CHAPTER 2

REVIEW OF RELATED LITERATURE

2.0 Introduction

Many research studies related to the nature of science had been conducted in the last three decades. A number of these studies dealt with the assessment of students' conceptions of the nature of science and the development as well as assessment of science curricula designed to promote a better understanding of the nature of science among the students. In addition, numerous studies pertaining to the assessment of prospective science teachers' and practising science teachers' understanding of the nature of science have been published in education journals. There have also been a number of studies carried out to investigate the relationships of teachers' conceptions of the nature of science with classroom practice and students' conceptions of the nature of science. However, much of this work has been carried out in the United States of America, Canada, and Nigeria (Abell & Smith, 1994; Akindehin, 1988; Bloom, 1989; Gustafson & Rowell, 1995, Kimball, 1967-1968; Lederman & Zeidler, 1987; Ogunniyi, 1982; Scharmann, 1988). In this study, it is the intention of the researcher to investigate the understanding of the nature of science among science graduate teacher trainees in Malaysia.

This chapter presents a review of literature on various instruments used to assess the understanding of the nature of science, and the findings of previous studies pertaining to the relationships of teachers' understanding of the nature of science with the independent variables of formal reasoning ability, academic background, and gender.

2.1 Instruments for Assessing the Understanding of the Nature of Science

The multifaceted definitions of the nature of science have resulted in the development of a variety of instruments for assessing the understanding of the nature of science. One of the earliest instruments purporting to measure the understanding of the nature of science was constructed in 1950 by Anderson (cited by Lederman, 1992). The instrument was used in the first assessment of teachers' understanding of the methodology of science.

In 1961, Cooley and Klopfer developed the Test on Understanding Science (TOUS) to measure the understanding about the scientific enterprise, scientists, and the methods and aims of science. Welch and Pella (1967-1968) developed the "Science Process Inventory" (SPI) to measure knowledge of the science processes. Kimball (1967-1968) on the other hand, created the Nature of Science Scale (NOSS) to measure the understanding of eight important aspects of the nature of science. The Test on Understanding the Nature of Science (TUNS) was constructed by Billeh and Malik (1977) to measure prospective science teachers' knowledge of the assumptions and processes of science, characteristics of scientific enterprise, and the ethics of science. Rubba and Andersen (1978) developed the Nature of Scientific Knowledge Scale (NSKS) to measure high school students' understanding of the nature of scientific knowledge. Scharmann et al. (1986) developed the Process Orientation Toward Science Scale (POTSS) to assess preservice elementary teachers' process orientation toward science. These instruments are discussed in detail in Sections 2.1.1 to 2.1.6.

2.1.1 Test on Understanding Science (TOUS)

The TOUS was developed by Cooley and Klopfer (1961) at the Harvard University Graduate School of Education. The test consists of sixty four-alternative multiple-choice items. These items are grouped into three subtests as shown in Table 2.1.

Table 2.1

Subtests of Test on Understanding Science (TOUS)

Subtest	Number of items
I. Understandings about the scientific enterprise	18
II. The scientists	18
III Methods and aims of science	24
Total	60

The content validity of TOUS was established by several consultants at the Harvard University and other institutions. The TOUS has a K-R 20 reliability coefficient of .76 and a correlation coefficient of .66 with scholastic aptitude (cited by Tulasi, 1999). Despite its acceptable reliability estimate, Wheeler (cited by Aikenhead, 1973) contended that the TOUS had too many items incorporating negative viewpoints of science.

2.1.2 Science Process Inventory (SPI)

The SPI was designed by Welch and Pella (1967-1968) to measure the "understanding of the methods and processes by which scientific knowledge evolves" (p. 64). Forms C and D of the SPI respectively contain 150 and 135 forced choice items pertaining to the assumptions, activities, products, and ethics of science. A respondent may respond by either agreeing or disagreeing to the idea contained in each statement. The respondent's total score is obtained by summing up the number of agreements with a standard key.

The validation of the SPI followed the following procedure: using the literature, using a model, employing the judgements of "experts", getting feedback from preliminary studies, and testing the instrument for its ability to distinguish among groups of students, teachers, and scientists (Aikenhead, 1973).

Form C of the SPI has a Hoyt reliability coefficient of .79 based on the scores of 1,283 high school students from grade 10 to grade 12 (Welch & Pella, 1967-1968) whereas Form D of this inventory has a K-R 20 reliability coefficient of .86 reported in another study (cited by Tulasi, 1999).

