CHAPTER 1

INTRODUCTION

1.0 Background of the Study

An understanding of the nature of science has been considered one of the primary outcomes of science education. It is also one of the most commonly stated objectives for science education (Hogan, 2000; Kimball, 1967-1968; Lederman, 1999; Meichtry, 1992; Miller, 1984; Ogunniyi, 1982; Rubba & Andersen, 1978). The importance of this perennial objective of science curricula is expressed in the following three-fold aims for science teaching listed by The National Society for the Study of Education in its 59th yearbook (cited by Mackay, 1971):

> First to teach some facts and principles of science; second to inculcate higher virtues, such as accuracy, critical thinking, scientific honesty and a more generally scientific method; and third to develop an understanding and appreciation of science and scientists. (p. 57)

In the early 1900s, the nature of science objective was expressed in terms of increased emphasis on scientific method in science curricula (Lederman, 1992). Bybee and DeBoer (1994) noted that the methods of science were seen as an ideal means to promote "scientific habits of mind".

In the 1960s, the instructional objective of developing an understanding of the nature of science was linked to the emphasis on the processes of science and the nature of scientific inquiry (Welch, 1979; Wood, 1972). Bybee and DeBoer (1994) reported that the structure of secondary curriculum projects of the 1960s indicated that scientific knowledge was generally to be achieved through the use of inquiry, and learning science through scientific inquiry was seen as a means of learning the structure of the discipline in a way that modeled how scientists thought and created knowledge.

Throughout the 1970s and 1980s, the understanding of the nature of science was included as a significant component of scientific literacy (Collete & Chiappetta, 1994; Fensham, 1983; Klopfer, 1969; Pella, O'Hearn, & Gale, 1966; Rubba & Andersen, 1978). The National Science Teachers Association (cited by Lederman & O'Malley, 1990) advocates an understanding of the nature of science as an essential characteristic of the scientifically literate individual and as a basic objective of the curricula which emphasize the Science-Technology-Society (STS) theme. In recent years, science educators have recommended educational practice that focuses on the goal of scientific literacy in general, and on understanding of the nature of science in particular (Aikenhead, 1997).

Clearly, an understanding of the nature of science is an important goal of science education. Smith and Scharmann (1999) observe that "there appears to be an almost universal commitment among science educators to promote the goal of student understanding of the nature of science" (p. 493). However, the advocacy for improved students' understanding of the nature of science must surely take into consideration teachers' views of the nature of science because it is the teachers' views that will be implemented into classroom practice (Brickhouse, 1990; Gallagher, 1991; Lantz & Kass, 1987; Robinson, 1969).

1.1 Rationale for the Study

In Malaysia, the teaching of science in secondary schools places emphasis on the processes of science and the nature of scientific inquiry in developing an understanding of the nature of science among the students (Kementerian Pendidikan Malaysia, 1993). Therefore, it stands to reason that science teachers must themselves first have a good understanding of the nature of science in order to convey it effectively to their students.

In view of the importance of teachers' conceptions of the nature of science, many research studies have been conducted to assess prospective as well as practising science teachers' understanding of the nature of science (Abell & Smith, 1994; Aguirre, Haggerty, & Linder, 1990; Behnke, 1961; Billeh & Malik, 1977; Kimball, 1967-1968; Ogunniyi, 1982). The findings of these studies revealed that, in general, the science teachers did not possess adequate conceptions of the nature of science.

In a study to compare the level of understanding of the nature of science between secondary science teachers and students, Schmidt (1967-1968) administered the Test on Understanding Science to students in grades 7 to 12 and to inservice science teachers. The results of the study showed that a sizable group of students in grade 9 and grades 11 to 12 (14 % and 47 % respectively) had scored higher than

25 % of the teacher sample. Schmidt concluded ironically that "some secondary science teachers understand science no better than students they may be assigned to teach" (p. 365).

Kimball (1967-1968), in his study to investigate the understanding of science teachers and scientists about the nature of science, reported that there was an apparent lack of change in their understanding of the nature of science with progression of time or with work experience. He concluded that "the concept of the nature of science is fairly well established by the time of graduation from college" (p. 118). Thus, if educators are to influence science teachers in acquiring a good understanding of the nature science, it must occur during their undergraduate course of study or during their teacher preparation training.

