CHAPTER 4

RESULTS AND DISCUSSIONS

4.0 Introduction

The purpose of this study was to assess science graduate teacher trainees' understanding of the nature of science as well as to identify their misconceptions. It also sought to determine the relationships between the trainees' understanding of the nature of science and their formal reasoning ability, academic background, and gender. Eighty KPLI trainees from four teacher training colleges in Peninsular Malaysia were selected as the subjects of the study. This study sought to answer the following questions:

1. What is the understanding of the nature of science of the KPLI trainees ?
2. What are the KPLI trainees' common misconceptions of the nature of science ?
3. Are there significant differences in the understanding of the nature of science among KPLI trainees of different formal reasoning abilities ?
4. Is there a significant difference in the understanding of the nature of science between KPLI trainees of different science majors ?
5. Is there a significant difference in the understanding of the nature of science between KPLI 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 KPLI trainees in their understanding of the nature of science ?

To answer these six research questions, data obtained from the POTSS and the TOLT were processed and analysed using the Statistical Package for the Social Science, SPSS (Norusis, 1997). An alpha level of .05 was used for all statistical tests. The results of the data analysis and corresponding interpretations were organized into six major categories as follows:

1. Profile of subjects of the study.
2. Teacher trainees' understanding of the nature of science.
3. Teacher trainees' common misconceptions of the nature of science.
4. Relationship between teacher trainees' understanding of the nature of science and their formal reasoning ability.
5. Relationships between teacher trainees' understanding of the nature of science and their academic background.
6. Relationship between teacher trainees' understanding of the nature of science and gender.

4.1 Profile of Subjects of the Study

The subjects in this study were 80 science graduate teacher trainees enrolled in the KPLI programme in four teacher training colleges in Peninsular Malaysia. The profile of these trainees was constructed based on the information obtained from the analyses of several items in Section A of the questionnaire (see Appendix B).

4.1.1 Distribution of Teacher Trainees by Gender

Table 4.1 displays the distribution of teacher trainees by gender. As shown in the table, 56.3 % (n=45) of the subjects were females whereas 43.7 % (n=35) were males. The unequal distribution of trainees by gender reflected the current ratio of trainees in the four participating teacher training colleges. Tulasi (1999), in an earlier study involving KPLI trainees, reported a similar gender distribution of 64.6 % female versus 35.4 % male trainees.

Table 4.1

Distribution of Teacher Trainees by Gender

Gender	Frequency n	Percentage %
Female	45	56.3
Male	35	43.7
Total	80	100.0

4.1.2 Distribution of Teacher Trainees by Science Major Type

The distribution of the science major type of the trainees is presented in Table 4.2. Among the 80 trainees, 36.3 % (n=29) were pure science majors while 63.7 % (n=51) were applied science majors. This distribution is in contrast to that reported in Tulasi's (1999) study in which 57.8 % of the KPLI trainees belonged to the pure science group and 42.2 % to the applied science group.

Table 4.2

Distribution of Teacher Trainees by Science Major Type

Science major type	Frequency n	Percentage %
Pure science	29	36.3
Applied science	51	63.7
Total	80	100.0

4.1.3 Distribution of Teacher Trainees by Formal Exposure to Philosophy of Science

Table 4.3 shows the distribution of teacher trainees who had been and those who had not been formally exposed to philosophy of science during their undergraduate studies. As shown in Table 4.3, a higher proportion of the trainees, 66.2 % (n=53), had not been formally exposed to philosophy of science compared to 33.8 % (n=27) who had been formally exposed to philosophy of science during their undergraduate studies.

Table 4.3

Distribution of Teacher Trainees by Formal Exposure to Philosophy of Science

Formal exposure to philosophy of science	Frequency n	Percentage %
Yes	27	33.8
No	53	66.2
Total	80	100.0

4.1.4 Distribution of Teacher Trainees by Formal Reasoning Ability

Formal reasoning ability in this study was defined in terms of five reasoning modes: proportional reasoning, controlling variables, probabilistic reasoning, correlational reasoning, and combinatorial reasoning. It was measured using the TOLT which consisted of ten items. Each item with the correct response and justification was awarded one point. The minimum and maximum attainable scores of TOLT were zero and ten respectively. Teacher trainees who were of high formal reasoning ability would have a high score on the TOLT while those who were of low formal reasoning ability would have a low score on the TOLT. On the basis of their scores on the TOLT, the trainees were categorized into three formal reasoning ability groups according to the classification scheme used by Garnett and Tobin (1984) as shown in Table 4.4.

Table 4.4

Categorization Scheme of TOLT Score

Formal reasoning ability group	TOLT score (Points)
Low	0 - 3
Medium	4 - 7
High	8 - 10

Table 4.5 displays the distribution of the formal reasoning ability of the trainees. It could be seen from Table 4.5 that, for the subjects as a whole, 25.0 % (n=20) were of low formal reasoning ability, 62.5 % (n=50) were of medium formal reasoning ability, and 12.5 % (n=10) were of high formal reasoning ability.