2.1.3 Nature of Science Scale (NOSS)

Kimball (1967-1968) developed the NOSS to measure the understanding of the nature of science. The scale was based on a theorectical model constructed from an extensive review of the literature on the nature and philosophy of science and all the review concurred with the views expressed by two philosophers of science, Bronowski and Conant. Kimball's model is composed of eight important aspects of the nature of science. The NOSS consists of 29 items and each item is a statement pertaining to an aspect of the nature of science. A respondent may respond to each statement by either agreeing, disagreeing, or signifying he or she is neutral about the item. The NOSS items are scored by awarding two points for each response in agreement with the theorectical model, one point for a neutral response, and no point is given for a response not in agreement with the theorectical model. Table 2.2 shows the number of NOSS items and the corresponding aspects of the nature of science as identified by Cobern (1989).

In his study, Kimball (1967-1968) carried out the validation and reliability measures of the NOSS with college graduates. The validation of the instrument followed closely the procedure described earlier for the SPI. The NOSS was reported to have a Spearman-Brown split-half reliability coefficient of .72 in one preliminary study and .54 in an extensive survey study.

Table 2.2

Aspects of the Nature of Science in NOSS

	Aspects of the nature of science (Condensed version)	Number of items
1.	The fundamental driving force in science is curiosity concerning the physical universe.	7
2.	Science is a dynamic, ongoing activity, rather than a static accumulation of information.	1
3.	Science aims at ever-increasing comprehensiveness and simplifications using mathematics as a simple, precise method of stating relationships.	2
4.	There are many methods of science.	9
5.	The methods of science are characterized by attributes that are more in the realm of values than techniques.	3
6.	A basic characteristic of science is a faith in the susceptibility of the physical universe to human ordering and understanding.	2
7.	Science has a unique attribute of openness; both openness of mind and openness of the realm of investigation.	1
8.	Tentativeness and uncertainty mark all of science.	4
	Total	29

2.1.4 Test on Understanding the Nature of Science (TUNS)

Billeh and Malik (1977) constructed the TUNS to measure the understanding of the nature of science among prospective science teachers. It is a four-alternative multiple-choice test containing 55 items. The test comprises two types of items. The first type measures the respondent's knowledge of the assumptions and processes of science, characteristics of scientific enterprise, and the ethics of science. The second type requires the respondent, when presented with specific situations, to make judgements in view of his or her understanding of the nature of science. The TUNS items are grouped into four subtests as presented in Table 2.3.

Table 2.3

Subtests of Test on Understanding the Nature of Science (TUNS)

Subtest		Number of items
I	Assumptions of science	10
II	Processes of science	20
III	Scientific enterprise	15
IV	Ethics of science	10
Total		55

The validation of the test followed closely the procedure described earlier for the SPI. Billeh and Malik (1977) computed two estimates of reliability for the test using Hoyt's ANOVA method and the K-R 20 formula for the various groups of prospective science teachers according to the type of training programme (Bachelor of Education, B.Ed.; Master of Education, M.Ed.; Master of Arts in Education, M.A.Ed.; and Bachelor of Science, B.Sc.) as well as pretraining and posttraining status. The Hoyt's ANOVA method for estimating the reliability of a test is based on the analysis of variance. The computation of the Hoyt's ANOVA yields similar results to those obtained from the K-R 20 formula (Hoyt, 1941). Table 2.4 presents the reliability coefficients for the three consolidated groups of prospective science teachers.

Table 2.4

Reliability Coefficients of TUNS for Three Consolidated Groups of Prospective Science Teachers

Groups of prospective science teachers	Reliability coefficient	
	Hoyt's ANOVA	K-R 20
M.Ed. and M.A.Ed. posttraining	.96	.96
M.Ed. pretraining & B.Ed. posttraining	.73	.89
B.Sc.	.93	.91

2.1.5 Nature of Scientific Knowledge Scale (NSKS)

Rubba and Andersen (1978) developed the NSKS to measure high school students' understanding of the nature of scientific knowledge. The development of the NSKS underwent a rigorous seven-step process to ensure its reliability and validity. The process involved the establishment of a model of the nature of scientific knowledge, item refinement, item pool preparation, field testing, and item selection.

The NSKS consists of six subtests. Each subtest comprises of eight items, four positive and four negative, corresponding to each of the aspects in the model of the nature of scientific knowledge. The 48 items are randomly arranged. The NSKS subtests are shown in Table 2.5.