Given the importance that science teachers need to have an adequate understanding of the nature of science in order to communicate it effectively to their students, it has thus become important for teacher educators to determine the conceptions of the nature of science among the science teacher trainees enrolled in their training programmes. The need to determine the understanding of the nature of science among science graduate teacher trainees in Malaysia leads the researcher to this present study.

A teacher's view about the nature of science is assumed to be an important factor influencing his or her teaching behavior (Robinson, 1969). Research in science education has suggested a possible relationship between teachers' conceptions of the nature of science and their classroom practice (Brickhouse, 1990;

Gallagher, 1991). Lantz and Kass (1987), in their study to examine the interpretive process used by three high school chemistry teachers in translating curriculum materials into classroom practice, found that these teachers, who used the same chemistry curriculum, taught very different lessons about the nature of science, as a result of differences in their views about the nature of science.

Similarly, using purposive sampling and a qualitative case study approach, Brickhouse (1990) investigated the relationship between science teachers' beliefs about the nature of science and classroom practice. Three secondary science teachers who had varied perspectives on the nature of science participated in the study. The results of the study showed that the teachers exhibited classroom practices that were consistent with their respective understanding of the nature of science. Moreover, Palmquist and Finley (1997) claim that it is necessary for science teachers to understand the nature of scientific enterprise because "the portions of scientific knowledge science teachers choose to teach and how they carry out the instruction present a particular view of the nature of science to their students" (p. 595). Hence, a better understanding of the nature of science is highly desirable for science teachers as their views about the nature of science will influence their classroom practice.

It should prove fruitful for teacher educators to investigate teacher trainees' understanding of the nature of science so as to ascertain whether they hold any misconceptions of the nature of science, considering that misunderstandings and misconceptions of science will adversely affect how science is taught in the classroom.

The general consensus among researchers that science teachers do not possess a good understanding of the nature of science has led to efforts to improve preservice and inservice science teachers' conceptions of science. Numerous studies have been conducted to investigate methods of promoting an understanding of the nature of science among prospective as well as practising science teachers (Bianchini & Colburn, 2000; Billeh & Hasan, 1975; Carey & Stauss, 1970; Lavach, 1969; Palmquist & Finley, 1997; Scharmann, 1988). It has been found that courses in the philosophy of science can promote an understanding of the nature of science in preservice teachers (Akindehin, 1988; Kimball, 1967-1968; King, 1991). Hence, this study seeks to investigate whether Malaysian teacher trainees who have been formally exposed to philosophy of science will also exhibit similar results.

It is also one of the objectives of this study to investigate whether teacher trainees of different formal reasoning abilities will have different levels of understanding of the nature of science. Scharmann (1988) reported that logical thinking ability was the most influential predictor of understanding the nature of science.

In Malaysia, graduates in science and science related fields are enrolled anually in the Diploma of Education (Dip. Ed.) programme conducted by the local universities and the "Kursus Perguruan Lepas Ijazah" (KPLI) programme conducted by the teacher training colleges to be trained to teach science subjects in the secondary schools. As of 2001, this postgraduate science teacher education programme will be conducted solely by the teacher training colleges of the Ministry of Education. The KPLI science trainees are mostly graduates from applied science background (Tan, 1998). In view of Tan's findings that KPLI trainees from pure science background were significantly better in terms of teaching competence and subject matter knowledge, it is deemed appropriate to investigate whether they will also have a better understanding of the nature of science.

Only a few studies (Pomeroy, 1993; Wood, 1972) have been carried out to investigate the influence of gender on the understanding of the nature of science. However, the findings of these studies have not been conclusive. This study also seeks to investigate if there is any significant difference in the understanding of the nature of science between the male and female KPLI trainees.

A considerable number of research studies have been carried out in other parts of the world to investigate the understanding of the nature of science of secondary science teachers and preservice teachers (Abell & Smith, 1994; Aguirre et al., 1990; Akindehin, 1988; Billeh & Hasan, 1975; Gallagher, 1991; Kimball, 1967-1968; Koulaidis & Ogborn, 1989; Ogunniyi, 1982). However, in Malaysia, as far as the researcher is able to determine, no empirical studies have been carried out to assess science teacher trainees' understanding of the nature of science. This study is an attempt to assess Malaysian science teacher trainees' understanding of the nature of science and to identify their misconceptions of the nature of science.