The data in Table 4.5 indicate that a big majority of the science graduate teacher trainees were of the low and the medium formal reasoning abilities. These findings were quite disturbing as only a small proportion (12.5 %) of the trainees were at the high end of formal reasoning ability. The results of this study are in contrast with the findings of Mah's (1999) study. In her study using 89 upper six physics students from Kuching, Mah found that 50.6 % were of high formal reasoning ability and the remaining 49.4 % were of medium formal reasoning ability.

Table 4.5

Distribution of Formal Reasoning Ability of KPLI Trainees

Formal reasoning ability	Frequency n	Percentage %
Low	20	25.0
Medium	50	62.5
High	10	12.5
Total	80	100.0

4.2 Teacher Trainees' Understanding of the Nature of Science

The first research question of this study focused on the understanding of the nature of science among the teacher trainees. Their understanding of the nature of science was examined with respect to the: (a) overall understanding of the nature of science and (b) understanding of the specific aspects of the nature of science.

4.2.1 Teacher Trainees' Overall Understanding of the Nature of Science

An aggregate score for the overall understanding of the nature of science was obtained for the trainee by summing up his or her correct responses to the 24 POTSS items. The scores of the subjects of the study for the overall understanding of the nature of science were examined in terms of percent mean score, standard deviation, minimum and maximum scores. Table 4.6 shows the mean, standard deviation, minimum and maximum scores for the overall understanding of the nature of science of the trainees.

Table 4.6

Mean, Standard Deviation, Minimum and Maximum of POTSS Scores Attained by Teacher Trainees

	Mean (%)	S.D (s)	Minimum (%)	Maximum (%)
POTSS score	14.11	2.96	7	22
	(58.8)		(29.2)	(91.7)

The data in Table 4.6 show that, for the subjects of the study, the percent mean score was 58.8 % while the range was from a minimum of 29.2 % to a maximum of 91.7 %. The results indicate that the overall understanding of the nature of science attained by the KPLI trainees was not high, and therefore was considered not satisfactory in that the mean hardly reached 60.0 % of the total score. These results concur with the results of other studies. Kimball (1967-1968), in his study to investigate the understanding of the nature of science among scientists and qualified science teachers, found that the percent mean scores obtained by the two groups on the NOSS were 58.9 % and 60.0 % respectively. A study conducted on preservice science teachers by Billeh and Malik (1977) revealed that the percent mean scores on the TUNS obtained by B.Ed., M.A.Ed., and M.Ed. groups of teachers were 34.75 %, 51.69 %, and 53.81 % respectively.

The finding of this study is a cause for concern, considering that the teacher trainees are expected to convey a good understanding of the nature of science to their students in their teaching after their graduation from the training programme. It is desirable that the trainees have a good understanding of the nature of science so as to be effective in transmitting it to their students.

4.2.2 Teacher Trainees' Understanding of Specific Aspects of the Nature of Science

Teacher trainees' understanding of specific aspects of the nature of science was obtained by analysing the frequencies and percentages of their correct responses to the 24 POTSS items. In addition, percent mean scores were reported for those aspects which were assessed by two or more POTSS items. Table 4.7 displays the distribution of frequencies and percentages of the trainees having the right conceptions of the nature of science.

The data in Table 4.7 show a wide range of levels of understanding of the various aspects of the nature of science among the teacher trainees, from 6.3 % (n=5) to 96.3 % (n=77). Trainees' understanding of the various aspects of the nature of science are presented in Sections 4.2.2.1 to 4.2.2.10. In the descriptions, the item numbers in parentheses refer to the POTSS items displayed in Table 4.7.

Table 4.7

Teacher Trainees' Conceptions of the Nature of Science

Aspect of the nature of science	Item no.	POTSS item	Teacher trainees having the right conceptions of the nature of science	
			Frequency n	%
Nature of classification in science	10.	Classification of birds allows us to understand patterns in their similarities and differences.	77	96.3
	1.	There are many different schemes for scientifically classifying any set of objects.	68	85.0
	8.	Two plants could look very different, yet still be classified in the same category.	63	78.8
	*16.	Once they have been accepted by practising scientists, classification schemes cannot be changed or refined.	62	77.5
	*20.	Scientists have shown that systems of classifications are operationally well defined because they are in fact, innate to the physical universe.	5	6.3
Percent mean score for the overall understanding of nature of classification in science = 68.8 %				
Nature of scientific measurement	*22.	Modern scientific measurements are presently so accurate, they contain no sources of error.	70	87.5
	15.	Scientists look upon the existence of measurement error as unavoidable.	67	83.8
	*12.	By using appropriate equipment and mathematical relationships, scientists are able to accurately and absolutely determine any object's mass on earth.	26	32.5
Percent mean score for the overall understanding of nature of scientific measurement = 67.9 %				