Table 2.5

Subtests of Nature of Science Knowledge Scale (NSKS)

Subtest	Number of items
1. Amoral	8
2. Creative	8
3. Developmental	8
4. Parsimonious	8
5. Testable	8
6. Unified	8
Total	48

The NSKS employs a five-point Likert scale. Responses to each NSKS item are scored 5, 4, 3, 2, or 1 for "strongly agree", "agree", "neutral", "disagree" or "strongly disagree" respectively. Scores are reversed for each negative item.

Rubba and Andersen (1978) assessed the reliability of the NSKS with seven samples of students in grades 9 to 16. The alpha coefficients were found to range from .65 to .89. They also established a test-retest reliability on the NSKS with two groups of high school students, 52 freshman general science students and 35 senior advanced chemistry students. The administration of the test and retest was held over an interval of six weeks. The Pearson product-moment correlation coefficients calculated between the test and the retest were .59 and .87 respectively for the freshmen and seniors.

The content of the NSKS was validated by a panel of three philosophers of science. The "judges" were asked to evaluate whether the items were consistent with the set of validation criteria. The construct validity was determined by comparing two groups of college freshmen with "known group differences". Results obtained from the *t*-test comparisons of NSKS scores between Biology and Philosophy of Science groups showed that the NSKS was able to discriminate between college freshmen who had taken and those who had not taken a course in philosophy of science. The ability of the NSKS to discriminate between these two groups of college freshmen was accepted as evidence of the NSKS construct validity (Rubba & Andersen, 1978).

2.1.6 Process Orientation Toward Science Scale (POTSS)

Scharmann, Harty, and Holland (1986) developed the POTSS to assess preservice elementary teachers' process orientation toward science. The construct "process orientation toward science" was defined as "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" (p. 376).

The three researchers started with an initial pool of 60 items. The items were written with reference to previously validated instruments such as the "Wisconsin Inventory of Science Processes" (Science Literacy Center, 1967) and the "Nature of Science Scale" (Kimball, 1967-1968). For instance, Item 4 of the POTSS (If scientists in the future find that electricity does not consist of electrons, electrical equipment will have to be redesigned.) was adapted from Item 25 of the NOSS. Likewise, Item 6 of the POTSS (If scientists repeatedly observe that condition A is followed by state B, they can infer that state B will probably occur whenever they observe condition A.) was adapted from Item 1 of the WISP. Unlike the WISP and the NOSS which employ the 3-point Likert scale whereby a respondent may respond to each item by either "agreeing", "disagreeing", or "signifying that he or she is neutral about the item", the POTSS utilizes the 5-point Likert scale. Responses to each item are scored 5, 4, 3, 2, or 1 for "strongly agree", "agree", "neutral", "disagree" or "strongly disagree" respectively. However, for statements which are inconsistent with the defined process-orientation construct, the scores for the responses "strongly agree", "agree", "neutral", "disagree", and "strongly disagree" were reversed (5 = 1, 4 = 2, 3 = 3, 2 = 4, and 1 = 5).

The content of the POTSS was validated by three science education professors, two advanced-level doctoral students and one philosophy of science professor based on their judgement as to whether the items were consistent with the four validation criteria. They were further asked to rate the items on six categories. The selection process reduced the size of the POTSS to 25 items.

Scharmann et al. (1986) also established predictive validity of the POTSS with a sample of 27 elementary preservice teachers enrolled in a course whose content was based upon the understanding, recognition, and application of science process skills. They reported predictive validity in that a significant Spearman's rho correlation was calculated between the entry level process orientation toward science of preservice elementary science teachers and their science process achievement levels four months later.

Construct validity was determined by comparing three groups of respondents who possessed different degrees of a "process orientation toward science" as it was related to an understanding of the nature of science. Results obtained indicated that the POTSS was capable of discriminating between elementary and secondary preservice teachers as well as between elementary preservice teachers and biology majors.

The 25 items in the POTSS were subjected to factor analysis. The factor analysis produced two categories, shown in Table 2.6, which the three researchers labelled as "Basic process skills orientation" and "Integrated process skills orientation". It should be noted that the terms "basic process skills" and "integrated process skills" used by them to identify these two categories were not in full agreement with the terms "basic science process skills" and "integrated science process skills" as defined in the Science: A Process Approach (SAPA) model (Livermore, 1964).

Table 2.6

Categories of POTSS Items

Category	Number of items
I. Basic process skills orientation	12
II. Integrated process skills orientation	12
Total	24

It should also be noted that Item 9 of the POTSS was not classified in any of the two categories since it was purported to directly assess the respondent's attitudes toward science as inquiry.

