PROSPECTIVE TEACHERS' CONCEPTIONS ABOUT THE NATURE OF SCIENCE: IMPLICATIONS FOR PLANNING SCIENCE LESSONS

BY

SANDRA P.M. LIU-EXNER

A thesis
Submitted to the Faculty of Graduate Studies
in Partial Fulfilment of the Requirements
for the Degree of

MASTER OF EDUCATION

Department of Curriculum: Mathematics and Natural Sciences
University of Manitoba
Winnipeg, Manitoba

ISBN 0-612-13308-7

Name SANDRA P. M. LIU - EXNER

Dissertation Abstracts International is arranged by broad, general subject categories. Please select the one subject which most nearly describes the content of your dissertation. Enter the corresponding four-digit code in the spaces provided.

EDUCATION - SCIENCES | 0714 | U·M·I

SUBJECT TERM | SUBJECT CODE

Subject Categories

THE HUMANITIES AND SOCIAL SCIENCES

COMMUNICATIONS AND THE ARTS
Architecture 0729
Art History 0377
Cinema 0900
Dance 0378
Fine Arts 0357
Information Science 0723
Journalism 0391
Library Science 0399
Mass Communications 0708
Music 0413
Speech Communication 0459
Theater 0465

EDUCATION
General 0515
Administration 0514
Adult and Continuing 0516
Agricultural 0517
Art 0273
Bilingual and Multicultural 0282
Business 0688
Community College 0275
Curriculum and Instruction 0727
Early Childhood 0518
Elementary 0524
Finance 0277
Guidance and Counseling 0519
Health 0680
Higher 0745
History of 0520
Home Economics 0278
Industrial 0521
Language and Literature 0279
Mathematics 0280
Music 0522
Philosophy of 0998
Physical 0523
Psychology 0525
Reading 0535
Religious 0527
Sciences 0714
Secondary 0533
Social Sciences 0534
Sociology of 0340
Special 0529
Teacher Training 0530
Technology 0710
Tests and Measurements 0288
Vocational 0747

LANGUAGE, LITERATURE AND LINGUISTICS
Language
General 0679
Ancient 0289
Linguistics 0290
Modern 0291
Literature
General 0401
Classical 0294
Comparative 0295
Medieval 0297
Modern 0298
African 0316
American 0591
Asian 0305
Canadian (English) 0352
Canadian (French) 0355
English 0593
Germanic 0311
Latin American 0312
Middle Eastern 0315
Romance 0313
Slavic and East European 0314

PHILOSOPHY, RELIGION AND THEOLOGY
Philosophy 0422
Religion
General 0318
Biblical Studies 0321
Clergy 0319
History of 0320
Philosophy of 0322
Theology 0469

SOCIAL SCIENCES
American Studies 0323
Anthropology
Archaeology 0324
Cultural 0326
Physical 0327
Business Administration
General 0310
Accounting 0272
Banking 0770
Management 0454
Marketing 0338
Canadian Studies 0385
Economics
General 0501
Agricultural 0503
Commerce-Business 0505
Finance 0508
History 0509
Labor 0510
Theory 0511
Folklore 0358
Geography 0366
Gerontology 0351
History
General 0578
Ancient 0579
Medieval 0581
Modern 0582
Black 0328
African 0331
Asia, Australia and Oceania 0332
Canadian 0334
European 0335
Latin American 0336
Middle Eastern 0333
United States 0337
History of Science 0585
Law 0398
Political Science
General 0615
International Law and Relations 0616
Public Administration 0617
Recreation 0814
Social Work 0452
Sociology
General 0626
Criminology and Penology 0627
Demography 0938
Ethnic and Racial Studies 0631
Individual and Family Studies 0628
Industrial and Labor Relations 0629
Public and Social Welfare 0630
Social Structure and Development 0700
Theory and Methods 0344
Transportation 0709
Urban and Regional Planning 0999
Women's Studies 0453

THE SCIENCES AND ENGINEERING

BIOLOGICAL SCIENCES
Agriculture
General 0473
Agronomy 0285
Animal Culture and Nutrition 0475
Animal Pathology 0476
Food Science and Technology 0359
Forestry and Wildlife 0478
Plant Culture 0479
Plant Pathology 0480
Plant Physiology 0817
Range Management 0777
Wood Technology 0746
Biology
General 0306
Anatomy 0287
Biostatistics 0308
Botany 0309
Cell 0379
Ecology 0329
Entomology 0353
Genetics 0369
Limnology 0793
Microbiology 0410
Molecular 0307
Neuroscience 0317
Oceanography 0416
Physiology 0433
Radiation 0821
Veterinary Science 0778
Zoology 0472
Biophysics
General 0786
Medical 0760

EARTH SCIENCES
Biogeochemistry 0425
Geochemistry 0996
Geodesy 0370
Geology 0372
Geophysics 0373
Hydrology 0388
Mineralogy 0411
Paleobotany 0345
Paleoecology 0426
Paleontology 0418
Paleozoology 0985
Palynology 0427
Physical Geography 0368
Physical Oceanography 0415

HEALTH AND ENVIRONMENTAL SCIENCES
Environmental Sciences 0768
Health Sciences
General 0566
Audiology 0300
Chemotherapy 0992
Dentistry 0567
Education 0350
Hospital Management 0769
Human Development 0758
Immunology 0982
Medicine and Surgery 0564
Mental Health 0347
Nursing 0569
Nutrition 0570
Obstetrics and Gynecology 0380
Occupational Health and Therapy 0354
Ophthalmology 0381
Pathology 0571
Pharmacology 0419
Pharmacy 0572
Physical Therapy 0382
Public Health 0573
Radiology 0574
Recreation 0575
Speech Pathology 0460
Toxicology 0383
Home Economics 0386

PHYSICAL SCIENCES
Pure Sciences
Chemistry
General 0485
Agricultural 0749
Analytical 0486
Biochemistry 0487
Inorganic 0488
Nuclear 0738
Organic 0490
Pharmaceutical 0491
Physical 0494
Polymer 0495
Radiation 0754
Mathematics 0405
Physics
General 0605
Acoustics 0986
Astronomy and Astrophysics 0606
Atmospheric Science 0608
Atomic 0748
Electronics and Electricity 0607
Elementary Particles and High Energy 0798
Fluid and Plasma 0759
Molecular 0609
Nuclear 0610
Optics 0752
Radiation 0756
Solid State 0611
Statistics 0463

Applied Sciences
Applied Mechanics 0346
Computer Science 0984
Engineering
General 0537
Aerospace 0538
Agricultural 0539
Automotive 0540
Biomedical 0541
Chemical 0542
Civil 0543
Electronics and Electrical 0544
Heat and Thermodynamics 0348
Hydraulic 0545
Industrial 0546
Marine 0547
Materials Science 0794
Mechanical 0548
Metallurgy 0743
Mining 0551
Nuclear 0552
Packaging 0549
Petroleum 0765
Sanitary and Municipal 0554
System Science 0790
Geotechnology 0428
Operations Research 0796
Plastics Technology 0795
Textile Technology 0994

PSYCHOLOGY
General 0621
Behavioral 0384
Clinical 0622
Developmental 0620
Experimental 0623
Industrial 0624
Personality 0625
Physiological 0989
Psychobiology 0349
Psychometrics 0632
Social 0451

PROSPECTIVE TEACHERS' CONCEPTIONS ABOUT THE NATURE OF SCIENCE:

IMPLICATIONS FOR PLANNING SCIENCE LESSONS

BY

SANDRA P.M. LIU-EXNER

A Thesis submitted to the Faculty of Graduate Studies of the University of Manitoba in partial fulfillment of the requirements of the degree of

MASTER OF EDUCATION

Abstract

This study investigated prospective secondary science teachers' conceptions and views about the nature of science, and how these conceptions and views are reflected in their science lesson plans. Prospective teachers enrolled in a secondary Science Curriculum and Instruction (C & I) course in the Faculty of Eduction, University of Manitoba were invited to respond to a questionnaire intended to elicit science teachers' conceptions about the nature of science, and the relationship between their conceptions of science and lesson plans. Five of the participating teachers were interviewed and their lesson plans were collected to study how their conceptions influence their lesson plans.

Most of the prospective secondary science teachers do not consistently adhere to any one particular philosophical view of the nature of science such as Kuhn's contextualism, Popper's hypothetico-deductivism, or science textbooks entrenched inductivism. However, Kuhn and Popper's views were the most favoured by the subjects in this study, representing a shift from the empirical inductivist view implied explicitly or implicitly in most science textbooks and commonly held by science teachers.

