComas, Almazroa & Clough, 1998). In principle, when teachers teach about the nature of science, they would also be exploring the philosophical and historical aspects of science. For the purpose of this study, some of the descriptions about the nature of science will have some similarities to what was described about the practice of science.

1.1.4 The practice of science

While the descriptions about the nature of science seemed to portray a somewhat sterile and stoic picture of science, in-depth ethnographic research about the practice of science described exactly the opposite (Barab & Hay, 2001; Collins & Pinch, 1994; Holton, 1978). The practice of science portrays the dynamism in science. It is about the life in science. It shows the need for scientists to cooperate among themselves and with other parties involved. It allows us to see the importance of communication. Formal forms of communication include meetings, seminars, conferences and publications. Equally important are the informal chats that take place in lounges, cafes and corridors. In both settings, important ideas are exchanged or generated. Descriptions about the practice of science allow us to see the "human aspects" of science – the commitment, the frustrations, the determination and the sacrifices. They do not gloss over instances of failures, mistakes and conflicts. From the works of Barab & Hay (2001), Collins & Pinch (1994) and Holton (1978), it can be seen that scientists compete for funds, recognition and financial rewards that can sometimes lead to bad science. Even the artefacts (buildings, laboratories, equipment and so on), inanimate though they may be, give life to the science activities that they represent.

1.1.5 Malaysian science education

The Ministry of Education of Malaysia, through science education, want our young generation to learn science so that they have some scientific knowledge and skills, not only to be informed consumers of scientific and technological products, but also to be innovators and contributors of science and technology (Ministry of Education, 2006). It is also important that through science education, young Malaysians will be aware that they need to preserve and conserve the environment. There are ten objectives for the secondary school science curriculum (Table 1.1).

The objectives in the curriculum specification for science encompasses some of the aspects of learning science that were put forward by Abruscato (2000) and Ziman (1988). Both described learning science as acquiring a body of knowledge (Objective 1) which encompasses the usage of science and thinking skills and the observance and practice of certain values and attitudes (Objectives 3 and 7) through purposeful human activities (Objective 9). Abruscato (2000) also mentioned technology as the use of science to help solve human problems (Objective 8). Although there are only ten objectives, they are very ambitious ones. To achieve all that requires much more that merely content-led or process-led teaching. It demands a lot from the science teachers, not just in terms of content knowledge and pedagogical content knowledge. The teachers need to be knowledgeable about the practices of science and be models of these practices.

Table 1.1
Objectives of science education in Malaysia

1. Acquire knowledge in science and technology in the context of natural phenomena and everyday life experiences.
2. Understand developments in the field of science and technology.
3. Acquire scientific and thinking skills.
4. Apply knowledge and skills in a creative and critical manner for problem solving and decision making.
5. Face challenges in the scientific and technological world and be willing to contribute towards the development of science and technology.
6. Evaluate science and technology related information wisely and effectively.
7. Practise and internalise scientific attitudes and good moral values.
8. Appreciate the contributions of science and technology towards national development and the well-being of mankind.
9. Realise that scientific discoveries are the result of human endeavour to the best of his or her intellectual and mental capabilities to understand natural phenomena for the betterment of mankind.
10. Be aware of the need to love and care for the environment and play an active role in its preservation and conservation.

Source : Curriculum Development Centre, Ministry of Education Malaysia (2006)
*Stated in Chemistry and Additional Science

1.2 Statement of the problem

Like all other countries, Malaysia continually seeks ways to improve her education system. One of the efforts taken is to continuously keeping abreast with the latest science curriculum requirements to meet current needs and contexts. The Ministry of Education also conducts in-service courses for teachers, especially when there are changes in the curriculum. Based on the researcher's experience as a facilitator for the State Education Department in conducting such courses, the flow of administration of these changes has always been top-down (Figure 1.2), where identified national goals are converted into policies. Occasionally, the state/district education departments or the Teacher Activity Centre (*Pusat Kegiatan Guru* – PKG) organize courses on the usage of computer software and technological hardware. These are to enable the teachers to employ new strategies of teaching and learning using electronic and technological gadgets. The government has even experimented with changing the medium of instruction for science and mathematics from the national and vernacular languages to the English language to meet the fifth and sixth objectives in the science curriculum for six years (2003 - 2009) before deciding to revert back the former mediums of instructions by the year 2012. Despite all that had been done, why are we not getting the desired outcomes? Fewer students are enrolling in the sciences at higher levels of education (Lee et.al., 1996; Ministry of Education, 2004) and based on the study by Ratnawati (2005), Malaysians' science knowledge are generally poor.

The top-down approach may be efficient but it does not take into considerations the readiness of the teachers as implementers. The researcher proposes that to achieve the aspirations of our national science education policy, its aims and objectives in creating a science literate society, the teachers must be the epitomes of the practice of science. However, before any recommendations to introduce new ideas or approaches in teaching science are made and implemented, the teachers must be prepared.