The reliability of the 25-item POTSS was estimated based on the scores of 27 elementary preservice teachers enrolled in a science process skills course. The POTSS possessed an alpha coefficient of .83 and item to total correlations ranging from .28 to .62.

2.1.7 Discussion of Instruments Reviewed

A summary of the instruments reviewed in Sections 2.1.1 to 2.1.6 is presented in Table 2.7.

Table 2.7

A Summary of Instruments for Assessing the Understanding of the Nature of Science

Instrument	Acronym of the instrument	Scale of measurement	Number of items	Target group of respondents
1. Test on Understanding Science	TOUS	Four-alternative multiple choice	60	Post secondary with science background
2. Science Process Inventory	SPI	Forced-choice type, either "agree" or "disagree"	135	Post secondary with science background
3. Nature of Science Scale	NOSS	Three-point Likert-type scale of "agree", disagree" or "neutral"	29	Post secondary with science background
4. Test on Understanding the Nature of Science	TUNS	Four-alternative multiple choice	55	Post secondary with science background
5. Nature of Science Knowledge Scale	NSKS	Five-point Likert-type scale of "strongly agree" to "strongly disagree"	48	Upper secondary science students
6. Process Orientation Toward Science Scale	POTSS	Five-point Likert-type scale of "strongly agree" to "strongly disagree"	25	Post secondary with science background

Table 2.8 shows that three instruments (TOUS, SPI, and TUNS) use the forced-choice responses whereas the other three instruments (NOSS, NSKS, and POTSS) employ the Likert scale. Measurements by all the instruments represent the multifaceted definitions of the nature of science. All the instruments with the exception of the NSKS are suitable for assessing the understanding of the nature of science among precollege students, undergraduates or graduates with a science background. The NSKS is, however, suitable for assessing high school students' understanding of the nature of science.

For this study, the POTSS was selected as the instrument to measure the teacher trainees' understanding of the nature of science, considering that the 24 items in the POTSS dealt with the various aspects of the nature of science. However, the classification of the items into "basic process skills orientation" and "integrated prosess skills orientation" was not normally used by other researchers in their studies on the understanding of the nature of science. Furthermore, the labels "basic process skills" and "integrated process skills" as used by Scharmann et al. (1986) might give the impression that these labels were totally in line with the terms "basic science process skills" and "integrated science process skills" as defined in the SAPA model (Livermore, 1964). To avoid such confusion, the researcher took the stand that the POTSS items basically measured the understanding of the nature of science. Hence, in this study, the POTSS items were not classified into the basic process skills orientation nor the integrated process skills orientation categories as carried out by Scharmann et al. (1986).

2.2 Teachers' Conceptions of the Nature of Science

Lederman (1992) in his review of literature on students' and teachers' conceptions of the nature of science reported that " ... if teaching is viewed as a purposeful and conscious act, a teacher must possess an adequate knowledge of what he/she is attempting to communicate to others" (p. 339). It therefore, follows that the understanding of teachers about the nature of science could significantly influence the quality of science teaching. In view of the importance of teachers, many studies have been conducted to assess their conceptions of the nature of science. A number of these research reports had consistently indicated that preservice teachers and practising science teachers did not have an adequate understanding of the nature of science (Billeh & Malik, 1977; Carey & Stauss, 1970; Kimball, 1967-1968; Schmidt, 1967-1968).

In his 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 (TOUS) to students in grades 7 to 12 and to inservice science teachers. The findings showed that 14 % of the students in grade 9 and 47 % of the students in grades 11 to 12 scored higher than 25 % of the teacher sample. Moreover, the results of the study showed that there was little apparent difference between the mean score on the TOUS of the inservice teachers (mean score = 45.5) and that of the students in grades 11 to 12 (mean score = 41.0).

Kimball (1967-1968), on the other hand, conducted a study to investigate the understanding of the nature of science among scientists and science teachers. He used the Nature of Science Scale (NOSS) to measure the respondents' understanding of the nature of science. The results of the study showed that the science teachers obtained a mean score of 35.4 out of a total of 58 on the NOSS. The findings suggested that the understanding of the nature of science of these qualified teachers was less than satisfactory.

Billeh and Malik (1977), in their study to investigate the relative levels of understanding of the nature of science by five groups of prospective science teachers, administered the Test on Understanding the Nature of Science (TUNS) to 191 prospective science teachers enrolled in the Bachelor of Education (B.Ed.), Master of Education (M.Ed.), Master of Arts in Education (M.A.Ed.), and Bachelor of Science (B.Sc.) programmes. The findings of the study showed that the percent mean score on the TUNS obtained by the five groups ranged from 33.35 % for the B.Sc. group to 53.81 % for the M.Ed. post-training group. Based on these results, they concluded that the understanding of the nature of science by all the groups of prospective science teachers was fairly low.