1.2 Research Questions

The aim of this study was to assess selected science graduate teacher trainees' understanding of the nature of science using the Process Orientation Toward Science Scale (POTSS), an instrument developed by Scharmann, Harty, and Holland (1986). It also sought to identify their common misconceptions of the nature of science. In addition, the study sought to investigate the relationships between teacher trainees' understanding of the nature of science and their formal reasoning ability, academic background, and gender. Specifically, this study sought to address the following research questions:

1. What is the understanding of the nature of science of the science graduate teacher trainees ?
2. What are the science graduate teacher trainees' common misconceptions of the nature of science ?
3. Are there significant differences in the understanding of the nature of science among science graduate teacher trainees of different formal reasoning abilities ?
4. Is there a significant difference in the understanding of the nature of science between science graduate teacher trainees of different science majors ?
5. Is there a significant difference in the understanding of the nature of science between science graduate teacher trainees who have been and those who have not been formally exposed to philosophy of science ?

6. Is there a significant difference between the male and female science graduate teacher trainees in their understanding of the nature of science ?

1.3 Definitions of Terms

The following operational definitions were used for the purpose of this study.

1.3.1 Science Graduate Teacher Trainees or KPLI Trainees

These were science graduate teacher trainees attending the Post Graduate Teaching Course (KPLI, the acronym for *Kursus Perguruan Lepas Ijazah,* as it is known in Bahasa Melayu) conducted by several selected Teacher Training Colleges in Peninsular Malaysia. The trainees were graduates in science or science related fields and were being trained to teach secondary science subjects. The science graduate teacher trainees would also be referred to as KPLI trainees, science teacher trainees, teacher trainees, or trainees. The terms "KPLI trainees", "science graduate teacher trainees", "science teacher trainees", "teacher trainees", and "trainees" were used interchangeably to refer to the same idea.

1.3.2 Teacher Trainees' Understanding of the Nature of Science

This refers to teacher trainees' demonstration of the right conception of the nature of science. This was measured by the Process Orientation Toward Science Scale (POTSS), an instrument developed by Scharmann, Harty, and Holland (1986).

The construct of the process orientation toward science, as used in this study, referred to "the ability to recognize/identify the basic and/or integrated science process skills consistent with their application within and contribution to an emergent understanding of the nature of science" as defined by Scharmann et al. (1986).

Trainees' understanding of the nature of science was examined with respect to the:

1. Overall understanding of the nature of science.

   This was defined as the sum of the responses in agreement with the model responses to the 24 POTSS items obtained by the teacher trainees. The trainees' overall understanding of the nature of science was expressed in terms of percent mean score.

2. Understanding of the specific aspects of the nature of science.

   This was expressed in terms of frequency and percentage of the correct response to each of the 24 POTSS items. The percent mean scores for the overall understanding of the specific aspects of the nature of science were also reported.

1.3.3 The POTSS

This was the acronym of the instrument used by the researcher to assess teacher trainees' understanding of the nature of science. POTSS was also used as an adjective to describe a noun such as POTSS items.

1.3.4 Misconception

The term misconception was defined as any conceptual idea that differred from the commonly accepted scientific consensus as used by Cho, Kahle, and Nordland (1985). Teacher trainees' misconceptions of the nature of science were those conceptions which were not in agreement with the model responses to the POTSS items.

1.3.5 Common Misconceptions of the Nature of Science

Common misconceptions of the nature of science refer to those misconceptions held by at least 40 % of the teacher trainees.

1.3.6 Formal Reasoning Ability

Formal reasoning ability was defined in terms of five reasoning modes: proportional reasoning, controlling variables, probabilistic reasoning, correlational reasoning, and combinatorial reasoning (Garnett & Tobin, 1984). The formal reasoning ability was assessed using the Test of Logical Thinking (TOLT), an instrument developed by Tobin and Capie (1981). The teacher trainee's total TOLT score gave a measure of his or her formal reasoning ability.