The study found that prospective secondary science teachers' lesson plans were not only affected by their view of science but also by the curriculum, their perceptions of their cooperating teachers' expectations, the grades they taught, and by provincial testing programs.

Acknowledgements

I would like to express my sincere thanks and appreciation to my thesis advisor, Dr. Harvey Williams, and my thesis committee: Dr. Arthur Stinner, Dr. Fred Drewe for their interest, insight, and support throughout this project.

I am indebted to Bob Exner and Grant Czerepak for their help in reading, editing and support in this project. I am also grateful to Charlotte Reid for her words of advice and encouragement.

Finally, I would like to extend my love and gratitude to my family: my husband, Bob Exner, my parents, Chhe Vin and Yu Shao Liu, and my brothers, especially Roland, for their love and support in my life.

Table of Contents

Chapter One

INTRODUCTION

For several decades research on teachers' conceptions of the nature of science has proliferated in educational research (Lederman, 1992). Research in this area is still thriving but the focus has moved from the earlier attempts to assess science teachers' conceptions of the nature of science and representations of science in programs/courses to documenting and analysing teachers' conceptions (Aguirre, Haggerty & Linder, 1990; King, 1991; Koulaidis & Ogborn, 1989) and how their beliefs about the nature of science relate to classroom practice (Brickhouse, 1990; Duschl & Wright, 1989; Gallagher, 1991; Lantz & Kass, 1987; Lederman, 1986; Lederman & Zeidler, 1987). According to Lederman (1992), researchers have identified very important variables such as specific instructional behaviours, activities, and decisions implemented within the context of a lesson that significantly influence students' beliefs about the nature of science.

A review of research on teachers' conceptions of the nature of science reveals that most research in this area has focused on experienced secondary science teachers (i.e., teachers with three or more years of classroom experience), and very little research is focused on prospective teachers' conceptions or beliefs about the nature of science. Moreover, only a few studies (e.g., Brickhouse, 1990; Duschl & Wright, 1989; Gallagher, 1991; Lantz & Kass, 1987; Lederman, 1986; Lederman & Zeidler, 1987) described how teachers' subject matter knowledge influenced planning and the delivery of instructional tasks.

1. What is science?

A brief background discussion of some of the most widely held views about the nature of science must precede an examination of conceptions of the nature of science held by prospective science teachers as reflected in their lesson plans.

The demarcation of science and non-science has been an ongoing debate among philosophers of science. To some philosophers of science, the demarcation between science and non-science is the falsifiability of its theoretical framework. Explanatory assertions that do not generate testable hypotheses which could lead to refutation are not admissible as science. A second view is that science is a matter of consensus among scientists. The first position is taken by inductivists and hypothetico-deductivists (e.g., Popper, Lakatos), and the latter view by contextualists (e.g., Kuhn). Both schools require evidence in support of scientific assertions.

A third view of science is extrapolated from the contextualist view of science by post-modernists. However, post-modernism deriving from social-constructivism is beyond the scope of this thesis.

2. What is the role of scientific theories?

Scientific theories are generated for organizing and interpreting observations or knowledge gained about the phenomenon under study. Theories serve as explanations that link diverse sets of data, and they provide a framework that we can fit our current understanding of a particular phenomenon. This description of theories is compatible with inductivist and hypothetico-deductivist accounts of scientific theories or knowledge. A good scientific theory will have both descriptive and predictive powers, for example Darwinian theory of evolution or kinetic molecular theory of gases (Stinner & Williams, 1993, p. 27). Besides serving as explanatory schemes, a theory can act as a basis from which hypotheses can be drawn. A hypothesis can be tested and based on the results, a theory maybe rejected or modified.

3. How does a scientific theory gain acceptance?

Thomas Kuhn in his influential book *The Structure of Scientific Revolutions* (1970) asserted that scientists who accept new theories are those that go through what he called a "Gestalt-switch". A "Gestalt-switch" involves a change in the conceptual network through which scientists view the world. One of the examples that Kuhn used to elaborate this was the different views taken by Galileo and Aristotle about the movement of a pendulum. To Galileo a pendulum was a body of repeating the same motion, and to Aristotle it was an example of 'constrained fall' (Kuhn, 1970; Donnelly, 1979). Because Galileo and Aristotle had different views about the pendulum motion, they arrived at different conclusions. According to Kuhn "this diversity is essential to the progress of science, preventing it from entering blind-alleys when paradigms are first adopted" (Donnelly, 1979, p. 496). Since there is no single set of criteria that scientists can use to justify a scientific theory, the social process of convincing and seeking approval within the scientific community becomes essential to the acceptance of a new scientific theory. To Kuhn, a scientific theory is evaluated on the basis of generally agreed upon criteria in the scientific community. The status of theory is tentative because new evidence may emerge or the criteria may change over time.

4. How does a scientist go about "doing" science?

A scientist does not have the "scientific method" to follow when doing science. The image of "doing" science portrayed implicitly or explicitly in most science textbooks is making unbiased observations, generating hypotheses through repeated empirical observations, experimental testing of the hypothesis and formulating a new theory. This empirical-inductive view of "doing" science portrayed in many textbooks does not paint an accurate picture of how scientists do science. According to most earlier research empirical inductivism was the most commonly held view by science teachers.

According to Kuhn and other philosophers of science, there is no universally applicable scientific method for "doing" science. Scientists are guided by a set of standards and methods that are relative to a variety of peoples interests and circumstances at a given time. Popper believes that science cannot be reduced to a formal, logical system or method. Most philosophers of science believe that theories are an invention based more on scientists intuition than preexisting empirical data, therefore observations and experimentations are often theory-driven.

5. How does science advance/progress?

Kuhn believes science advances through an endless succession of long peaceful periods, which he calls "normal science", which are interrupted by brief intellectual revolutions. During the "normal science" periods, scientists are guided by a set of theories, standards and methods, which Kuhn referred as a "paradigm" (Kuhn, 1970). According to Kuhn when scientists repeatedly fail to resolve an anomalous problem within current paradigm, it results in the emergence of a 'crisis' which attracts the attention of most able scientists in the field into an effort to find a solution that incorporates the anomaly. A combination of crisis and a change in the current paradigm constitutes what Kuhn called a "scientific revolution". The emerging paradigm provides solutions to problems and new hopes for future scientific endeavour. Popper, however, believes science progresses by free, rational pursuit of the truth. He believes that each theory improves upon its predecessor, and approaches nearer to the truth.

In general, the process of scientific inquiry distinguishes scientific knowledge from other kinds of knowledge. Scientific knowledge is gained by observation and reasoning. There is no universal specifiable method to pursue this knowledge but rather is a result of a combination of intuition and imagination. Scientific theories, the products of a scientific inquiry, serve as explanations which link to diverse data and help us to predict similar phenomena in the future. Theories also guide future research. A scientific theory has both explanatory and predictive powers, and its acceptance is sometimes influenced by politic and public attitude. Science can therefore be advanced in a variety of ways depending on the availability of resources and of societal needs.

The Purpose of the Study

This study examines the conceptions of the nature of science held by prospective secondary science teachers who were in their final year of the Bachelor of Education program, and to explore how these conceptions influence their science lessons in their university field placement. The investigation will seek to answer two questions:

1. What are prospective secondary science teachers' conceptions about the nature of science?
2. How do prospective secondary science teachers' conceptions of the nature of science influence their lesson plans?

Rationale for the Study

Fostering positive attitudes toward science has been a major goal of the science curriculum reform in the last quarter of century. However, the effects on students' attitudes and interest in science are still found to be discouraging (Hodson, 1988). Hodson points out that science teachers' inadequate views about the nature of science hinder them from promoting positive attitudes about science to their students. According to Hodson, the most important factors determining students' attitudes to science are the teacher's teaching style and his/her image of science.