In addition to assessing the overall understanding of the nature of science, many studies have been conducted to examine preservice teachers as well as practising science teachers' conceptions of the specific aspects of the nature of science (Abell & Smith, 1994; Aguirre et al., 1990; Behnke, 1961; Bloom, 1989; Cobern, 1989; Gallagher, 1991; Gustafson & Rowell, 1995; Hashweh, 1996; Kimball, 1967-1968; Koulaidis & Ogborn, 1989; Ogunniyi, 1982; Ogunniyi & Pella, 1980; Palmquist & Finley, 1997).

Behnke (1961) used a 50-statement questionnaire to measure the understanding of science teachers and scientists with respect to certain aspects of science and science teaching. The questionnaire used a three-option response format (favoring, opposing, and neutral) to assess their understanding of the nature of science, science and society, the scientist and society, and the teaching of science. The study sample comprised of 200 biology teachers, 421 physical science teachers, and 70 scientists. Results of the study indicated that over 50 % of the science teachers exhibited the misconception that scientific findings were not tentative. Even more surprising was that 20 % of the scientists felt the same way. This led Behnke to conclude that there were many science teachers who viewed the substantive content of science as fixed and unchangeable. The findings also showed that more than 50 % of the science teachers misconceived the goals of science as practical and aimed primarily at the improvement of human welfare. This result is consistent with the findings of Kimball (1967-1968). Data from Kimball's study revealed that more than 40 % of the science teachers felt that the primary objective of the working scientist was to improve human welfare.

Similarly, Ogunniyi (1982), in his study on 53 Nigerian prospective science teachers' understanding of the nature of science using some of the NOSS items, reported that 79 % of the teachers thought that the primary objective of the working scientist was to improve human welfare.

Cobern (1989) compared the understandings about the nature of science of 21 American preservice science teachers with 32 Nigerian preservice science teachers using Kimball's NOSS. He found two significant differences between the groups. The primary difference was that Nigerian preservice teachers were more inclined to view science as a way of producing useful technology. This result concurs with the findings of Ogunniyi (1982). The second difference was that Nigerian preservice teachers perceived scientists as being nationalistic and secretive about their work. They failed to see that science had a unique attribute of openness.

In his study to assess preservice elementary teachers' understanding of science and how certain contextual variables contribute to this understanding, Bloom (1989) administered a questionnaire comprising six questions related to knowledge of science, theories, and evolution to eighty preservice elementary teachers. A 21-item rating scale pertaining to previous experiences with science, the nature of science, science teaching, evolution, and creationism was also administered to the subjects. A qualitative analysis of the subjects' responses revealed that most individuals held the misconception that science was people centred and its primary purpose was to benefit mankind. Bloom also claimed that there was much confusion among the preservice elementary teachers concerning the meaning of scientific theories.

Another interesting study was carried out by Aguirre, Haggerty, and Linder (1990). They used a case study approach to assess 74 preservice secondary science teachers' conceptions about the nature of science, teaching, and learning. All the subjects in the study had completed a Bachelor degree in pure science or engineering. A questionnaire consisting of eleven open-ended questions about science, teaching of science, and learning of science was administered to the subjects. A qualitative analysis of the questionnaire responses revealed that most of the prospective science teachers believed that science was either a body of knowledge consisting of a collection of observations and explanations or of propositions which had been proven to be correct. The prospective teachers failed to understand that scientific knowledge was tentative and that science did not provide absolute proof.

The lack of understanding that scientific knowledge is tentative is also reported in Hashweh's (1996) study. In his study to investigate science teachers' beliefs about learning and about scientific knowledge, Hashweh administered two questionnaires to 91 science teachers. Based on the results of the study, Hashweh found that two thirds of the teachers believed the main aim of science was to gather facts about nature rather than recognizing that science was an attempt to explain natural phenomena and events. He also reported that more than 80 % of the teachers believed that scientific knowledge developed through accretion, a static accumulation of information rather than through a dynamic, on-going activity.