* Denotes negative statement

(*table continues*)

Table 4.7 *(continued)*

Aspect of the nature of science	Item no.	POTSS item	Teacher trainees having the right conceptions of the nature of science	
			Frequency n	%
Scientific knowledge is developmental	*7.	A scientific hypothesis may have to be altered on the basis of newly discovered information, but a physical law is permanent.	7	8.8
Scientific knowledge is testable	*17.	Results from experiments can only be interpreted when they closely match a set of established results from experimentation.	54	67.5
	*2.	Scientific observations are only valid when the results closely match observations obtained from previous experimental research.	48	60.0
Percent mean score for the overall understanding of testability of scientific knowledge = 63.8 %				
Scientific knowledge is replicable	18.	Scientists should reject data and observations from an experiment if their observations cannot be replicated in the next experiment conducted.	29	36.3
The predictive power of science	6.	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.	62	77.5
	*5.	If a mineral is known to exist in volcanic soil, we should not expect to find that same mineral at the ocean bottom.	47	58.8
Percent mean score for the overall understanding of predictive power of science = 68.1 %				

* Denotes negative statement

(table continues)

Table 4.7 *(continued)*

Aspect of the nature of science	Item no.	POTSS item	Teacher trainees having the right conceptions of the nature of science	
			Frequency n	%
The primary aim of science is not to produce useful technology	*4.	If scientists in the future find that electricity does not consist of electrons, electrical equipment will have to be redesigned.	39	48.8
Science is a shared social enterprise	*24.	Scientists should not record detailed observations because they might bias the insights of other scientists attempting to solve the same problem.	72	90.0
Nature of controlled experiments	11.	One phase of an experiment is the establishment of a set of conditions under which observations are made.	72	90.0
	*14.	A scientist should vary many factors simultaneously in an experiment to obtain faster results.	58	72.5
	*21.	In order to compare the soil temperature of ten potted plants, a scientist should use ten different thermometers in order to record the data simultaneously.	29	36.3
Percent mean score for the overall understanding of nature of controlled experiment = 66.3 %				

* Denotes negative statement

(table continues)

Table 4.7 *(continued)*

Aspect of the nature of science	Item no.	POTSS item	Teacher trainees having the right conceptions of the nature of science: Frequency n	%
Scientific methods	*23.	If two scientists disagree in making scientific observations, both of them could not be correctly using the processes of science.	53	66.3
	*9.	Scientific experiments always follow the same approved five-step procedure.	15	18.8
Percent mean score for the overall understanding of scientific methods = 42.5 %				
Science is creative	*3.	When a prediction comes true, a scientist has successfully proven his/her hypothesis to the exclusion of other hypotheses.	34	42.5
Science is empirical	*19.	If scientists wanted to know how much caffeine was in a specific coffee sample, they would consult a chemical reference book.	47	58.8
	*13.	Observations and descriptions derived purely from numerical measurements are superior to observations and descriptions derived purely from verbal expressions and interpretations.	25	31.3
Percent mean score for the overall understanding that science is empirical = 45.0 %				

* Denotes negative statement

4.2.2.1 Nature of Classification in Science

As shown in Table 4.7, the percent mean score for the overall understanding of the nature of classification in science was 68.8 %. It could be seen from Table 4.7 that a substantial percentage of the trainees generally understood the nature of classification in science. A total of 96.3 % (n=77) of the trainees knew that classification of objects allowed the understanding of patterns in their similarities and differences (Item 10). Furthermore, 85.0 % (n=68) of the trainees understood that there were many different schemes for classifying any set of objects (Item 1) while 78.8 % (n=63) agreed that two plants could look very different and yet still be classified in the same category (Item 8). More than three-quarters of the trainees (77.5 %) understood that classification schemes, once accepted by practising scientists, could be changed or refined (Item 16). Interestingly, although more than 75 % of the trainees (considering Items 1, 8, and 16) recognized the arbitrariness of the schemes of classification, a very small percentage of the trainees (6.3 %) understood that systems of classifications were not innate to the physical universe (Item 20). One possible reason for this marked disparity in their performance in items on the nature of classification is that the idea of innateness is not assessed in Items 1, 8, 10, and 16. In contrast, Item 20 explicitly assesses the trainees' understanding of the innateness of the systems of classification in the physical universe. The findings imply that the trainees do not understand that classification schemes are devised and imposed upon the nature by scientists as useful methods of organizing scientific observations. These classification schemes need to be devised first before the task of classifying the objects can be performed. A plausible reason for this lack of understanding is that the trainees, during their school and undergraduate science studies, were not exposed to the fact that classification schemes are imposed upon nature by members of the scientific community and that these schemes are not inherent in the materials being classified.