1.3.7 Academic Background

The academic background of the teacher trainees was defined in terms of science majors and exposure to philosophy of science.

1.3.7.1 Science Majors

This refers to science graduate teacher trainees who were either pure science majors or applied science majors.

1. Pure science majors were teacher trainees who had majored in one or more pure science subjects during their undergraduate studies, such as biology, botany, zoology, microbiology, geology, chemistry, and physics.
2. Applied science majors were teacher trainees who had majored in the sciences which had applied emphases during their undergraduate studies, such as engineering, veterinary, pharmacy, horticulture, agriculture, and food technology.

1.3.7.2 Formal Exposure to Philosophy of Science

This refers to the formal course in philosophy of science taken by the science graduate teacher trainees during their undergraduate studies.

KPLI trainees who had been formally exposed to philosophy of science were those who had taken at least a two-unit formal course in philosophy of science during their undergraduate studies.

1.4 Model of Nature of Science Used in the Study

The term "nature of science" has been defined in numerous ways in literature. Although there is a general consensus among science educators on the need to promote student understanding of the nature of science (Aikenhead, 1997; Hogan, 2000; Lederman, 1992; Smith & Scharmann, 1999), there is still no common agreement on a universal definition of the nature of science. Herron (1969) commented that "... anything as complex as the nature of scientific knowledge ... is capable of being seen from a variety of points of views" (p. 106). Therefore, different researchers would use different models of the nature of science in their research on the understanding of the nature of science. Some of these models are described below.

Cooley and Klopfer's (1961) model covers three major areas of understanding of the nature of science and scientists: Understandings about the scientific enterprise, scientists, and the methods and aims of science. Within each of the three areas are a number of themes identified as important aspects of an understanding of the nature of science and scientists. The themes for each of the areas are presented in Table 1.1.

Table 1.1

Major Aspects of the Nature of Science in Cooley and Klopfer's Model

	Area	Aspects of the nature of science
1.	Understanding about the scientific enterprise	(a) Human element in science (b) Communication among scientists (c) Scientific societies (d) Instruments (e) Money (f) International character of science (g) Interaction of science and society
2.	Understanding about scientists	(a) Generalizations about scientists as people (b) Institutional pressures on scientists (c) Abilities needed by scientists
3.	Understanding about the methods and aims of science	(a) Generalities about the scientific methods (b) Tactics and strategy of sciencing (c) Theories and models (d) Aims of science (e) Accumulation and falsification (f) Controversies in science (g) Science and technology (h) Unity and interdependence of the sciences

Another model is Kimball's (1967-1968) model of the nature of science which consists of eight important aspects of the nature of science as shown in Table 1.2.

Table 1.2

Major Aspects of the Nature of Science in Kimball's Model

	Aspects of the nature of science
1.	The fundamental driving force in science is curiosity concerning the physical universe. It has no connection with outcomes, applications, or uses aside from generation of new knowledge.
2.	In the search for knowledge, science is process oriented; it is a dynamic, ongoing activity, rather than a static accumulation of information.
3.	In dealing with knowledge as it is developed and manipulated, science aims at ever-increasing comprehensiveness and simplifications, emphasizing mathematical language as the most precise and simplest means of stating relationships.
4.	There is no one "scientific method" as often described in school textbooks. Rather, there are as many methods of science as there are practitioners.
5.	The methods of science are characterized by a few attributes which are more in the realm of values than techniques. Among these traits of science are dependence upon sense experience, insistence on operational definitions, recognition of the arbitrariness of definition and schemes of classification or organization, and the evaluation of scientific work in terms of reproducibility and of usefulness in furthering scientific inquiry.
6.	A basic characteristic of science is a faith in the susceptibility of the physical universe to human ordering and understanding.
7.	Science has a unique attribute of openness, both openness of mind, allowing for willingness to change opinion in the face of evidence, and openness of the realm of investigation, unlimited by such factors as religion, politics, or geography.
8.	Tentativeness and uncertainty mark all of science. Nothing is ever completely proven in science, and recognition of this fact is a guiding consideration of the discipline.