A number of researchers and practitioners (Aguirre et al., 1990; Brickhouse, 1990; Gallagher, 1991; King, 1991; Lederman, 1986; Lederman et Zeidler, 1987) have studied teachers' beliefs in order to develop an understanding of how these effect the teaching process. A few of the researchers (Brickhouse, 1990; Gallagher, 1991; Lantz & Kass, 1987) have indicated that a relationship does exist between teacher beliefs about science and how they teach science. For example, Brickhouse found that a teacher's questioning strategies and tests were linked to the teacher's beliefs in accumulation of scientific knowledge. Jackson, Clark and Peterson also urged the educational research community to pay attention to the "importance of describing the thinking and planning of teachers as a means to fuller understanding of classroom processes" (Jackson, 1968; Clark & Peterson, 1986, p. 256). Unfortunately most of the research in this area has focused on veteran science teachers. As a science teacher, I am interested in studying the relationship between the prospective science teachers' beliefs about the nature of science and the planning of their teaching tasks. To most of the prospective secondary science teachers, lesson planning is an essential component of their science teacher education (King, 1991). Therefore, prospective science teachers' lesson plans have become important in investigating the relationship between their beliefs and how they act on their beliefs about the nature of science.

Limitations of the Study

One limiting factor of this study is the difficulty in assessing prospective teachers' beliefs. Mayer and Goldsberry (1987) have hypothesized that prospective teachers' beliefs tend to be in a state of flux. Furthermore, as pointed out by Brickhouse (1990), the prospective science teacher has to reconcile his/her own beliefs about science and science teaching, as well as outside constraints to his/her teaching.

Many variables such as background knowledge in science prior to a teaching experience, the nature of the science teacher education program, the climate in the school and the expectations of the supervising teachers may influence prospective secondary science teachers' planning of science lessons. However, this study focused only on describing the prospective secondary science teachers' beliefs about the nature of science with respect to lesson plans.

Teacher planning is a very complex process. As pointed out by Clark & Peterson (1986) teacher planning is very difficult to study because it is both a psychological process and a practical activity. According to Clark & Peterson (1986,

p. 260) teacher planning has been conceptualized by many researchers as: (a) a set of basic psychological processes in which a person visualizes the future, inventories means and ends, a construct or a framework to guide his or her future action; and (b) the things that teachers do when they are planning. This study only gives a very limited snapshot of the complex process of teacher planning.

Significance of the Study

The study may identify significant areas where prospective secondary science teachers' conceptions are incongruous with contemporary views in the history and philosophy of science and the nature of science. This information may be useful to help design prospective science teacher training programs aimed at helping teachers to examine critically the role of scientific knowledge, science learning and science teaching.

Chapter Two

LITERATURE REVIEW

The review of the related literature has been organized into three sections. The first section deals with research on teachers' conceptions of the nature of science from 1950 to 1980, and the second section focuses on science teachers' conceptions since 1980. The importance of considering teachers' beliefs or conceptions about science in relation to science education, particularly teachers' practice in science classroom, will be reviewed in the third section.

The importance of history and philosophy of science to the learning of science by students has been pointed out by several writers. For example, Fleury, Bentley and SUNY-Oswego (1991) have argued that the nature of science is a global conception that frames one's total scientific knowledge. Bohm and Peat (1987) have called it "the infrastructure of scientific knowledge - the set of tacit beliefs and skills which allow one to understand and build scientific knowledge" (Fleury et al., 1991, p. 58). A consensus among science educators on the importance of the history and philosophy to science literacy is now generally accepted among science educators.

Early Assessment of Teachers' Conceptions of Science

Early research on science teachers' conceptions of the nature of science were based on the intuitive notion that a teacher must possess an adequate knowledge of what he/she is attempting to communicate to students (Lederman, 1992). The first assessment of teachers' conceptions was done in Minnesota by Anderson in 1950. Fifty-eight biology teachers and 55 chemistry teachers constituted the sample. These teachers were asked to answer a total of eight questions on scientific method, and the result indicated that both groups of teachers possessed serious misconceptions (Lederman, 1992).

Behnke (1961) used a 50-statement questionnaire to assess the understanding of scientists and science teachers. The sample consisted of 400 biology teachers, 600 physical science teachers, and 300 professional scientists. Results indicated that over 50% of the science teachers felt that scientific findings were not tentative.

Miller (1963) compared the Test on Understanding Science (TOUS) scores of secondary biology teachers and secondary students. The teacher sample consisted of 51 biology teachers from 20 Iowa high schools. Miller concluded that many teachers did not understand science as well as their students, and did not understand science well enough to teach it effectively.

Schmidt (1967) replicated Miller's study four years later using a much smaller sample. Schmidt found that a certain proportion of grade 9 and grades 11-12 scored higher than 25% of the teacher sample. He concluded that the problem identified by Miller earlier still existed and recommended that techniques must be developed to improve in-service teachers' conceptions of the nature of science (Lederman, 1992).

Carey and Stauss in 1968 assessed 17 prospective secondary science teachers at the University of Georgia with the Wisconsin Inventory of Science Processes (WISP). Prospective teachers were tested at the beginning, and at the end, of a methods course "specifically oriented toward the nature of science". Pretest scores on the WISP indicated that these teachers did not possess adequate conceptions of the nature of science. Posttest scores on the WISP showed a significant improvement. Furthermore, academic variables such as grade-point average, math credits, specific courses, and years of teaching experience were found not to be significantly related to teachers' conceptions of science. Two years later, Carey and Stauss (1970a) reported that the experienced teachers' WISP results were consistent with their previous study.

Kimball (1968) developed and validated a scale to measure understanding of the nature of science referred to as the Nature of Science Scale (NOSS). This 29 item scale was based on a theoretical model constructed from a review of the literature on the nature and philosophy of science. The following eight points are reflected in the literature:

1) Curiosity is the fundamental driving force in science.
2) Science is process-oriented.
3) Science aims at ever-increasing comprehensiveness and simplification, emphasizing mathematical language as the most precise and simplest means of stating relationship.

4) There is no one "scientific method".

5) "The methods of science are characterized by a few attributes which are more in realm of values than techniques" (Anderson, Harty and Samuel, 1986, p. 45).

6) The universe is susceptible to human ordering and understanding.

7) Science is characterized by openness.

8) Tentativeness and uncertainty mark all of science.

Kimball used the NOSS to compare the understandings of the nature of science of professional scientists to those of science teachers. He concluded that there is no difference in the concept of the "nature of science" held by scientists and by science teachers when their academic backgrounds are similar.

In another comparative study Carey and Stauss (1970b) compared 35 prospective secondary science teachers and 221 prospective elementary teachers. WISP scores indicated that no relationship existed between either secondary or elementary teachers' conceptions of science and the academic background variables. Some background variables were high school science courses, college science courses, college grade-point average, and science grade-point average of the participating teachers.

In one study Gruber (1963) surveyed 314 high school teachers who attended institutes designed to help science teachers view science as a way of thinking. Gruber concluded that the institutes did not significantly change high school teachers' general understandings of the nature of science.

Welch and Walberg (1968) pre- and posttested 162 physics teachers in a summer institute program for physics teachers. The teachers at all four sites showed significant gains on both the TOUS and the Science Process Inventory. However, the study was not able to establish the goals and activities that led to differential gains in the understanding of the nature of science.

In another investigation of the effectiveness of a program for improvement of teachers' understanding of the nature of science, Lavach (1969) designed, organized, and conducted an inservice program in the historical development of selected science concepts. Twenty-six science teachers participated; 11 constituted the experimental group and 15 served as the control group. The experimental group received instruction in selected aspects of astronomy, mechanics, chemistry, heat, and electricity. Laboratory activities were geared to replicate or perform an experiment conducted by the scientist under discussion. All teachers were pre- and posttested on the TOUS. The teachers in the experimental group exhibited statistically significant gains in their understanding of the nature of science.

Billeh and Hasan (1975) attempted to identify factors that would increase the understanding of the nature of science held by science teachers. Their sample consisted of 186 secondary science teachers in Jordan. The teachers were divided into four groups: biology, chemistry, physical science, and physics. All teachers received a pre- and posttest on the Nature of Science Test (NOST). All groups except the biology group received 12 lectures specifically related to the nature of science. Lectures stressed the nature of science, but were not oriented toward the content of the NOST. An analysis of covariance showed significant increases in the mean scores of the chemistry, physical science, and physics groups. The biology group did not show a significant gain. The result also indicated that there was no significant relationship between the teachers who scored high on NOST and their academic backgrounds. Additionally, neither science teaching experience nor teaching subject was significantly related to gaining on NOST scores.

Recent Assessment of Teachers' Conceptions of Science

Bloom (1989) assessed 80 prospective elementary teachers' understanding of science and the variables contributing to this understanding. He used a questionnaire and a 21-item rating scale to find out these teachers' prior experience with science, beliefs about the nature of science, and science teaching. His study indicated that these teachers' teaching were significantly influenced by their prior beliefs about the nature of science. In particularly he found that the anthropocentric nature or people centred beliefs about science significantly influenced these teachers' conceptualization of science, and how they teach evolution. Lederman concurred that teachers' "understanding of the nature of science is not a simple matter of being exposed to accurate readings or instruction" (Lederman, 1992, p. 344).