4.2.2.2 Nature of Scientific Measurement

Table 4.7 shows that the percent mean score for the overall understanding of the nature of scientific measurement was 67.9 %. An examination of the responses to Items 12, 15, and 22 revealed that the trainees were not consistent in their understanding of the nature of scientific measurement. A high proportion (87.5 %) of the trainees knew that even though modern scientific measurements were very accurate, they contained sources of error (Item 22) while 83.8 % (n=67) understood that scientists looked upon the existence of measurement error as unavoidable (Item 15). However, the performance of the trainees was not good in Item 12. This item did not explicitly assess the understanding of the inherent error in scientific measurement. Only 32.5 % (n=26) agreed that scientists, using appropriate equipment and mathematical relationships, were not able to accurately and absolutely determine any object's mass on earth. One probable reason for these results is that the trainees may not have understood the term "absolutely". They may have failed to realise that the term "absolutely" denotes exactly which could mean being devoid of errors.

4.2.2.3 Nature of Scientific Knowledge

The data in Table 4.7 shows a wide range of levels of understanding of the different aspects of scientific knowledge among the trainees.

With regard to the developmental nature of scientific knowledge, it was found that the trainees did not possess a good understanding of the tentativeness of scientific knowledge. A high proportion (91.2 %) of the trainees believed that scientific hypotheses were subjected to revision in the face of new evidence, but physical laws were permanent (Item 7). Only 8.8 % (n=7) understood that both scientific hypotheses and physical laws were tentative. One probable reason for this result is that students generally tend to think of hypothesis as an educated guess. For instance, when they are asked to propose a hypothesis during a laboratory experiment, the term hypothesis is perceived to mean a prediction. Therefore, hypotheses are tentative and subjected to alteration when presented with new information. However, with sufficient evidence, generalising hypotheses may become laws. In such contexts, the trainees could have misconceived that physical laws were supposed to hold true in all places and for all time. In addition, the lack of understanding that scientific laws can be subjected to change when new information is presented suggests that the trainees do not understand that laws are generally discovered through the process of induction and induction by itself cannot guarantee the validity of the laws. This finding could imply that the trainees tend to believe in a maturational relationship between hypotheses and physical laws which is not true in science.

As to the understanding that scientific knowledge is testable, about 60 % of the trainees understood that scientific knowledge was testable and that consistency among test results was a necessary, but not a sufficient condition for the validity of scientific knowledge (Items 2 and 17). The percent mean score for the overall understanding of the testability of scientific knowledge was 63.8 %.

In contrast, only 36.3 % (n=29) knew that scientific knowledge was replicable. They agreed that scientists should reject data and observations from an experiment if these observations could not be replicated in the next experiment conducted (Item 18). This result indicates that almost two thirds of the trainees failed to understand that the evidence for scientific knowledge must be replicable.

4.2.2.4 The Predictive Power of Science

In the overall understanding of the predictive power of science, the percent mean score was 68.1 %. As shown in Table 4.7, a total of 77.5 % (n=62) of the trainees agreed that if scientists repeatedly observed that condition A was followed by state B, they could infer that state B would probably occur whenever they observed condition A (Item 6). However, only 58.8 % (n=47) understood that if a mineral was known to exist in volcanic soil, it could be expected that the same mineral be found at the ocean bottom (Item 5). These results imply that the trainees were not able to apply their understanding of the predictive power of science in the specific situation presented by the item.

4.2.2.5 The Primary Aim of Science

As shown in Table 4.7, a total of 48.8 % (n=39) of the trainees knew that the primary purpose of science was to acquire knowledge of the physical world and therefore did not view science as a primary aim of producing useful technology (Item 4). This result indicates that slightly more than half of the trainees tended to view the purpose of science in terms of technology. One plausible reason for the trainees holding such erroneous view is their tendency to associate science with technology as commonly presented in school science textbooks.

4.2.2.6 Science is a Shared Social Enterprise

An analysis of the responses to Item 24 revealed that a big majority of the trainees understood that science was a shared social enterprise. A total of 90.0 % (n=72) of the trainees knew that scientists should record detailed observations without fearing that the observations might bias other scientists in their attempts to solve the same problem (Item 24). This result indicates that the trainees understood very well that scientists published their research findings so that other members of the scientific community might independently evaluate their works. Such understanding could be due to the publication of the many scientific findings in the media that the trainees were exposed to, for example newspapers, magazines, journals, television, and radio.