The study by Abell and Smith (1994) focused on preservice elementary teachers' definitions of science. They administered a questionnaire to 140 preservice elementary teachers enrolled in the elementary science methods course. The questionnaire aimed to solicit the respondents' views about the nature of science and about teaching elementary school science. Responses to the questionnaire were analysed using the technique of analytic induction. The analysis revealed that about 44 % of the teachers defined science mainly as a process of discovering what existed in the world and 34.3 % of the subjects defined science as a product, as a set of ideas to be studied. Thus, most preservice teachers tended to view science as a process of exploring the world and discovering its truths. Furthermore, findings of the study showed that the teachers held the misconception that science was the way to make sense of the world. According to Abell and Smith, these teachers did not seem to understand that scientific knowledge had its limitations. The results of the study revealed that a small number of the teachers viewed the purpose of science as a societal one, which was, to benefit humankind. Such findings are in agreement with those of Ogunniyi's (1982) and Bloom's (1989) studies.

Gustafson and Rowell (1995) carried out a study to assess elementary preservice teachers' conceptions of learning science, teaching science and the nature of science. Questionnaires and semi-structured interviews were employed in the study to elicit their conceptions of learning science, teaching science, and the nature of science. The questionnaires were administered to 27 preservice teachers at the beginning and end of two undergraduate elementary science education courses. Eight of the 27 teachers then participated in the interviews. The responses and comments to the questionnaires and interviews were analysed. An analysis of the responses revealed that the preservice teachers held the misconception of science as a body of knowledge, separate from man and waiting to be 'discovered'. This view supports the findings of Aguirre et al.'s (1990) and Abell and Smith's (1992) studies.

The review of the above studies shows that prospective science teachers as well as practising science teachers possessed a variety of conceptions about the nature of science. Many of these teachers had expressed views which indicated their misconceptions about the nature of science. It is thus deemed appropriate to determine whether science teacher trainees in Malaysia exhibit similar misconceptions of the nature of science.

2.3 Relationships of Understanding of the Nature of Science with Formal Reasoning Ability

The literature is devoid of studies involving the establishment of direct relationships between teacher trainees' understanding of the nature of science and their formal reasoning ability. However, a study by Scharmann (1988) has helped to illuminate a probable relationship between the understanding of the nature of science and logical thinking ability.

In his study on the influence of locus of control as a discriminator of the ability to foster an understanding of the nature of science, Scharmann (1988) investigated six predictor variables (that is, logical thinking ability, science content knowledge, academic achievement, science achievement, verbal aptitude, and quantitative aptitude) for their power to predict an understanding of the nature of science. The subjects of the study comprised of 135 preservice elementary teachers. The subjects' understanding of the nature of science was measured by the Nature of Science Scale (NOSS: Kimball, 1967-1968) while their logical thinking ability was measured by the Test of Logical Thinking (TOLT: Tobin & Capie, 1981). Results of the study showed that logical thinking ability had the highest correlation with the understanding of the nature of science. Based on the data, Scharmann concluded that logical thinking ability was the most influential predictor of an understanding of the nature of science. This finding suggests that promoting growth in critical aptitudes could enhance the understanding of the nature of science.

2.4 Relationships of Understanding of the Nature of Science with Science Major Type

As far as the researcher could trace, no study had been conducted to investigate the relationship between the understanding of the nature of science and the groups of pure science and applied science major type. However, a study had been conducted locally by Tulasi (1999) to investigate the relationship between scientific attitudes and the different science major types. He adapted the Test on Scientific Attitudes (Kozlow & Nay, 1976) to assess the scientific attitudes. Using the Adapted Test On Scientific Attitudes (TOSA-A), he carried out an empirical survey with 263 KPLI trainees. The TOSA-A consisted of 39 multiple-choice items covering six aspects of the scientific attitudes: (a) critical-mindedness, (b) suspended judgement, (c) respect for evidence, (d) intellectual honesty, (e) objectivity, and (f) willingness to change opinions. Some of the TOSA-A items, for instance, Items 1, 2, 3, 4, 6, 13, 15, 19, and 26 assessed the understanding of a few aspects of the nature of science as used in this study. The results of the study indicated that there were no significant differences at $p < .05$ level between the pure science major and the applied science major groups in their overall scientific attitudes as well as in all the aspects of the scientific attitudes.

There had been studies carried out at the international scene to investigate whether science teachers expressed the same view of the nature of science as scientists. Kimball (1967-1968) conducted a study to address the question whether fully certified science teachers had the same level of understanding of the nature of science as practising scientists. The statistical analysis of the NOSS scores from a sample of 419 scientists and 78 science teachers showed that there was no significant difference in their understanding of the nature of science when their academic backgrounds were similar. However, the science teachers group had a slightly higher mean score (35.41) compared to that of the scientist group (34.73), but the difference was not significant at the $p < .05$ level.