Koulaidis and Ogborn (1989) recently assessed beginning teachers' and prospective science teachers' view about scientific knowledge. A multiple-choice questionnaire with 16-items was administered to 12 beginning science teachers and 11 prospective science teachers. Based on the responses, the subjects were categorized into the following five predetermined categories of philosophical belief: inductivism, hypothetico-deductivism, contextualism-rationalist, contextualism-relativist, and relativism. The results indicated that teachers do not generally possess views that are consistently associated with a particular philosophical position. Overall, most science teachers viewed that scientific method is definitely a part of science, but they also thought that procedures involved a consensus amongst practitioners at a given time.

More recently, King (1991) looked into the beginning teachers' knowledge of the history and philosophy of science. Thirteen beginning students registered in a Science Curriculum and Instruction course were given a questionnaire on the first day of the course, and eleven of the 13 were interviewed after they had been student teaching for at least one week. Responses from the questionnaires showed that only 3 of the 13 teachers had taken courses in the history or philosophy of science. The curriculum course evaluations at the end of the course clearly showed that most student teachers believed learning the nuts and bolts of teaching (e.g., lesson planning, evaluation, etc.) was more important than the history of science (King, 1991; Lederman, 1992). Data from the interviews indicated that the prospective science teachers have difficulty making the connection between the history and/or philosophy of science and teaching of science.

A case study by Aguirre, Haggerty and Linder (1990) assessed 74 beginning secondary teachers' conceptions of the nature of science, teaching, and learning. Eleven open-ended questions about science, teaching of science, and learning of science were given to the subjects on the first day of their General Science Methods course. The qualitative analysis of the responses revealed that most individuals generalized science either as a body of knowledge consisting of a collection of observations and explanations, or as a collection of propositions. The concepts of the role of a teacher as "dispenser of knowledge" and "guide/mediator of understanding" in science teaching were evenly divided among the subjects. Approximately one-third of these teachers conceptualized learning as an "intake of knowledge" (Aguirre et al., 1990; Lederman, 1992). Aguirre et al. conjectured that prospective teachers' positivistic-empiricist view of science may lead these teachers to adopt a transmission approach to teaching.

Although the context of these studies are different, the findings are similar. The research so far had documented the areas or conceptions of the nature of science held by science teachers. Conceptions that may not be in line with contemporary thinking in history or philosophy of science. All of the studies thus far had assumed that a science teacher's inadequate conceptions about the nature of science would have a less desirable effects on his or her students. However, none of these studies have examined how science teachers' conception of the nature of science affect their teaching. The next cluster of studies explored how science teacher's conceptions of the nature of science might influence teachers' instructional practice.

The Role of Teachers' Conceptions in Teaching Science

In one study, Lederman and Zeidler (1987) assessed 18 senior high school biology teachers' knowledge about the nature of science, as well as their classroom behaviour. Pre- and post tests of the Nature of Scientific Knowledge Scale (NSKS) were used as a control for any changes in teachers' conceptions during the investigation. Teachers were categorized as "high" or "low" with respect to NSKS scores. Each teacher's classroom was observed for the entire fall semester, and attempts were made to record all teacher and student verbalizations, chalkboard notes, handouts, assignments, teacher mannerisms, nonverbal cues, and physical plan of the classroom. These classroom observations resulted in 44 classroom variables that were related to teachers' conceptions of the nature of science. Some of the classroom variables (Lederman and Zeidler, 1987, p.727) include (a) *rote memory/recall* - material is (is not) presented at the factual or knowledge level, (b) *creativity* - scientific knowledge is (is not) presented as a product of human imagination and creativity, (c) *developmental* - scientific knowledge is (is not) presented as being tentative, (d) *testable* - the importance of empirical validation of subject matter is (is not) stressed, and (e) *down time* - class time is (is not) often characterized by students waiting for next activity.

This study found that none of the 44 classroom variables, with the exception of one variable, down time, significantly differentiated between the "high' and "low" teachers. In other words, classroom behaviour of science teachers who had knowledge of the nature of science showed no difference from teachers who had little knowledge in the nature of science. The result from this study indicated that irregardless of their conceptions of the nature of science, science teachers were not conveying their conceptions of science to their students. However, the study did not investigate why science teachers were not communicating their beliefs to students.

In another study, Gallagher (1991) and his graduate students studied 25 experienced science teachers' classroom practices over a two year period. They conducted several hundred formal and informal interviews with teachers and their administrators. Observations of these teachers' classrooms showed that they all taught science as a body of knowledge. The classwork, homework, and tests were all geared to learning terminology of science, and virtually no class time was devoted to discussion of the nature of science. To most of these teachers the objectivity of science demarcates science from other teaching subjects. Gallagher concluded that teacher's conceptions of science influence his/her instructional approach and classroom climate.

Duschl and Wright (1989) focused their study on the relationship between science teachers' knowledge of the nature of science and teachers' pedagogical decision making. They observed and interviewed 13 experienced science teachers in a high school located in the suburbs of Atlantic city. The results of their study indicated that science teachers' beliefs about the nature of science had little influence on their pedagogical decision making. Duschl and Wright (1989) found that teachers' considerations for (a) student development, (b) curriculum guide objectives, and (c) pressures of accountability greatly influenced these teachers in making curricular and instructional decisions.

Lantz and Kass (1987) studied three experienced chemistry teachers. These teachers were interviewed and their classrooms were observed. A 90-item Chemistry Classroom Practice Survey (CCPS) questionnaire was developed to collect these teachers opinions on objectives, factors influencing curriculum adaptation, and teaching strategies. In addition, Lantz and Kass used six open-ended questions to elicit teachers' concerns of classroom use of the ALCHEM (textbooks that are authorized for grade 10, 11, and 12 chemistry courses in Alberta). Lantz and Kass found that three high school chemistry teachers who used the same chemistry curriculum taught very different lessons about the nature of science, as a result of differences in their understanding of the nature of chemistry. For example, Lantz and Kass found that if a teacher values applied chemistry in high school chemistry, the teacher will select elective time to study applied chemistry topics in the curriculum. On the other hand, a teacher who values major theoretical concepts and principles in high school chemistry will use elective time to stress theoretical topics such as equilibrium. Lantz and Kass (1987) research indicates that teachers' views of the nature of science influence their decisions over selection and emphasis of particular topics in chemistry.

A recent study (Brickhouse, 1990) on the effect of teachers' beliefs about the nature of science on their classroom practice, Brickhouse studied three science teachers. She interviewed each teacher about their understanding of the nature of science, and she observed each teacher's classroom for at least 35 hours. Her findings indicated that these teachers differed in their views of the nature of scientific theories, scientific process, and the progression and change of scientific knowledge. Furthermore, these teachers' beliefs about science influenced not only explicit lessons about the nature of science, but also shaped an implicit curriculum concerning the nature of scientific knowledge. For example, Brickhouse found that a teacher, who believe science has progressed through successive modification of previous theories rather than changes in theory, discussed models such as atomic theory as building on one another. Brickhouse also found that the teacher's questioning strategies were consistent with the teacher's cumulative view of scientific knowledge.

Summary of the Literature Review

The purpose of most of the early research on teachers' conceptions of the nature of science was assessment or attempts to improve teachers' understanding of the nature of science. Thus, a number of researchers have attempted directly to assess teachers' understanding of the nature of science with or without comparison to other groups such as professional scientists or high school science students. A number of other researchers assessed the effectiveness of programs or courses in improving science teachers' understanding of science. On the other hand, the focus of more recent research is on the difference of conceptions held by science teachers', and the examination of the impact of these differences on teachers' classroom practice.

Research on science teachers' conceptions of the nature of science are predominately focused on experienced science teachers at the secondary level. Moreover, methodology of earlier research was generally quantitative and involved with relatively large samples of teachers, and standardized inventories or scales commonly used to collect data. Furthermore, most of these scales were developed based on one or more of the following invalid assumptions:

1. (All) scientists are characterized by specific personality attributes and attitudes.
2. There is a static relationship between science (and scientific organization) and society.
3. The "nature of science" is known. (Lucas, 1975, p. 482)

According to Aikenhead (1973), instruments such as TOUS, WISP, and NOSS have limitations to their appropriate use because they failed in their research design to detect the effects of different teacher characteristics and teaching strategies (p. 546).