4.2.2.7 Nature of Controlled Experiments

The percent mean score for the overall understanding of the nature of controlled experiments in laboratory was 66.3 %. The data in Table 4.7 shows that a high proportion (90.0 %) of the trainees held the view that one phase of an experiment was the establishment of a set of conditions under which observations were made (Item 11) while 72.5 % (n=58) agreed that a scientist should not vary many factors simultaneously in an experiment in order to obtain faster results (Item 14). These results imply that the trainees understand that experiments are never real replications of the physical universe. On the other hand, only 36.3 % (n=29) understood that in order to compare the soil temperature of ten potted plants, a scientist should not use ten different thermometers in order to record the data simultaneously (Item 21). The trainees did not understand that the use of ten different thermometers in recording the data simultaneously could not provide a fair comparison.

4.2.2.8 Scientific Methods

The understanding that there is no one, single scientific method was generally not well exhibited by the trainees. The percent mean score for the overall understanding of this aspect of the nature of science was 42.5 % which was lower than the percent mean score for the overall understanding of the nature of science (58.8 %). A total of 66.3 % (n=53) of the trainees understood that if two scientists disagreed in making scientific observations, both of them could still be correctly using the processes of science (Item 23) whereas less than 20 % understood that there was no one "scientific method" and that scientific experiments did not always follow the same approved five-step procedure (Item 9). One possible reason for this result is the common tendency to present a simplified hypothetico-deductive method as the only example of scientific method in school science textbooks.

4.2.2.9 Science is Creative

As shown in Table 4.7, slightly more than 40 % of the trainees knew that when a prediction came true, a scientist had not successfully proven his or her hypothesis to the exclusion of other hyotheses (Item 3). More than half of the trainees lacked the understanding that science did not provide absolute proof and that evidence could provide support or validation for a hypothesis but would never prove the hypothesis to be true. Moreover, they also failed to recognize that science was creative and that two scientists with the same expertise could observe the same facts and reach different conclusions. According to Bronowski (cited by Cleminson, 1990), the analysis of nature is "a personal and highly imaginative creation" (p. 436). Hence, no scientist could successfully prove his or her hypothesis to the exclusion of other hypotheses.

4.2.2.10 Science is Empirical

The percent mean score for the overall understanding that science was empirical was 45.0 % which was comparable to that for the overall understanding of scientific methods (42.5 %). An analysis of the responses to Item 19 showed that the trainees who understood that factual evidence was produced primarily by means of experimentation constituted 58.8 % (n=47). A smaller proportion of the trainees (31.3 %) understood that observations and descriptions derived purely from verbal expressions and interpretations were as good as those derived purely from numerical measurements (Item 13). The results imply that the trainees do not fully understand that one of the traits that characterizes the methods of science is dependence upon sense experience (Kimball, 1967-1968). A probable reason for these results is that throughout their school science studies, the trainees have been taught to associate the importance of laboratory experiments with quantitative data rather than qualitative data. Therefore, they misconceive that observations and descriptions derived from numerical measurements are superior to those derived from verbal expressions and interpretations.

As shown in Table 4.7, the best understood concept of the nature of science by the KPLI trainees was that classification of objects allowed the understanding of the patterns in their similarities and differences (Item 10) while the least understood concept was that systems of classifications were not innate to the physical universe (Item 20). Only six (Items 1, 10, 11, 15, 22, and 24) out of the 24 POTSS items were understood by more than 80 % of the trainees. The findings imply that the majority of the KPLI trainees generally do not possess a good understanding of the nature of science.

With regard to the understanding of the various aspects of the nature of science, the ranking for the trainees' understanding (in terms of percent or percent mean score) in descending order is shown in Table 4.8.

Table 4.8

Rank Order of Trainees' Understanding of Various Aspects of the Nature of Science

	Aspects of the nature of science	No. of items	Level of understanding (*percent or percent mean score)
1.	Science is a shared social enterprise	1	90.0 %
2.	Nature of classification in science	5	68.8 %
3.	The predictive power of science	2	68.1 %
4.	Nature of scientific measurement	3	67.9 %
5.	Nature of controlled experiments	3	66.3 %
6.	Scientific knowledge is testable	2	63.8 %
7.	The primary aim of science	1	48.8 %
8.	Science is empirical	2	45.0 %
9.	Scientific methods	2	42.5 %
10.	Science is creative	1	42.5 %
11.	Scientific knowledge is replicable	1	36.3 %
12.	Scientific knowledge is developmental	1	8.8 %

*Percent is used for the aspect of the nature of science which is assessed by a single item.
Percent mean score is used for the aspect of the nature of science which is assessed by two or more items.

4.3 Teacher Trainees' Common Misconceptions of the Nature of Science

As mentioned earlier in Section 4.2.1, the percent mean score on the POTSS obtained by the teacher trainees was 58.8 %. This result indicated that slightly less than 60 % of the trainees exhibited correct conceptions of the nature of science. Hence to answer Research Question 2, the common misconceptions of the nature of science were operationally defined as those misconceptions possessed by at least 40% of the trainees in this study. These common misconceptions were identified from the analysis of their responses to all the 24 POTSS items. The common misconceptions together with the percentages of trainees having the misconceptions are presented in Table 4.9.

