CHAPTER 5

SUMMARY AND CONCLUSIONS

5.0 Introduction

The purpose of this study was to determine KPLI trainees' understanding of the nature of science and to investigate the relationships between their understanding and the independent variables of formal reasoning ability, academic background, and gender.

This study utilised the survey approach to collect the data. The subjects of the study comprised 80 graduate science teacher trainees enrolled in the KPLI science programme in Semester I of the 2000 academic session. These trainees were from four selected teacher training colleges in Peninsular Malaysia. The instruments used were the Nature of Science Questionnaire and the TOLT. The Nature of Science Questionnaire consisted of two sections. Section A was developed by the researcher to obtain information about the subjects such as gender and academic background whereas Section B consisted of 24 POTSS items adopted from Scharmann et al.'s (1986) instrument to assess their understanding of the nature of science. The TOLT was used to measure the trainees' formal reasoning ability.

Statistical techniques employed to analyse the data gathered in this study included descriptive statistics, Pearson product-moment correlation, and *t*-tests.

5.1 Summary of the Findings

The findings of this study were summarized as follows:

1. The overall understanding of the nature of science of the KPLI trainees in term of percent mean score was 58.8 %.

   The overall understanding for the various aspects of the nature of science (in terms of percent or percent mean score) in descending order was:

   (a) Science is a shared social enterprise (90.0 %)

   (b) Nature of classification in science (68.8 %)

   (c) The predictive power of science (68.1 %)

   (d) Nature of scientific measurement (67.9 %)

   (e) Nature of controlled experiments (66.3 %)

   (f) Scientific knowledge is testable (63.8 %)

   (g) The primary aim of science (48.8 %)

   (h) Science is empirical (45.0 %)

   (i) Scientific methods (42.5 %)

   (j) Science is creative (42.5 %)

   (k) Scientific knowledge is replicable (36.3 %)

   (l) Scientific knowledge is developmental (8.8 %)

2. The trainees' common misconceptions pertaining to the following aspects of the nature of science were:

   (a) Nature of classification in science.

   In Item 20, a total of 93.7 % of the trainees wrongly understood that systems of classifications were innate to the physical universe.

   (b) Nature of scientific measurement.

   In Item 12, a total of 67.5 % of the trainees wrongly perceived that scientists were able to accurately and absolutely determine any object's mass on earth using appropriate equipment and mathematical relationships.

   (c) Scientific knowledge is developmental.

   In Item 7, a total of 91.2 % of the trainees wrongly perceived that while a scientific hypothesis might be subjected to alteration when new information was presented, a physical law was permanent.

   (d) Scientific knowledge is testable.

   In Item 2, a total of 40.0 % of the trainees wrongly understood that scientific observations were only valid when the results closely matched observations obtained from previous experimental research.

(e) Scientific knowledge is replicable.

In Item 18, a total of 63.7 % of the trainees wrongly perceived that scientists should not reject data and observations from an experiment if their observations could not be replicated in the next experiment conducted.

(f) The predictive power of science.

In Item 5, a total of 41.2 % of the trainees wrongly perceived that if a mineral was known to exist in volcanic soil, it should not be expected to be found at the ocean bottom.

(g) The primary aim of science.

In Item 4, a total of 51.2 % of the trainees wrongly perceived that the primary aim of science was to produce useful technology.

(h) Nature of controlled experiments.

In Item 21, a total of 63.7 % of the trainees wrongly understood that 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.

(i) Scientific methods.

In Item 9, a total of 81.2 % of the trainees wrongly understood that there was a single scientific method which followed the same approved five-step procedure.

(j) Science is creative.

In Item 3, a total of 57.5 % of the trainees wrongly perceived that a scientist could prove his or her hypothesis to the exclusion of other hypotheses.

(k) Science is empirical.

(i) In Item 19, a total of 41.2 % of the trainees wrongly perceived that experimentation was not the primary means of establishing the credibility of factual evidence.

(ii) In Item 13, a total of 68.7 % of the trainees regarded that observations and descriptions derived purely from numerical measurements were superior to observations and descriptions derived purely from verbal expressions and interpretations.

3. There was no significant difference between the low and medium formal reasoning ability groups in the overall understanding of the nature of science at $p < .05$ level.

4. There was a significant difference between the pure science major and the applied science major groups in the overall understanding of the nature of science at $p < .05$ level of significance. The pure science major group was found to perform significantly better than the applied science major group in understanding the nature of science.

5. There was no significant difference between KPLI trainees who had been and those who had not been formally exposed to philosophy of science during their undergraduate studies in their overall understanding of the nature of science at $p < .05$ level.
6. There was no significant difference between the male and female KPLI trainees in their overall understanding of the nature of science at $p < .05$ level.

5.2 Implications of the Findings

Several important implications to science teacher education in the teacher training colleges could be drawn from the findings of this study.

In general, the findings indicate that the subjects of the study did not possess a good understanding of the nature of science. It has been well documented that teacher's views about the nature of science would influence their classroom practice (Brickhouse, 1990; Gallagher, 1991; Lantz & Kass, 1987; Robinson, 1969). The findings therefore highlight the need to promote a better understanding of the nature of science among the trainees.