Pomeroy (1993) employed a 50-item survey in her comparative study of scientists' and science teachers' beliefs about the nature of science. The participants of the study comprised of 71 Alaskan research scientists and 109 secondary science and elementary teachers in Alaskan cities. Among the scientists, 45 % were involved in the area of physical science, 49 % in biological and/or environmental science, and 6 % in social science. For the teacher sample, two thirds of them had no experience in scientific research. The finding showed that the scientists had a significantly higher mean score (3.14) than that of the teachers (2.92) in the traditional views of science. This finding indicated that views expressed by the scientists were significantly more traditional than the teachers. This result is contrary to the findings of Kimball's (1967-1968) study.

Koulaidis and Ogborn (1989), on the other hand, investigated the relationships of teachers' understanding about the scientific knowledge with their teaching subject. Using a questionnaire, they carried out an empirical survey with 40 prospective science teachers and 54 beginning science teachers. The items in the questionnaire pertained to scientific method, criteria of demarcation, patterns of scientific change, and status of scientific knowledge. The results of the study showed that, with regard to scientific method, biology teachers were more inclined to inductivism whereas physics teachers favoured a contextualised view. Chemistry teachers, however, were largely labelled 'eclectic'. On the other hand, chemistry teachers had a more contextualist or pragmatic view than physics or biology teachers for criteria of demarcation. The results for patterns of scientific change showed that among the subject groups, only physics teachers were inclined towards the relativist version of contextualism. On the status of scientific knowledge, the findings revealed that biology teachers showed a strong tendency towards relativism whereas physics teachers preferred a pragmatic view while chemistry teachers appeared to have 'eclectic' views. These findings suggested that there were variations among the different groups of teachers in their views about scientific knowledge.

The literature reviewed above suggest that the studies were not conclusive in determining whether science teachers from different backgrounds differred significantly in their understanding of the nature of science.

2.5 Relationships of Understanding of the Nature of Science with Formal Exposure to Philosophy of Science

In his study to determine whether science teachers had the same view of science as scientists, Kimball (1967-1968) found that philosophy majors actually scored higher than the science majors on the NOSS. He noted that the philosophy majors seemed to have a better understanding of the methodological aspects of science. Based on the results, he concluded that the inclusion of a philosophy of science course in teacher preparation programmes would help to correct the deficiencies.

Lavach (1969) investigated changes in attitude toward an understanding of the nature of science of teachers who had been exposed to a historically oriented programme. He designed and conducted an inservice programme in the historical development of selected physical science concepts to eleven science teachers in the experimental group. Fifteen science teachers served as the control group. All teachers in the experimental as well as control groups were pretested and posttested on the TOUS. Lavach found that teachers in the experimental group showed statistically significant gains in their understanding of the nature of science. However, these gains were not related to teaching experience, subjects taught, undergraduate major, previous inservice participation, or length of teaching experience in the same subject.

During the validation of the NSKS, Rubba and Andersen (1978) examined the difference in the understanding of the nature of scientific knowledge between two groups of college freshmen from the same university. The first group consisted of 40 freshmen who were completing an introductory college philosophy of science course. The second group consisted of 125 college freshmen without any formal history and philosophy of science background and who were completing a biology course for nonscience majors. The two groups were tested on the NSKS. The results showed that the group of freshmen who had studied philosophy of science had a higher mean score on the NSKS compared to the group of biology students. Therefore, based on the results, it could be concluded that formal exposure to philosophy of science enhanced the understanding of the nature of science.

Akindehin (1988) developed an instructional package, The Introductory Science Teacher Education (ISTE), for investigating the effect of the ISTE on preservice science teachers' understanding of the nature of science and acquisition of science-related attitudes. The ISTE was a nine-unit, instructional package consisting of lectures, class discussions, and laboratory experiences on topics such as Forms and Fields of Knowledge, Nature of Science, Ways of Scientists, History of Science, Science and Superstition, and The Scientist at Work. The study sample consisted of 145 preservice science teachers who were divided into four groups (two experimental and two control groups). Preservice teachers in the experimental groups were exposed to the ISTE. All the preservice teachers were posttested on the NOSS and the "Teacher Science-Related Attitude Scale" (TESRA) but only two of the four groups of the study were pretested on the NOSS and TESRA. The preservice teachers in the experimental group exhibited statistically significant gains in their understanding of the nature of science. Therefore, on the basis of the results, Akindehin concluded that preservice science teachers exposed to the ISTE developed a better understanding of the nature of science than those who were not exposed to the ISTE.