Table 4.9

Teacher Trainees' Common Misconceptions Identified from Their Responses in POTSS

Aspect of the nature of science	Item no.	Misconceptions involved	Percentage of teacher trainees having misconceptions (%)
Nature of classification in science	20.	Systems of classifications are innate to the physical universe.	93.7
Nature of scientific measurement	12.	By using appropriate equipment and mathematical relationships, scientists are able to accurately and absolutely determine any object's mass on earth.	67.5
Scientific knowledge is developmental	7.	A scientific hypothesis may have to be altered on the basis of newly discovered information, but a physical law is permanent.	91.2
Scientific knowledge is testable	2.	Scientific observations are only valid when the results closely match observations obtained from previous experimental research.	40.0
Scientific knowledge is replicable	18.	Scientists should not reject data and observations from an experiment if their observations cannot be replicated in the next experiment conducted.	63.7

(table continues)

Table 4.9 (*continued*)

Aspect of the nature of science	Item no.	Misconceptions involved	Percentage of teacher trainees having misconceptions (%)
The predictive power of science	5.	If a mineral is known to exist in volcanic soil, it should not be expected to be found at the ocean bottom.	41.2
The primary aim of science is not to produce useful technology	4.	If scientists in the future find that electricity does not consist of electrons, electrical equipment will have to be redesigned.	51.2
Nature of controlled experiments	21.	In order to compare the soil temperature of 10 potted plants, a scientist should use 10 different thermometers in order to record the data simultaneously.	63.7
Scientific methods	9.	Scientific experiments always follow the same approved five-step procedure.	81.2
Science is creative	3.	When a prediction comes true, a scientist has successfully proven his/her hypothesis to the exclusion of other hypotheses.	57.5
Science is empirical	13.	Observations and descriptions derived purely from numerical measurements are superior to observations and descriptions derived purely from verbal expressions and interpretations.	68.7
	19.	Experimentation is not the primary means of establishing the credibility of factual evidence.	41.2

In the following descriptions, the item numbers in parentheses refer to the POTSS items displayed in Table 4.9.

As shown in Table 4.9, the misconception pertaining to the nature of classification in science was held by the highest proportion of teacher trainees. A total of 93.7 % of the trainees misconceived that systems of classifications were operationally well defined because they were innate to the physical universe. They failed to recognize that classification schemes were imposed upon nature by scientists. This belief was also shown by qualified science teachers in Kimball's (1967-1968) study. The data from his study revealed that 54.0 % of the teachers held the misconception that classification schemes were inherent in the materials classified. Compared to Kimball's (1967-1968) finding, the result of this study indicates that a very much higher percentage of the KPLI trainees held this misconception.

With regard to the nature of scientific measurement, 67.5 % of the trainees held the misconception that scientists, using appropriate equipment and mathematical relationships, were able to accurately and absolutely determine any object's mass on earth (Item 12). The result indicates that the trainees failed to recognize that scientific measurement had inherent error.

Misconceptions pertaining to the various aspects of the nature of scientific knowledge were also held by the trainees. The data in Table 4.9 reveal that the trainees had not fully understood that scientific knowledge was replicable, testable, and tentative and that scientific findings were used to predict the occurrence of events in the physical universe.

The misconception pertaining to the tentativeness of scientific knowledge was held by a high proportion of the trainees. A total of 91.2 % of the trainees misconceived that while a scientific hypothesis might be subjected to alteration when new information was presented, a physical law was permanent (Item 7). This result is in contrast to that of Kimball's (1967-1968) study where only 37.0 % of the science teachers held the same misconception. The absolutist view of scientific knowledge was also found to be held by students from grades 9 to 12 in Lederman and O'Malley's (1990) study. According to McComas (1996), one of the most enduring misconceptions held by students regarding the scientific enterprise was the general belief that with accumulated evidence there would be a developmental sequence through which "scientific ideas pass through the hypothesis and theory stages and finally mature as laws" (p.10). The finding implies that the trainees did not understand that tentativeness was one of the marks of scientific knowledge and that scientific knowledge was never absolute.

In their understanding of the testability of scientific knowledge, 40.0 % of the trainees held the misconception that scientific observations were only valid when the results closely matched observations obtained from previous research (Item 2). The trainees did not understand that although consistency among test results was necessary, it was not a sufficient condition for the validity of scientific knowledge.

The misconception that scientific findings need not be replicable (Item 18) was exhibited by 63.7 % of the trainees. They failed to understand that scientists should reject data and observations from an experiment if those observations could not be replicated in the next experiment conducted. This result implies that the trainees do not understand that evidence for scientific knowledge must be repeatable.