On the other hand, recent research on teachers' conceptions are interpretative in nature. Observations and interviews are commonly used in the recent research method, and thus has greater potential for supplying qualitative feedback to a researcher and science educator.

Overall, there is a general consensus in the literature that science teachers' level of understanding of the nature of science are critical with respect to science education. Furthermore, research efforts are needed to focus on the interaction between teachers' beliefs and teachers' action. Brickhouse (1990) stated that:

> Further study of the influence of teachers' beliefs and instructional strategies is needed to determine how teacher' beliefs are translated into pedagogical content knowledge and through it into practices that affect students' scientific understanding and their activity in science. (p. 61)

The relationship between prospective teachers' understanding of the nature of science and classroom practice is difficult to study. Unlike experienced teachers, a prospective teacher has to reconcile his own conflicting beliefs or the impact of institutional constraints on his teaching (Brickhouse, 1990). In addition, there are many other variables such as experience, environmental constraints, that may prevent a prospective teacher from using instructional strategies that are congruent with his beliefs in science (Brickhouse, 1990). The classroom practice of prospective science teachers has proven to be difficult to study as found by Brickhouse. She found that classroom instruction of a prospective teacher under study was variable, and could not be predicted from interview data. In this study since it was not possible to observe each participating preservice science teacher in action, it therefore focused on prospective secondary science teachers' beliefs about science and how it affected their lesson plans.

Chapter Three

METHODOLOGY

This study used a qualitative methodology to explore prospective science teachers' conceptions or perceptions of the nature of science and how it relates to their science lesson planning. Because the data sources were the language, thoughts, feelings, perceptions, and lesson plans of subjects, interpretation was necessary. Qualitative methodology was used because it allowed for a variety of data-gathering methods such as questionnaire, interview, and document collection.

Subjects

Subjects for the study were 15 prospective secondary science teachers enrolled in the final year of a Bachelor of Education program in the University of Manitoba. All subjects had completed undergraduate degrees in science and had recently completed a 10-week course in Science Curriculum and Instruction (C & I), followed by a 5-week student-teaching session. The course, at an introductory level included a coverage of topics in science curriculum and methods of teaching science. The history and philosophy of science was an important component of the C & I course and many students had completed a course that dealt with that topic in some detail. Subjects were informed about this study at the end of the course. The letter (Appendix A) was invitation for prospective science teachers to participate in this study.

Data Collection

At the end of the 5-week student-teaching session, questionnaires were sent to these individuals. For this study data were collected in the following three phases.

Phase 1

The first phase of data-collection was the administration of a questionnaire (see Appendix C) consisting of 6 items. Ten of the 15 questionnaires distributed were returned.

The first 5 items provided data relating to research question 1 and were designed to elicit subjects' conceptions about the nature of science. The sixth item was aimed at determining the relationship between subjects' conceptions of science and their lesson planning. Its intent was to explore how the subjects connect their science planning with their views or beliefs about the nature of science. Item six supplied data relating to research question two, which was to be further explored through the interviews described in Phase 2.

Phase 2

The second phase of this study was a semi-structured interview (see Appendix D) with the subjects. These six interview questions focused on the relationship between the subjects' conceptions and lesson planning. Out of ten who returned the questionnaire, five agreed to be interviewed. Each interview lasted 15 to 20 minutes and was audio-tape recorded. All interview tapes were transcribed and later destroyed when the transcription was completed.

Phase 3

The last phase of data-collection for this study was the gathering and photocopying of actual lesson plans developed by 5 prospective secondary science teachers. All lesson plans were developed and used by the prospective teachers during their 5-week science classroom teaching in different schools. These lesson plans in conjunction with the questionnaire and the interview with the subjects were used to examine the relationship between the subjects' conceptions and their lesson plans.

Interpretation of Data

The questionnaire responses from the first phase of data collection were analyzed to determine the qualitative differences of the subjects' conceptions of the nature of science. The data from the second and third phases were analyzed to determine how the subjects' conceptions about the nature of science were carried out through their lesson plans.

Chapter Four

RESULTS AND ANALYSIS

Results

The finding of this study did not support the results reported from previous studies (e.g., Aguirre et al., 1990; Gallagher, 1991; King, 1991) on science teachers' conceptions about the nature of science. The results of this study indicated that most prospective science teachers can articulate their view about the nature of science upon recently completing a 10-week Science Curriculum and Instruction course followed by a 5-week classroom teaching practicum. Not all of their views were in alignment with contemporary philosophers of science. For example, a few of them still believe science is a search for the truth and there is a stepwise scientific method.

The results of this study also did not support findings such as those of King (1991), that prospective secondary science teachers lack knowledge of how to connect the history and philosophy of science to science teaching. Seven out of 10 of the subjects were able to describe on the questionnaires how they would include the nature of science in their lesson plans. Of five prospective science teachers interviewed, three subjects reported that they had taught science in accordance with what they believed about the nature of science.

Analysis of the Questionnaire Return

The questionnaire responses revealed various conceptions about the nature of science held by the prospective secondary science teachers. The following table was a result of re-reading and re-sorting of the responses to each item on the questionnaire.

Table 1. Subjects' conceptions of the nature of science

Conception of what science is	
A way of knowing	8
A search for truth	2
Conception of the role of scientific theories	
Explain	8
Predict	2
Conception of the acceptance of a scientific theory	
Cannot be refuted/falsified	6
Change in thinking/transform in vision	4
Conception of "doing" science	
No single specifiable "Scientific Method"	7*
"Scientific Method"	4*
Conception of progress in science	
Kuhnian revolutions in science	6
Apply "scientific method"	2
Technology	1
Question not answered	1
Connection of science lessons and teachers' view of science	
Connection	7
No connection	3

*Answers represented more than one category.

1. What is science? (or what is science about?)

The responses to questionnaire item 1 (Appendix C) provided the data for the identification of subjects' conceptions of science. Subjects' conceptions of science fell into two groupings, science as a way of knowing and science as a search for truth.

(i) **Science as a way of knowing**: Here science was portrayed as a way to find out how the world, or the universe works. It provides explanations to what is observed. An explanation is seen as important to make sense of what is observed, how and why things work. Typical responses of "a way of knowing" were:

> a) Science is the "methods" we use to explain what one observes, why things happen to be the way they are, how things are transformed, and the reasons why they occur;
>
> b) Science is the attempt to explain why the world is the way it is, why phenomena behave in the manner in which they do.

(ii) **Science as a search for the truth**: These responses assumed the real world is knowable and the truth is out there. Science involves a search for the truth about our world. However, this search will never end up finding the ultimate truth, but closer to the truth. Therefore, science is a constant search for the truth. For example:

a) Science involves the constant search for truth in which human beings are practising since early times;

b) Science is a search to find the truth, however, science doesn't necessarily equal the truth.

2. Give examples of scientific theories, and then discuss their role.

Responses to questionnaire item 2 indicated that most of the subjects see the role of scientific theories as either providing explanations or predictions about the natural phenomena. None of their responses identified the importance of both explanation and prediction. Some of the responses that identified the role of theories providing explanations were:

a) The role of scientific theories is to explain the world and universe in which we live;

b) They play a role in attempting to "explain" an observation.

An example of a response that favours the role of a theory to provide a prediction is:

c) This theory helps us predict reaction products.

3. How does a scientific theory become an accepted theory?

Responses to item 3 of the questionnaire identified two major categories; one, in favour of Popper's assertion about falsification and the other Kuhn's "Gestalt-switch" .

<u>(i) In favour of Popper</u>

Six out of 10 subjects in this study tend to agree with the philosopher of modern science, Karl Popper's falsifiability, or refutability, or testability of scientific theory. To Popper, theories are conjectures, or tentative hypotheses. He asserted that scientific theories can never be proved through observations or experimental tests but only disproved, or "falsified". A theory can be rejected or accepted based on the results of tests. To most of the subjects, a scientific theory is accepted if it can survive many tests without being falsified. Examples of responses that fell into this category include:

a) ...if it lasts for a long period of time without being proven false;

b) ...theories which are not proven false and which conform to the current paradigm of science;

c) When all the ideas/hypotheses that are part of the theory cannot be falsified.