It is not sufficient to expose them to the new curriculum or pedagogies. The manner in which the implementation of English for the Teaching of Mathematics and Science is going to be shelved by 2012 is a stark reminder to educators that the success of any education programs depends greatly on the teachers.

In order to teach the practice of science, the Ministry of Education must ensure that Malaysian teachers have the necessary knowledge and skills first. Do our science teachers know how science is practised? Do they see the practice of science as scaled up school laboratory exercises? This are questions that the curriculum planners have to address if the objectives stated in Table 2.2 and Table 2.3 are to be achieved since the teachers' views and knowledge about the practice of science affects the teaching and learning outcomes (Lidar, Lundqvist, & Östman, 2006; Martin-Diaz, 2006).

The paper presented by Subahan (1999) suggested the present pre-service and in-service courses for science teachers are inadequate to prepare them to handle the implementation of the curricular and pedagogical changes that had taken place. Taking the national science education philosophy (Table 1.2) into consideration, where the nation via its science education, hopes to develop what it termed as Science and Technology Culture, the teachers need to have knowledge about the practice of science. This is the first step towards achieving the aims and objectives of our national science education. The question remains, what do our in-service and pre-service teachers know about the practice of science? This issue needs to be addressed before recommendations for training courses are put forward. This study is to explore our in-service and pre-service science teachers' knowledge about the practice of science.