Yet another model of the nature of science, used by Billeh and Malik (1977) in their study, is composed of four main components of the nature of science, namely the assumptions of science, processes of science, scientific enterprise, and ethics of science. The aspects that characterize these components are presented in Table 1.3.

Table 1.3

Major Aspects of the Nature of Science in Billeh and Malik's Model

Component	Aspects of the nature of science
1. Assumptions of science	(a) The world is real (b) The physical universe is intelligible (c) Phenomena of nature are causal (d) Phenomena of nature are continuous and consistent (e) Phenomena of nature are dissoluble (f) Phenomena of nature are deterministic
2. Processes of science	(a) Observation (b) Measurement (c) Classification (d) Experimentation (e) Communication (f) Formulation of hypotheses, theories, laws, and models (g) Prediction

(table continues)

Table 1.3 *(continued)*

Component	Aspects of the nature of science
3. Scientific enterprise	(a) Science is amoral (b) Factual statements of science are empirically testable (c) Science is a self correcting enterprise (d) Scientific knowledge is parsimonious (e) Scientific knowledge is tentative (f) Laws of science are probabilistic (g) Laws and theories are different in nature (h) Technology is application of science
4. Ethics of science	The persons engaging themselves in the pursuit of science (scientists): (a) have an inquiring mind (b) are curious (c) careful and accurate (d) distinguish between fact and opinion (e) are open minded (f) are objective (g) are not superstitious (h) are anti-authoritian

On the other hand, the model of the nature of scientific knowledge, used by Rubba and Andersen (1978), is composed of six aspects of scientific knowledge as displayed in Table 1.4.

Table 1.4

Major Aspects of Scientific Knowledge in Rubba and Andersen's Model

	Aspect of scientific knowledge	Description
1.	Amoral	Scientific knowledge provides man with many capabilities, but does not instruct him on how to use them. Moral judgment can be passed only on man's application of scientific knowledge, not on the knowledge itself.
2.	Creative	Scientific knowledge is a product of the human intellect. Its invention requires as much creative imagination as does the work of an artist, a poet, or a composer. Scientific knowledge embodies the creative essence of the scientific inquiry process.
3.	Developmental	Scientific knowledge is never "proven" in an absolute and final sense. It changes over time. The justification process limits scientific knowledge as probable. Beliefs which appear to be good ones at one time may be appraised differently when more evidence is at hand. Previously accepted beliefs should be judged in their historical context.
4.	Parsimonious	Scientific knowledge tends toward simplicity, but not to the disdain of complexity. It is comprehensive as opposed to specific. There is a continuous effort in science to develop a minimum number of concepts to explain the greatest possible number of observations.
5.	Testable	Scientific knowledge is capable of empirical test. Its validity is established through repeated testing against accepted observations. Consistency among test results is a necessary, but not a sufficient condition for the validity of scientific knowledge.
6.	Unified	Scientific knowledge is born out of an effort to understand the unity of nature. The knowledge produced by the various specialized sciences contribute to an interrelated network of laws, theories, and concepts. This systemized body gives science its explanatory and predictive power.

Although there are many different models of the nature of science used by different researchers as exemplified by the above four models, nevertheless, certain common aspects of the nature of science are found in some of these models. Among these aspects reported by Eflin, Glennan, and Reisch (1999) are:

1. The main purpose of science is to acquire knowledge of the physical world. Science is an attempt to explain natural phenomena and events.
2. There is an underlying order in the world which science seeks to describe in the most simple and comprehensive manner.
3. Science is dynamic, changing, and tentative. As a result, scientific knowledge is never "proven" in an absolute and final sense.
4. There is no one, single scientific method.

For the purpose of this study, Scharmann et al.'s (1986) model of the nature of the science was used. The aspects of the nature of science in Scharmann's model, shown in Table 1.5, were identified by the present researcher from an analysis of the POTSS items with reference to the aspects of the nature of science described in the aforementioned models.