<u>(ii) In favour of Kuhn</u>

Others tend to adopt what Kuhn called a "Gestalt-switch". A Gestalt-switch involves a change of one's world view. Kuhn believes that a new theory becomes accepted if many scientists can make a Gestalt-switch. The following response from the questionnaire described a change of view about the combustion and the nature of air, from phlogiston or "fixed air" to oxygen.

> ...the discovery of oxygen. At that time the scientific community was diligently accepting the theory of phlogiston, when Lavoisier came with the revolutionary idea of the existence of oxygen gas. After several attempts to demonstrate this new idea, Lavoisier finally conquered the scientific community approval. This approval was acquired by the change of vision on the scientists of that time that were pro-phlogiston.

Two subjects had even gone further to point out the differences in views among scientists themselves and the difficulty for some scientists to accept a new theory even in face of evidence. They also pointed out that a scientific theory may take a long time to gain acceptance. For example:

> a) Some theories only gain acceptance after all the "old thinkers" have either died or retired and the new generation of scientists who believe this theory have become the influential scientists. (Questionnaire return)
>
> b) Accepted theories are theories which are not proven false and which conform to the current paradigm of science. Thus radical theories which

challenge the established or conventional wisdom have a hard time gaining acceptance. (Questionnaire return)

4. How does a scientist go about "doing" science?

Four subjects responses to questionnaire item 4 indicated that "doing" science means following a stepwise method or a recipe. In one instance, this 5 steps of doing science was given.

1. Scientists observe something
2. They propose an experimental plan (hypothesis)
3. Test or explain that hypothesis
4. Results may prove or disprove the hypothesis
5. If hypothesis is disproved, then the results obtained would require the construction of a new theory, (or replace the discarded theory), and to account for the new results.

This is the Pearsonian image of science that Stinner & Williams (1993) pointed out is commonly portrayed in science textbooks from the middle grades to high school. This picture of "doing" science was based on Karl Pearson's *The Grammar of Science* and has a profound effect in some science textbooks still in use. It is not surprising to find that some subjects still adhered to this view of "doing" science.

Nevertheless, most of the subjects think science has a range and variety of methods and there is no universally applicable scientific method. For example, some described a variety of ways that scientists do science, as follows:

> a) They [scientists] set up experiments to test their ideas, and read the works of other scientists to guide their ideas.
>
> b) Scientists take available information that is available to them from scientists papers, from their own observations, from talking to colleagues, etc. to derive theories about "phenomenon". A scientist then makes hypotheses based on a particular theory and tests these hypotheses.
>
> c) "Doing science" may include systematic step-by-step procedures, or random - sometimes accidental discoveries. There is no one set method which describe how scientists "do" science.

<u>5. How do you think science advances/progresses?</u>

Responses to item 5 of the questionnaire indicated that 6 subjects subscribed to Thomas Kuhn's view of normal science and revolutions in science. Within normal science only models or theories consistent with an existing view or paradigm are accepted. Also, according to Kuhn, science does not advance or progress in a smooth, linear fashion, but in a series of "revolutions" involving changes to existing views or paradigms. New scientific theories solve problems which cannot otherwise be resolved by existing theories. Examples of subjects' responses that subscribed to Kuhn's view were:

> a) Scientific progress has not been linear rather it has been through revolutions. Before reading Kuhn, I too, thought of science as being absolute, objective and free from outer influences. But as I have found out this is certainly not true and advancement in science does not follow a linear path. It takes a revolution for scientists to get rid of old "dogma" and entrenched ideas to consider new views. (Questionnaire return)
>
> b) Science progresses as a series of increasingly better explanations about phenomenon. New theories replace older ones as new evidence arises or as new explanations explain anomalies that were present in a precious theory. (Questionnaire Return)

Three subjects pointed out that factors from outside the scientific community also have a strong impact on the progress in science. Politics, funding and public attitude were identified as having a strong hold on scientific activities, as illustrated here:

> ...progress may be hampered by politics, funding, and general attitudes held by the scientific community. In some cases, new ideas are repressed.

From time to time, in some areas, we may actually regress. Causes of regression are rooted in social and economic realities - established authorities repress certain scientific endeavours for social or economic reasons.

One respondent considered scientific knowledge - an end-product of activities as a result of the application of 'scientific method'. He depicted scientific progress as "following the steps done in question No. 4" [a stepwise, so-called "scientific method"] (Questionnaire return). One other respondent indicated that technology is responsible for progress in science. No doubt it is difficult sometimes to pinpoint which one leads the other as we know progress in science and in technology have gone hand in hand. Even though they are interdependent, science and technology have different aims.

<u>6. Name a conception or unit in science you plan to teach. Describe how you would plan to incorporate the ideas about science that you have just described above into the lesson plans for the named science conception or unit.</u>

The last item of the questionnaire was concerned with the link between prospective teachers' planning and their conceptions of science. It was found that most of them included historical development of a model or a theory under the discussion in their lesson plans. For example, one of them who taught a biology topic wrote:

> To introduce the topic of DNA and the double helix, I talked about the history of the development of the double helix model from the discovery of nucleic acids and the theories of chemical bonding up to the discoveries made by Watson, Crick and Franklin based on what was previously known and what they reasoned from x-ray crystallography.

Another prospective science teacher who taught organic chemistry wrote:

> I told them how the term organic came to be used in this case - Wöhler's urea synthesis/vital force theory etc. - how even though the term [organic] is not quite correct it continues to be used.

A third prospective science teacher challenged the students with the public image of scientists as nerds or authoritarians. The prospective teachers' lesson plan included the students performing skits on the life of either Aristotle, Count Rumford, James Joules, or Lord Kelvin in order to "instill in students the idea that scientists are not necessarily 'inspired geniuses' but individuals with personalities and quirks" (Questionnaire return).

The following excerpts from the questionnaire returns indicated what, and how, the subjects had incorporated in their science lessons in order to convey the impact of politics and funding on science endeavours. Illustrated here also were the exhibition of the notion of human biases, beliefs or ethical dilemma involved in science.

> a) I showed them a video on cold fusion and gases. This video explained unexpected results do occur, data manipulation occurs, political interference in research occurs.
>
> b) I also showed them a CBC video from the *Witness* series on cold fusion. This video shows clearly that science and scientists are dependent on such things as government grants, and the support of accepted scientific journals. The video also showed that science is not objective - sometimes scientists manipulate data to protect a paradigm.

Only 3 of the subjects' lesson plans failed to indicate a clear connection between their conceptions of science and their science lessons. In these lesson plan objectives, definitions, theories, activities, and evaluation seemed to dominate the subjects' planning. No part of the lesson plans were devoted to the historical development of a theory under study, nor were issues around the nature of science included.

Summary

Table 1.1 summarizes the written responses to all the items in the questionnaire. The responses to the first 5 items of the questionnaire indicate that the predominate view about science is a way of knowing, and a systematical search of how and why the world works. The role of scientific theory is to explain the phenomenon under study. More than one half of the respondents agreed with Popper, who maintains that a scientific theory can never be proved through experimental tests, but only through falsification of hypotheses generated from the theory. Most of the respondents also believed that there are various methods of "doing" science. In addition, other factors such as politics, religion, and funding also influence scientific endeavours. Kuhn's "revolutions in science" is commonly accepted as the way science progresses.

The written responses to the last item of the questionnaire indicate that most prospective science teachers would incorporate their views about the nature of science into their lesson plans. A majority of the respondents either incorporated historical developments into the topic they taught, or incorporated a discussion on non-objectivity or non-absoluteness in carrying out scientific activities.

Overall the prospective secondary science teachers participated in this study can articulate their views about the nature of science. In addition, most of them seemed to have an adequate view of the nature of science. However, only a few of the subjects' views were found to be incongruous to the contemporary views about the nature of science. For example, two subjects still held-on to the wholly rationally, logical approach of "doing" science, which dismissed the creative and the innumerable paths that may have been taken in a single scientific endeavour.

Analysis of Subjects' Interview and Lesson Plans

The following section addresses research question two on how beliefs about the nature of science affect prospective science teachers' lesson plans, if at all. Five subjects to whom I have assigned the fictitious names of Michelle, Jason, Susan, John and Dennis were interviewed. In each case, the first step was to establish the individual's view on the nature of science based on the questionnaire return and the interview. The second step was to examine their lesson plans in light of their views about the nature of science.

Michelle

Michelle holds a Bachelor degree in Chemistry. Chemistry and Biology are her major and minor teaching subjects respectively. During a 5-week student-teaching period, she taught grade 12 Chemistry, grades 6 and 8 General Science in a small town north of Winnipeg.