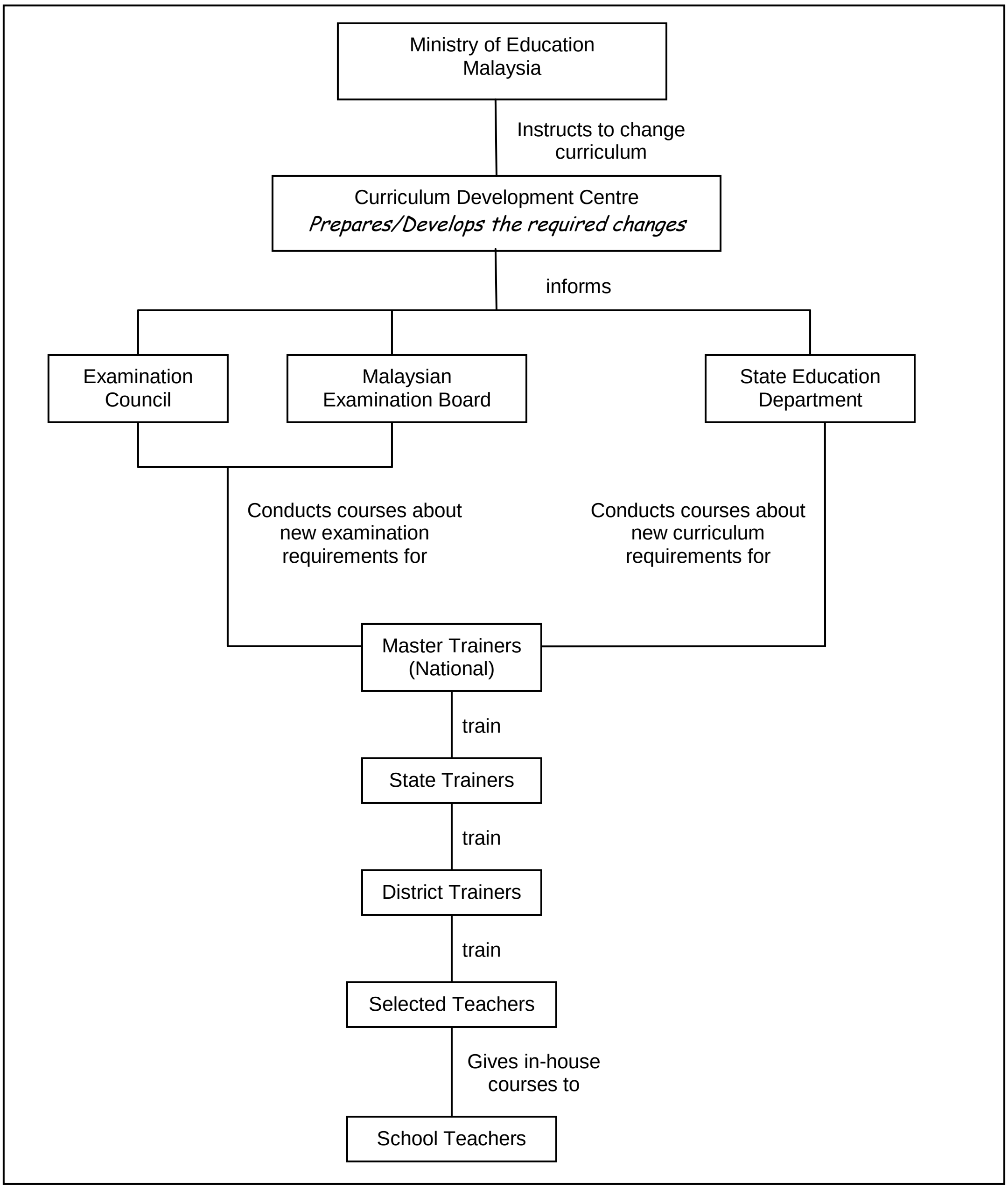

Figure 1.1 : Administration of Curriculum Changes

Table 1.2
National Science Education Philosophy

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

Source : Curriculum Development Centre, Ministry of Education Malaysia (2005)

1.2.1 The Purpose of This Study

It has been generally accepted that science, its nature and practices, are socially and culturally embedded (Lederman, 1998; Tan, 2004). To ensure the effective implementation of our science education aims and objectives, the researcher proposes that Malaysian school science teachers need to have knowledge about the practice of science. Collaborations with scientists in higher education institutions to expose science teachers to actual practices will definitely help (O'Neill & Polman, 2004). However, the training and courses conducted for teachers must be planned, to a certain extent, using the bottom-up approach. Thus the researcher suggests that the curriculum planners need to have some ideas what the teachers know about the practice of science before the implementation of any programs that would necessitate the knowledge about the practice of science. With the availability of some data and ideas about what Malaysian teachers know about the practice of science and what their perceived roles as science teachers are, we can plan better and more relevant training programs for them.

Based on the above understanding, this study has two objectives. They are

1. To explore secondary school science teachers' and the trainees' knowledge about the practice of science.
2. To determine how the knowledge about the practices of science is reflected in:
    i. the science teachers' classroom practices and their perceived roles as science teachers
    ii. the trainees' perceptions about their roles and duties as future science teachers.

1.2.2 Research Questions

When we analyse the objectives of science education in Malaysia (Table 1.1), carefully, and the current teaching and learning practices in the science classes (Tan, 2010), it is difficult to see how the objectives 4, 6 and 7 listed can be achieved. For example, the science experiments are already determined (Ministry of Education, 2005; Ministry of Education, 2003; Malaysian Examinations Council, 2002). After the experiments, the teachers' discussions are mainly to provide answers to their students (Tan, 2010). How can get contribute to the application of the students' knowledge and skills in a creative and critical manner (Objective 4)? Based on the current practices (Tan, 2010; Sharifah & Rohaida, 2005), have our teachers shared the knowledge about the practice of science which leads to the construction of science knowledge with their students? In the context of this study, do the teachers have that knowledge to share? Are our science students taught how to evaluate information wisely and effectively (Objective 6)? As was raised by Russel and Mundy (1989), can they also practice and internalize scientific attitudes (Objective 7) when they are more concerned about the products rather than the process of science experiments? PEKA may have helped our students improve their science process and manipulative skills (Sharifah & Rohaida, 2005), and they may have achieve Objective 3, but the regimented scientific method does not reflect the practice of science (Morris, 1999).

The importance of Objectives 4, 6 and 7 are known to all science teachers in Malaysia. The researcher believes that in order to be able to realize these objectives, the teachers need to have knowledge about the practice of science. Hence, to meet the training needs of the science teachers, the researcher proposes that the teachers' current knowledge about the practice of science and the perceptions of their roles, which influence current practices (in-service teachers) and future practices (pre-service teachers) need to be ascertain. This will help the Ministry of Education to plan long term teacher professional programs to meet the demands for informed decision making (O'Neill & Polman, 2004). Based on the premises put forward, the questions in this study are:

1. What knowledge about the practice of science do our in-service and pre-service science teachers have?
2. How is the knowledge about the practices of science reflected in the
   i. in-service science teachers' perceived roles and classroom practices

ii. pre-service teachers' perceptions about their roles and duties as science teachers.

1.2.3 Significance of This Study

In this time and era, the public cannot be ignorant or indifferent to the influence of science. From the findings of this study, the researcher hopes that those who are concerned about Malaysian science education are able to have a better vision of the roles of policy makers, scientists and science educators play to better inform our students about the practice of science. Maybe then the interests in science and science careers will improve. Even if the students are not directly involved in science and do not intend to pursue a career in science, they must be knowledgeable about how it is practised and how it affects them. In other words, the students need to be science literate. The fundamental contention in this study is that it is not enough to know scientific facts and laws. A good academic credential in science cannot be equated to science literacy (Shamos, 1995). This is also the reason for this study to focus on the knowledge about the practice of science. Knowing science is not the same as knowing about science. Good decisions cannot be based on knowing the facts alone. It is as important, if not more important, to know the dynamics that gave rise to the facts. This involves knowing the who(s), what(s), how(s), why(s) and when(s). It has been found that most adults were not able to give explicit explanations of their procedural understandings of science in their work, even when they are working in science research environments (Gott, Duggan & Johnson, 1999). The knowledge of how science works is important because

1. it helps us evaluate policies
2. it helps us analyse and weigh scientific evidence
3. it enhances learning and interest
4. it helps us understand that knowledge is just the “end product” and can be a tool for further research.