As to the nature of the predictive power of science, 41.2 % of the trainees held the misconception that if a mineral was known to exist in volcanic soil, it should not be expected to be found at the ocean bottom (Item 5).

With regard to the primary aim of science, slightly more than half (51.2 %) of the trainees held the misconception that if scientists in the future found that electricity did not consist of electrons, electrical equipment would have to be redesigned (Item 4). In contrast, only 10.0 % of the science teachers in Kimball's (1967-1968) study held the same misconception. The trainees who held this misconception wrongly perceived that science aimed primarily to produce useful technology. They failed to understand that science was an attempt to explain natural phenomena and events, and that it had no connection with outcomes, applications, or uses aside from the generation of new knowledge (Kimball, 1967-1968). Such erroneous view was also reported in studies carried out by Behnke (1961) and Ogunniyi (1982) as described in Section 2.2 (page 40). Behnke (1961) found that more than 50 % of the science teachers misconceived that the primary goal of scientific work was the improvement of human welfare while Ogunniyi's (1982) study revealed a higher percentage of Nigerian prospective science teachers (79.0 %) holding similar misconception.

In the area of the nature of controlled experiments, 63.7 % of the trainees held the misconception that in order to compare the soil temperature of 10 potted plants, a scientist should use 10 different thermometers in order to record the data simultaneously (Item 21).

The misconception that there is a single scientific method (Item 9) was exhibited by 81.2 % of the trainees. They held the view that scientific experiments always follow the same approved five-step procedure. This misconception was also reported in Kimball's (1967-1968) study. In his study, it was found that a similar percentage of the science teachers (85.0 %) held the erroneous view that the scientific method followed the five regular steps of defining the problem, gathering data, forming a hypothesis, testing it, and drawing conclusions from it. The result of this study supports the widespread belief that a general and universal scientific method exists (McComas, 1996). The trainees failed to understand that there was no one scientific method, but there were as many methods as there were practitioners.

In Item 3, a total of 57.5 % of the trainees held the erroneous view that a scientist could prove his or her hypothesis to the exclusion of other hypotheses. The result indicates that the trainees failed to recognise that science was creative and that there could be two or more different hypotheses that fit the same observed facts.

Two misconceptions pertaining to the nature that science is empirical were held by the teacher trainees. The misconception that observations and descriptions derived purely from numerical measurements were superior to those derived purely from verbal expressions and interpretations (Item 13) was held by 68.7 % of the trainees. This result implies that the trainees lacked understanding in the nature of quantification in science. A smaller percentage of the trainees (41.2 %) had the wrong conception that experimentation was not the primary means of establishing the credibility of factual evidence (Item 19). They failed to recognize that science was empirical and data collected were based on sense experience.

4.4 Relationship Between Teacher Trainees' Understanding of the Nature of Science and Their Formal Reasoning Ability

As noted earlier in Section 4.1.4, teacher trainees' formal reasoning ability was classified into the high, medium, and low formal reasoning ability groups. The number of trainees in the high, medium, and low formal reasoning ability groups were 10, 50, and 20 respectively. Since the number of trainees in the high formal reasoning group was less than 15, this group of trainees was not taken into account in the analysis of the relationship between trainees' understanding of the nature of science and their formal reasoning ability. Therefore, in order to answer Research Question 3, as to whether there are significant differences in the understanding of the nature of science of the trainees of different formal reasoning abilities, *t*-test analysis was employed instead of the one-way ANOVA of the overall POTSS scores to determine if there was any significant difference between the medium and low formal reasoning ability groups in their understanding of the nature of science. Table 4.10 shows the results of the *t*-test analysis.

Table 4.10

***t*-test Comparison of POTSS Mean Scores Between Low and Medium Formal Reasoning Ability Groups**

	Formal reasoning ability		*t*-value	Level of significance
	Low (n=20)	Medium (n=50)		
POTSS score				
Mean	13.60	14.46	- 1.09	.28
S.D	3.60	2.70		

n denotes the number of trainees.

The data in Table 4.10 show that the low formal reasoning ability group had a mean POTSS score of 13.60 while the POTSS mean score of the medium formal reasoning ability group was 14.46. The *t*-test indicated that the means between the low and medium formal reasoning ability groups were not significantly different at the $p < .05$ level. These results indicate that the trainees who were low in formal reasoning ability did not differ from the trainees who were average in formal reasoning ability in their understanding of the nature of science.

As an additional check to see if there was still any relationship between trainees' formal reasoning ability and their understanding of the nature of science, a correlational analysis of trainees' TOLT scores and POTSS scores was carried out. A computation of the Pearson product-moment correlation of these two scores gave a coefficient of .09 which was not significant at the $p < .05$ level. The result of this correlational analysis was in line with that of the above *t*-test analysis. The findings indicate that formal reasoning ability did not influence the understanding of the nature of science. These results contradict the findings of the study conducted by Scharmann (1988) who reported that logical thinking ability was an influential predictor of an understanding of the nature of science.