Table 1.5

Major Aspects of the Nature of Science in Scharmann, Harty and Holland's Model

	Aspects of the nature of science	Description
1.	Nature of classification in science	Among the many traits of science is the recognition of the arbitrariness of definition and schemes of classification. A classification scheme is an invention of man used for organizing data.
2.	Nature of scientific measurement	Scientific measurement has inherent error and is a method of quantification.
3.	Scientific knowledge is developmental	Scientific knowledge is never "proven" in an absolute and final sense. Tentativeness is characteristic of all science.
4	Scientific knowledge is testable and replicable	The validity of scientific knowledge is established through repeated testing against accepted observations. Consistency among test results is a necessary, but not a sufficient condition for the validity of scientific knowledge.
5.	The predictive power of science	Science explains and predicts. The interrelated network of laws, theories, and concepts gives science its explanatory and predictive power.
6	The primary purpose of science is to acquire knowledge of the physical world.	Curiosity concerning the physical universe is the fundamental driving force in science. Science is an attempt to explain natural phenomena and events. The primary aim of science is not to produce useful technology.
7.	Science is a shared social enterprise	Science is a complex social activity. Communication of scientific information is important in making available the information for independent verification and confirmation.

(*table continues*)

Table 1.5 *(continued)*

	Aspects of the nature of science	Description
8.	Scientific methods	There is no one, single scientific method.
9.	Science is creative	Scientific knowledge is a product of the human intellect and it embodies the creative essence of the scientific inquiry process.
10.	Science is empirical	One of the traits of science is dependence upon sense experience. Scientific knowledge is based on or derived from observations of the natural world. The validity of scientific conclusions should ultimately be based on evidence.
11.	Nature of controlled experiment	Experiment involves the identification, manipulation, and control of variables.

1.5 Significance of the Study

One of the objectives of science education is scientific literacy for all students. An understanding of the nature of science is an important component of scientific literacy (Fensham, 1983; Klopfer, 1969; Lederman, 1999; Meichtry, 1993). Thus, it is important that teacher trainees have a good understanding of the nature of science to equip them to effectively communicate it to their students. Studies have shown that teacher trainees' views about the nature of science have some influences on their classroom practice (Brickhouse, 1990; Gallagher, 1991; Lantz & Kass, 1987).

As far as the researcher is able to determine, no documented study on the understanding of the nature of science among preservice secondary science teachers has been done in Malaysia. Therefore, the findings from this study will be useful to teacher educators as well as curriculum planners and developers as this is the first time that a local study is exclusively carried out to assess teacher trainees' understanding of the nature of science.

The findings from this study will provide feedbacks to teacher educators in the teacher training colleges with useful insights of the trainees' conceptions of the nature of science. Identification of the misconceptions of the nature of science held by them will help teacher educators in improving instructional planning and pedagogical practices. Teacher educators can consider developing resources and teaching strategies that will initiate and encourage discussions about the nature of the scientific endeavor among the trainees which will lead them to the correct conceptions of the nature of science.

The findings from this study will also be useful to teacher training curriculum planners. If findings show that the understanding of the nature of science by the trainees is not satisfactory, then ways of improving their understanding of the nature of scientific enterprise should be planned. Furthermore, the results of the study can also provide the curriculum planners with the much needed information for future revision of existing preservice secondary science teacher training programmes or in designing new programmes to correct the deficiencies of the trainees' understanding of the nature of science.

If the findings indicate that there are significant differences in the understanding of the nature of science for the variables of formal reasoning ability, science major type, formal exposure to philosophy of science, and gender, then the effect of these variables should be taken into account in the future revision of the preservice science teacher education programmes.

1.6 Limitations of the Study

The subjects of the study were confined to science graduate teacher trainees drawn from only four selected teacher training colleges in Peninsular Malaysia. Therefore the findings of this study could not allow generalization to be made on science graduate teacher trainees enrolled in similar teacher training programmes conducted by other teacher training colleges in Malaysia. The findings would also not be generalizable to science graduate teacher trainees enrolled in other teacher training programmes conducted by local unversities.

In order to achieve the objectives of this study, a questionnaire was used to elicit responses from a group of 80 subjects. This questionnaire had its limitations in that it was difficult for the researcher to probe further the responses given by the trainees. Hence, their understanding of the nature of science and their specific misconceptions were inferred from an analysis of their responses to the POTSS items.