(McComas, Almazroa & Clough, 1998; AAAS, 1990).

The benefits of a scientifically educated public are numerous. When Malayisan students are better trained, the quality of the nation’s workforce will improve. This will in turn enhance our economy because of better inputs and innovations. On an everyday basis, when the nation’s population is science literate, they will have a better understanding of what goes on around them, be better informed. When it comes to issues that affect them, they will be more likely to make sound decisions. The reasons for ensuring the public is science literate has been clearly argued by many writers (Duggan & Gott, 2002; Stocklmayer & Gilbert, 2002; Zeidler et al., 2002; AAAS, 1990). Issues like nuclear power generation, waste disposal, fertility drugs and their effects affect many people and any decisions made concerning them can only be properly made when the people are science literate.

The importance and benefits of having a science literate society are very relevant to Malaysia. This study will

i. be a first step for the stakeholders of science education to evaluate how much science teachers and future science teachers know about the practice of science

ii. allow the stakeholders of science education to determine whether they are satisfied and comfortable with the indications in the findings and if necessary

iii. allow the stakeholders of science education to review and change our educational policies, science curriculum and approaches in teaching science.

1.2.4 Limitations of This Study

The success of this study depends very much on the cooperation of all parties. The choice of participants and the number of participants can be influenced by factors beyond the control of this study. The number of secondary science teacher respondents is rather limited and only three states are involved. This cannot be avoided due to the lack of manpower and resources required to carry out a more massive and comprehensive study.

Only some of the respondents can be interviewed. Although the researcher would like to control the selection of the teachers, in reality, it was quite difficult to get the teachers to be interviewed. Only 13 teachers and 11 trainees were interviewed in this study. However, those who agreed were very helpful and gave their sincere views and opinions.

Despite these limitations, it is hoped that this study will act as a catalyst for educationists and scientists to ponder over the issues raised and maybe consider the following questions – where do we want to go and how do we get there?

1.3 Definition of terms

Science

i. An organised, well-founded body of knowledge of natural phenomena.

ii. A field or domain of systematic enquiry in which understanding about the natural phenomena is sought.

(McGinn, 1991 : pp 15-16)

Knowing science

It is the knowledge about scientific facts, theories and laws. It includes the generalisations made in science and the experiments carried out by the scientists.

(Lee et.al, 2002)

Knowing about science

It is the knowledge about science and takes into consideration the social-cultural, economical and ethical influences in a scientific enterprise. It is also about the awareness of these influences on the practice of science.

(Lee et.al, 2002)

Practice of Science

The variety of activities scientists are engaged in that support their scientific explorations. It includes cultivating interests, communicating with others, thinking, being flexible and receptive, policing themselves and performing different kinds of scientific investigations. *It should also include* *beliefs, the communities, the emotions and the trials and tribulations that scientists experience in the course of their work* (italics, own).

(Morris, 1999)

Scientific enterprise

The total societal enterprise of science, that is, the complex of knowledge, people, skills, organisations, facilities, technique, physical resources, methods and technologies, taken together and the relationship to one another.

(McGinn, 1991 : pp 15-16)

Science literacy

Being aware that science, mathematics and technology are interdependent human enterprises, with strengths and limitations, understanding key concepts and principles of science, having a capacity to use scientific knowledge and ways of thinking for personal and social purposes.

(American Association for the Advancement of Science, 1990)

The knowledge of

1. What science is.
2. How science works.
3. How scientists operate
4. How society and scientific enterprises influence one another.

(Spector, Burkett & Duke, 2001)

Positivistic knowledge

The idealised view of truth inherited from the past. The tenets of the positivist philosophy are:

1. there is one method common to all sciences
2. scientific statements can be systematically verified
3. scientific observations are theory-free and theories are based on facts and observations
4. science is objective and rational.

Post-modern knowledge

Post-modern knowledge of science views that truth is dynamic, changing and bounded by time, space and perspective. It includes the stand that scientific knowledge is affected by social and cultural conditions (Valiela, 2001).

Stakeholders

The people who will be directly/indirectly involved in or impacted by the changes and outcomes of the Malaysian science education. Specifically, they are the curriculum planners, the institutions for training science teachers, the science teachers and students. In general, they include the employers and the general public.