4.5 Relationships Between Teacher Trainees' Understanding of the Nature of Science and Their Academic Background

As mentioned in Chapter 1, the academic background of the teacher trainees was defined in terms of: (a) science majors and (b) formal exposure to philosophy of science. To answer Research Questions 4 and 5, *t*-tests were employed to test for significant differences in the POTSS mean scores obtained by pure science major and applied science major groups, and teacher trainees who had been and those who had not been formally exposed to philosophy of science during thir undergraduate studies.

4.5.1 Science Major Type and Trainees' Understanding of the Nature of Science

As shown in Table 4.11, the pure science major group had a POTSS mean score of 15.00 and a standard deviation of 2.88 whereas the applied science major group had a POTSS mean score of 13.60 and a standard deviation of 2.91. The *t* value of 2.07 was significant at the $p < .05$ level. The results indicate that the pure science major group performed better in understanding the nature of science when compared to the applied science major group. Hence the results show that there was a significant difference in the understanding of the nature of science between teacher trainees of different science majors.

Table 4.11

***t*-test Comparison of POTSS Mean Scores Between Pure Science Major and Applied Science Major Groups**

	Science major type		*t*-value	Level of significance
	Pure science (n=29)	Applied science (n=51)		
POTSS score				
Mean	15.00	13.60	2.07*	.04
S.D	2.88	2.91		

* denotes *t*-value is significant at $p < .05$
n denotes the number of trainees.

This finding could not be compared with the findings of other studies as the researcher could trace no earlier studies on the relationship between prospective science teachers' understanding of the nature of science and their science major type. However, as mentioned in the review of literature in Section 2.4 (page 46), a study that investigated the relationship between graduate science teacher trainees' scientific attitudes and different science major type was carried out by Tulasi (1999). The instrument (TOSA-A) used in his study had some items, for instance, Items 1, 2, 3, 4, 6, 13, 15, 19, and 26 pertaining to some aspects of the nature of science as used in this study. Tulasi reported that the pure science major and applied science major groups were not different in their overall scientific attitudes and in each of the aspects of the scientific attitudes.

4.5.2 Formal Exposure to Philosophy of Science and Trainees' Understanding of the Nature of Science

Table 4.12 displays the results of the *t*-test comparison of POTSS mean scores between the teacher trainees who had been and those who had not been formally exposed to philosophy of science during their undergraduate studies.

Table 4.12

***t*-test Comparison of POTSS Mean Scores Between Trainees Who Had Been and Those Who Had Not Been Formally Exposed to Philosophy of Science**

	Formal exposure to philosophy of science		*t*-value	Level of significance
	Yes (n=27)	No (n=53)		
POTSS score				
Mean	14.78	13.77	1.45	.15
S.D	2.41	3.17		

n denotes the number of trainees.

The data in Table 4.12 show that there was no significant difference in the POTSS mean scores between the trainees who had been and those who had not been formally exposed to philosophy of science. The results imply that the trainees who had been formally exposed to philosophy of science did not differ from those who had not been formally exposed to philosophy of science in their understanding of the nature of science. However, it should be noted that the percent mean scores for both groups were not high: 61.6 % for trainees who had been formally exposed to philosophy of science and 57.4 % for those who had not been formally exposed to philosophy of science.

This finding differs from the findings of studies carried out by Kimball (1967-1968), Lavach (1969), Rubba and Andersen (1978), Akindehin (1988), and King (1991) where the respondents who had been formally exposed to philosophy of science significantly developed a better understanding of the nature of science.

4.6 Relationship Between Teacher Trainees' Understanding of the Nature of Science and Gender

In order to answer Research Question 6, as to whether there is any significant difference between the male and female trainees in the understanding of the nature of science, the *t*-test was again carried out. The results of the *t*-test comparison are presented in Table 4.13.

Table 4.13

***t*-test Comparison of POTSS Mean Scores Between Male and Female Trainees**

	Gender		*t*-value	Level of significance
	Male (n=35)	Female (n=45)		
POTSS score				
Mean	14.08	14.13	- 0.07	.94
S.D	3.45	2.55		

n denotes the number of trainees.

As shown in Table 4.13, there was no significant difference in the POTSS mean scores between the male and female trainees at the $p < .05$ level. The results imply that gender was not a significant factor in influencing the trainees' understanding of the nature of science.

This finding is in agreement with the finding from Wood's (1972) study where male and female prospective science teachers did not differ significantly in their understanding of the nature of science. However, this finding contradicts the finding of the study carried out by Pomeroy (1993) who reported that the male scientists and science teachers tended to show more agreement with the traditional views of science than the females.