She viewed science as a way of knowing the world or the universe. To make sense of different observations, organizing principles or models are indispensable in her conceptions of science. She also pointed out that models are powerful in terms of predicting future occurrences of a particular phenomenon. The importance of prediction in science also influenced her view on how a scientific theory becomes accepted. She wrote: "Theories become accepted as they prove consistent with a large body of data, and make predictions that are found to be true" (Questionnaire return). Moreover, she was also aware that other factors such as politics, religion and money have an impact on the status of a theory. In addition, her response to questionnaire item 6 on lesson planning is consistent with her view on the role of a scientific theory is prediction. The following is the excerpt from the questionnaire item 6:

> In teaching about atomic theory, I would discuss how the theory has changed, and why the old theories were limited rather that "wrong". I want my students to get the idea that the current theory is not the final word, but it is very powerful in terms of prediction.

The following excerpt from the interview showed that Michelle incorporated her view about a model as providing explanations, and that a model changes in light of new evidence. She even challenged her students by encouraging them to provide alternative models about heat conduction.

> In grade 8 we were doing heat, we looked at an old model, a couple of old models of how heat conduction works, and I have students create their own models on convention current and then offer some kind of hypotheses about what that model would imply and then we tested

> them. So we both looked at the classic scientific method according to the textbook description, but also at how the models have changed and they aren't bad models. They were just incomplete, new information causes them to evolve.

In a lesson plan on Heat for a grade 8 Science class, there was a sketch on the historical development of theories on heat. From Aristotle's theory of matter to explain hotness or heat, to 1750's caloric theory to measure heat content, then to the present day kinetic molecular theory to define heat as a measure of the kinetic energy of particles. However, her lesson plan on acids and bases for grade 12 chemistry were laden with scientific facts. There were lists of objectives, problems for students to work on, definitions and an outline of activities. She explained in her interview:

> You have a lot of material to cover, a lot types of problems they have to be able to do, specially given, but there is a provincial exam so I did less of that [nature of science] in the grade 12.

Michelle's lesson plans for grade 12 seemed to be preoccupied with covering the standardized tests and curriculum. Constraints such as province-wide evaluation on student learning identified here seemed to have a great impact on the teachers' planning, as found in other subjects lesson planning as well.

<u>Jason</u>

Jason has a Master's degree in zoology. He also has some teaching experience before entering the Bachelor of Education programme. During the 5-week practise teaching, Jason taught grade 11 Biology and grade 10 Science.

Jason's view of science is one of systematic pursuit of knowledge about the world. According to Jason theories give us rational explanations, and guide us to seek better explanations or theories about the world. The status of a theory is based on the time it can last without being disproved. Jason believes there is no specifiable scientific method to do science, instead scientists take what's available to work with to come up with better explanations about a phenomenon. His view about theories that explain anomalies, which previous theories could not, was compatible with Kuhn's view about what a theory is about. Science then advances as more new theories can provide "a series of increasingly better explanations about phenomenon." (Questionnaire return)

Jason taught a topic about gene action in Biology. His science lesson included a discussion of the origin of DNA and the historical development of the DNA model. The following excerpts from the interview alluded to his view about science theories, or models, as being a result of increasingly better explanations in face of new evidence.

To introduce the topic of DNA and the double helix, I talked about the history of the development of the double helix model from the discovery of nucleic acids and the theories of chemical bonding up to the discoveries made by Watson, Crick and Franklin based on what was previously known and what they reasoned from x-ray crystallography.

An examination of the lesson plan revealed nothing related to the origin of the concept of DNA. However, the responses to the questionnaire and the interview with Jason convinced me that the written lesson plan was not his entire teaching plan. He explained that most of his lesson plans were in his 'head' and I have no doubt about that given the knowledge he has in biology. Nevertheless, from his response to the questionnaire and the interview it is evident that Jason emphasized the history of science in almost every lesson he taught. The following excerpt from the interview justified his view that science lessons should incorporate historical development of the concept or theory.

> Otherwise the kid is just taking what you said as facts or memorizing it and pretending they believed that what is...if you can give them some more information on theory behind what actually goes on, where it comes from, makes more believable and makes more interesting too...

Jason also pointed out that the curriculum and time allotment did not permit him to do an in-depth analysis about the history of science on the topic he taught. The data from the interview revealed that he had come to a compromise among his conceptions of science, the curriculum, and the time needed to complete the lesson.

> I guess, you cannot spend too much time on it. But I think you can work in where you can. Yeah, I think you should have, it is obvious in the curriculum you don't, the way it is, you don't have time to do a real in-depth analysis of history exactly what experiments were carried out to show certain phenomena of it. I think you can fit it in where you can without taking up too much time.

Susan

Susan has a degree in Biology and is in her final year of her Bachelor degree in Education. During her student-teaching period, she taught General Science to an "alternate" class (i.e. class consists of students with learning difficulties due to culture, or language or home environment) in a large high school in Winnipeg.

To Susan science involves "the constant search for truth" (Questionnaire return). Her belief is that human curiosity and sense of exploration have propelled this search for truth. Scientific knowledge is therefore a product of this persistent endeavour. According to Susan this knowledge helps us to understand the physical and biological factors that affect our lives. Susan agreed with Kuhn in that a Gestalt-switch is a necessary process for scientists to come to accept a new theory. The following excerpts from her response to questionnaire item 3 illustrated the process of convincing and seeking approval from the scientific community.

> After several attempts to demonstrate this new idea, Lavoisier finally conquered the scientific community approval. This approval was acquired by the change of vision on the scientists of that time that were pro-phlogiston.

Susan believed there is a scientific method or recipe for scientists to follow when they are carrying out science activities. However, her belief about progress in science is not clear because she simply outlined the steps that Kuhn believes about how science progresses, including paradigm, normal science, crisis, scientific revolution, and new paradigm to normal science. Susan exhibited knowledge of Kuhn's assertion about the nature of scientific development, but her own conception seemed yet to formulate.

Susan's view about the nature of science does not seem to have a substantial effect on her science teaching plans. The written responses to item 6 did not provide any clues to the connection between her views about science and science lesson plans. A subsequent interview with Susan found that knowing student levels are important when it comes to her science lesson planning. She said: "First thing, I see what kind of group of students I have, okay. I have to plan according to their levels..."

(Interview with Susan). Her science teaching plans were primarily concerned with learning objectives, procedures by students or herself on how to carry out an activity, materials to use, and the assessment of students' learning. Her weekly plan also reflected her concerns of organization, and day to day instructional routines of science teaching.

John

John has a degree in Chemistry and he has worked in the chemical industry for some time. During his practise teaching he taught grade 11 Biology, grade 12 Chemistry and grade 10 Science.

To John science is "a collection of methods" (Questionnaire Return) used to seek explanations about what we observe. A theory explains what occurs in physical nature. A new theory is accepted if it can explain all the observations made about a phenomenon, or if a new theory can explain problems that an existing theory cannot. John believes there is a systematic way of doing science. He outlined the steps as:

1. Scientists observe something
2. They propose an experimental plan (hypothesis)
3. Test or explain that hypothesis
4. Results may prove or disprove the hypothesis
5. If hypothesis is disproved, then the results obtained would require the

construction of a new theory, (or replace the discarded theory), and to account for the new results.

John believed that there is a so-called "scientific method". His responses showed an inductivist's commitment to precedence of observation over theory. He also subscribed to the inductivists' notion of initial unbiased observations as the basis for building scientific theories. John also believed that science advances by recycling the above steps which according to Hodson (1988) is only partial insight into the methods used by scientists. In addition, John's view of "doing" science had a positivist flavour. He stated that scientists can "prove" or "disprove" a hypothesis (Questionnaire Return). Furthermore John's view on how science progresses through the application of "scientific method" influenced his lesson planning. In particularly, he thought experiments and the applications of chemistry in daily life are the ways to convey his science ideas to students. He said: "The nature of science, the nature of chemistry, when one talks about chemistry, I always related to something of daily life... how do they found out these, I mean is by experiment." (Interview with John). Therefore, 'hands-on' activities were found in almost all of his lesson plans.

John has the most comprehensive written lesson plans compared to other subjects in this study. For example, one lesson plan about solutions in chemistry he developed for a grade 11 class consisted of a list of objectives, an introduction to the subject, followed by the procedure, problem solving and a conclusion at the end. His lesson plans included examples of solutions in students' everyday lives, experiment demonstrations to illustrate a particular concept, and 'hands-on' activities for his students.