King (1991) investigated beginning teachers' knowledge of and atitudes toward history and philosophy of science. Thirteen preservice teachers participated in the study. All of them were college graduates with a bachelor degree in their subject area. Three of them had taken formal courses in the history and philosophy of science during their undergraduate studies. A questionnaire consisting of 14 questions was administered to the subjects on the first day of their introductory course in curriculum and instruction in science. Eleven of the subjects were selected for an interview at the end of the course and after they had begun teaching for at least a week. The findings of the study revealed that the three preservice teachers who had been formally exposed to history or philosophy of science were able to give more articulate and reasoned responses to the the question "What is science ?"

An implication of all the studies reviewed above is that formal courses in the history and/or philosophy of science should be included in the undergraduate science programme or teacher preparation progamme for its ability to promote a better understanding of the nature of science in preservice teachers. It is therefore the intent of this study to investigate whether science teacher trainees in Malaysia who have been formally exposed to philosophy of science will similarly exhibit a better understanding of the nature of science than those who have not been formally exposed to philosophy of science.

2.6 Relationships of Understanding of the Nature of Science with Gender

The relationship between gender and the understanding of the nature of science have not been investigated extensively. A review of the literature showed that few studies had been undertaken to determine if there were gender differences in the understanding of the nature of science among prospective science teachers.

Wood (1972) conducted a study to investigate if there were any sex-related differences in the understanding of the nature and processes of science among prospective elementary and secondary science teachers. The teachers' understanding of the nature of science was assessed by the Wisconsin Inventory of Science Processes (WISP). The results of the study showed that when the WISP scores were correlated with the variable sex, there appeared to be little, if any, relationship between gender and the teachers' understanding of the nature of science.

In his study to investigate whether the male and female KPLI trainees differed in their scientific attitudes, Tulasi (1999) employed the TOSA-A scale consisting of 39 multiple-choice questions pertaining to the following aspects of scientific attitudes: (a) critical-mindedness, (b) supended judgement, (c) respect for evidence, (d) intellectual honesty, (e) objectivity, and (f) willingness to change opinions. Several items (Items 1, 2, 3, 4, 6, 13, 15, 19, and 26) in TOSA-A assessed the understanding of a few aspects of the nature of science as used in this study. The *t*-test analyses of the TOSA-A scores from a sample of 93 male and 170 female KPLI trainees showed that except for the aspect of critical-mindedness, the male and female trainees did not differ in their overall scientific attitudes as well as in the other aspects of scientific attitudes.

In their study on females and science achievement, G. L. Erickson and L. J. Erickson (1984) reported some findings of sex-related differences in science achievement from a science assessment project in British Columbia. The science achievement tests used in the project were developed based on the folllowing goals: (a) Understanding scientific knowledge, which included the knowledge and comprehension of concepts of science; (b) understanding the processes of science, which included the basic processes of observing, classifying and integrated processes such as controlling variables and designing experiments; (c) application, which included the ability to apply scientific knowledge to given problems; (d) safety, which included the knowledge of safe procedures in the laboratory; and (e) scientific literacy, which included understanding and appreciation of the nature of science. The tests were administered to students in grades 4, 8, and 12. In their report, G. L. Erickson and L. J. Erickson observed that the differences between the male and female students at any of the grade level for the area of scientific literacy were small. This finding seemed to suggest that there was no significant difference between the male and female students in their understanding of the nature of science.

However, a study conducted by Pomeroy (1993) to examine the relationship between scientists' and science teachers' beliefs about the nature of science and their gender showed otherwise. Pomeroy employed a 50-item survey consisting of agree-disagree statements on a 5-point Likert scale. The participants of the study comprised of 71 scientists and 109 science teachers. Of the 71 scientist respondents, there was a

3:1 ratio of men to women whereas of the 109 teacher respondents, there was a 1:2 ratio of men to women. The *t*-test comparison of the mean scores of the responses of all men combined versus all women combined indicated that the men tended to show more agreement with the traditional views of science than the women. This result is contrary to the finding of Wood's (1972) study.

The review of literature above shows that the relationship between understanding of the nature of science and gender was not conclusive. Pomeroy's (1993) study indicated that gender had significant influence on the understanding of the nature of science while other studies (G. L. Erickson & L. J. Erickson, 1984; Wood, 1970) showed that gender and the understanding of the nature of science were not significantly related.