This study reveals that, despite having completed their bachelor degree in pure or applied science, the trainees still held numerous misconceptions pertaining to the various aspects of the nature of science. This imply that remedial work to address trainees' misconceptions of the nature of science should be carried out during their teacher training if it is desired that science teachers have a better understanding of the nature of science. As mentioned in Section 4.5.2, the trainees who had been and those who had not been formally exposed to philosophy of science during their undergraduate studies did not have high percent mean scores (61.6 % and 57.4 % respectively) for POTSS. Thus, curriculum planners should give greater attention to the inclusion of the history and philosophy of science in the curriculum for the teacher training progamme. This inclusion could be implemented in several ways.

Firstly, the history and philosophy of science could be incorporated and made an integral feature in the methodology course of the training programme. The various aspects of the nature of science could then be introduced into the methodology course. According to Aikenhead (1973), the implementation of special materials which emphasized knowledge about science and scientists in existing courses had appeared to be successful in improving students' learning about science and scientists.

Secondly, the history and philosophy of science could be taught as an elective subject in the teacher training programme. Materials such as historical case studies could be included in the subject's syllabus as these are viable means for conveying a deeper understanding about science and scientists to the trainees. Rogers (1982) claimed that well-chosen case studies from the history of science could make a major contribution to the development of student's scientific understanding. This was supported by Matthews (1990) who claimed that one of the aims of the history of science in science teaching was the richer understanding of the scientific method, and, more generally, the nature of science among students. Moreover, in view of the high proportion (91.2 %) of the trainees who held the misconception that scientific knowledge was not tentative, the inclusion of historical record of the development of scientific ideas would certainly help the trainees to understand the probationary status of scientific theories and laws.

Lastly, in line with the advocacy of integrating the use of instructional technology in the implementation of the curriculum in the teacher training programme (Malaysia, 1998), the history and philosophy of science could be introduced to the trainees as a computer-based enrichment programme. This programme could be easily accessed by the trainees at their convenience and after formal classroom instruction. It is hoped that the computer-based tutorials and self-quizzes in the enrichment programme would capture the trainees' interest and enhance their understanding of the nature of science concepts.

The trainees' common misconceptions of the nature of science identified in the study (see pages 89 and 90) warrant curriculum planners to take steps to correct them. They could incorporate materials that deal with these specific aspects of the nature of science into the content of the history and philosophy of science. These materials would help the trainees to be aware of such misconceptions and lead them to acquire the right conceptions of the specific aspects of the nature of science.

Besides the inclusion of the history and philosophy of science in the curriculum, college teacher trainers should also expend their time and efforts in developing teaching strategies which could bring about improvements in trainees' understanding of the nature of science. Bianchini and Colburn (2000) claim that "... providing [the trainees] opportunities to conduct inquiry investigations does not inevitably and directly lead to rich discussions of science's nature" (p.203). It follows therefore, that college teacher trainers must not only offer hands-on activities but must also engage the trainees in discussions that connect the activities to the concepts of the nature of science. This would hopefully encourage the trainees to take an interest in understanding the nature of science.

This study also shows that there was a significant difference between the pure science major and the applied science major groups of trainees in their understanding of the nature of science. Trainees from the pure science major group had a significantly better understanding of the nature of science compared to those from the applied science major group. This implies that the variable of science major type should be considered as one of the criteria in the selection of KPLI trainees. Therefore, trainees with pure science major should be given preference over those with applied science major, considering all other trainee characteristics are the same, for selection into the KPLI science programme. This recommendation is consistent with that of Tan's (1998) findings. In her study, Tan found that the pure science trainees had a better grade point average in the KPLI science course and were more competent to teach science in schools than the applied science trainees. Thus, applicants who are pure science graduates should be selected over applied science graduates for KPLI training if a better batch of science teachers is desired.

5.3 Suggestions for Future Research

In this study, the subjects were graduate science teacher trainees in the teacher training colleges in Peninsular Malaysia, thus the findings could not be generalised to the bigger population of Malaysian science teacher trainees. It is recommended that similar studies be carried out with science teacher trainees in the local universities as well as with non-graduate science teacher trainees in the teacher training colleges so as to get a better representation of the understanding and misconceptions of the nature of science among Malaysian science teacher trainees.

Another recommendation for future research is to use other measures of the nature of science to see if indeed the findings of this study are consistent. Possible alternatives are the Test on Understanding the Nature of Science (Billeh & Malik, 1977) and the Nature of Scientific Knowledge Scale (Rubba & Andersen, 1978).

The findings presented in this study provide good insights into the KPLI trainees' misconceptions of the nature of science. However, this study is only exploratory and further research should be conducted to provide a more detailed picture of the trainees' misconceptions of the nature of science. The task-based clinical interview could be carried out to further probe the trainees' misconceptions of the nature of science.

An experimental study could also be carried out to investigate the effectiveness of formal exposure to history and/or philosophy of science in overcoming the teacher trainees' misconceptions of the nature of science.