Another example of John's lesson plan that is consistent with his view of "doing science" was the law of conservation of mass for grade 9 Science. John introduced the concept of "conservation of mass" and gave the students a brief introduction to the origin of the concept. Students were assigned groups to carry out a "hands-on" activity with potassium iodide and lead nitrate.

A lesson plan that he had developed for grade 10 Science was about atomic structure and chemical bonding between atoms. In the procedure section of this lesson plan, he had described the atom theory from Democritus of ancient Greece to Rutherford's experiment with gold foil. John thinks it is very important for students to have a sense about the change of thinking for things we observe. He remarked:

> It's just to help to motivate them [his students] in their thinking about science. It shows them how people before them saw it, how did they think, and how did they arrive at the consequences or how to explain things which they have observed. (Interview with John)

<u>Dennis</u>

Dennis holds a degree in Science. Before working towards a Bachelor degree in Education, he worked in the forestry industry for several years. During his 5 weeks of student-teaching he taught grade 10 General Science and grade 11 Biology.

According to Dennis science is about understanding our environment and about how people and the environment interact with one and another. Dennis believes that theories link different data and help us to explain a phenomenon under study. A theory becomes a scientific theory if we fail to disprove it, which is in agreement with Popper's position. Dennis is also in agreement with Kuhn, in how scientists do science and how science advances. His responses to the last item of the questionnaire indicated that he would incorporate the change of theories, for example, the replacement of the phlogiston theory of fire by the modern theory of fire as combustion.

An examination of Dennis' lesson plans revealed that his plans mainly consisted of notes and overheads for the science classes he taught. His lesson planning seemed to be profoundly affected by his perception of the cooperating teachers' demands. The following excerpts from the interview transcription indicated that giving out scientific facts was what he was expected to do by his cooperating teachers.

> A lot of time they [cooperating teachers] piled up information and the volume of the information, I mean, it all comes down to time too. If they gave you more information to deliver to the students, a lot of it is facts. Well, I got to

give it to them [students].

Time was another thing that Dennis felt impinged on his science planning. Dennis stated that learning about the nature of science is important for science students, however, teaching time is the big factor to prevent him from teaching the nature of science. He said "You have to cover the curriculum. That's laid out for you. My ideals sometimes have to be pushed aside" (Interview with Dennis).

Summary

Michelle, Jason and John's conceptions of the nature of science played a key role in each of their science lessons during a 5 week classroom practicum. Most of their science lessons had incorporated some aspects of their conceptions of the nature of science. This implied a link between what they believe and what they practice. For example, most of the prospective science teachers had included a description or discussion about the origin and the development of a particular model or theory under the study. Michelle had discussed in great detail with her students the development of the modern atomic theory. They used the history of science as an introduction to the topic to help students tune into the evolution of a theory, so their students could get a sense of history and human endeavour in science.

Lesson plans and interview data indicated that Susan and Dennis' conceptions of the nature of science did not play an important role in their science lessons. Their views about the nature of science were not implied anywhere in their lesson plans, instead their lesson plans were devoted to scientific facts. This may be attributed to the nature of the topics they were assigned, for example, they both taught ecology. Topics that may not have a direct, immediate grand theory, or lack of knowledge or flexibility on their part in adapting lessons to incorporate some aspects of the nature of science. There are other variables such as curriculum, time, and expectations of supervising teachers that have significantly influenced their way of planning science lessons.

The lack of consistency of subjects' conceptions of science and their lesson plans helped to identify relevant variables that need to be thoroughly examined in future studies. Variables such as science curriculum, schedule, expectations of cooperating teachers, and provincial testing programs that affect how teachers teach science.

Chapter Five

DISCUSSION, CONCLUSIONS, AND RECOMMENDATIONS

Discussion

The results of the study must be considered in the light of the fact that a relatively small number of subjects were selected from a large group by volunteering to participate in the study. Accordingly, this study may not be reflective of prospective secondary science teachers at large. Most prospective secondary science teachers in this study had been exposed to issues concerning the nature of science, and developed what seems to be an adequate view about the nature of science. The study revealed a tension between incorporation of the nature of science in science lessons, curriculum demands and provincial testing. Michelle, Jason and Dennis consistently verbalized their teaching experience with this tension. Michelle, Jason and John reconciled the tension between their view of the importance of the nature of science and outside constraints on their teaching by incorporating the nature of science into their lessons whenever and wherever it seemed possible. Dennis, on the other hand, decided to put his ideals aside for awhile.

The lesson plan format emphasized in education courses is comprehensive but difficult and time-consuming for science teachers to emulate in their day-to-day teaching. It is not surprising therefore, that lesson plans were not complete detailed blueprints for each class period but outlines of objectives, activities and a sketch of the development of the class activities. On the other hand, the lesson plans, in conjunction with the interviews, revealed some beliefs about the nature of science held by the subjects when planning their science lessons.

The curriculum guide and standardized evaluation greatly affected three of the subjects' lesson planning. For example, two subjects reported that they have no room for the discussion of the nature of science at higher grades, such as grade 11 or 12. They perceived themselves to be tied down by the curriculum and standardized evaluation. This reflects the unimportant role the history and nature of science play in the current high school science curriculum in this province. A more balanced treatment of content knowledge and the nature of science may be needed in teaching and evaluation in the high school science curriculum.

Further Study

This study investigated prospective secondary science teachers' conceptions about the nature of science and how these conceptions influence the prospective science teachers lesson plans. A natural extension of this study would be to investigate the relationship between teachers' conceptions and their students conceptions about the nature of science. It would be particularly useful to find out how students' conceptions of the nature of science is affected by teachers' conceptions of the nature of science.

The present study identified variables that affect the extent a prospective science teacher incorporates the nature of science into lesson plans. Variables such as science curriculum, schedule, and expectations of supervising science teachers. Perhaps in future studies the role of each of these variables can be examined thoroughly.

Conclusions

This study has revealed that prospective secondary science teachers do not consistently adhere to any one particular philosophical view of the nature of science, such as Kuhn's contextualism, Popper's hypothetico-deductivism, or science textbooks entrenched inductivism. However, Kuhn and Popper's views were mostly favoured by the prospective science teachers in this study, representing a shift from the empirical inductivist view implied explicitly or implicitly in most science textbooks and commonly held by the majority of science teachers.

The study found that there is a link between the subjects' conceptions and their lesson plans. One of the common conceptions of the five subjects' studied in some detail concerns scientific theories. Three of the subjects' lesson plans were influenced by their understanding of the nature of scientific theories, which is tentative and they evolve over a long period of time. The process involves creativity and imagination of many peoples, and through modification or replacement of previous theories with better theories. However, the subjects' lesson plans were not only affected by their view of science but also by the curriculum, their perception of the cooperating teachers' expectation, grades they taught, and provincial-wide testing programs.

The study also found that a prospective science teacher can cover the curriculum material without making any reference to the nature of science. It seems the nature of science has no explicit place in the present science curriculum, so it is up to the conscientious teachers to give a balanced view of the science as it is to students. Perhaps a more balanced treatment of "factual" content and philosophy of science may be needed in teaching and evaluation procedure in school science curriculum.

Recommendations

Recommendation 1

The results of this study support the recommendations of Hodson (1986 & 1988), Gallagher (1991) and others for science curriculum revision that links scientific knowledge more closely with the epistemology of science. Without such a revision, science teachers will continue to emphasize the coverage of scientific facts, while paying only lip service to the history and philosophy of science. Accordingly, it is recommended that provincial science curriculum be revised so that it reflects modern ideas about the nature of science and promotes an understanding of science in students.

Recommendation 2

Strongly held but out-dated views about the nature of science such as John's belief in a rational and logical stepwise scientific method were probably instilled during high school and/or college years, and reinforced by science textbooks. Accordingly, it is recommended that university science courses include information on the history and philosophy of science in the context of the respective subject matter. Further, it is recommended that educators encourage science textbook publishers to remove references to "a scientific method". Particularly, the one of Pearson's from their textbooks and revise their depiction of science as a purely inductive process to incorporate modern perspectives on the nature of science.

Recommendation 3

Studies revealing the inadequate view of the nature of science held by prospective science teachers abound (Aguirre et al., 1990; Hodson, 1988; Gallagher, 1991; King, 1990; Lederman and Zeidler, 1987). Insufficient conceptions of the nature of science may, at times, provide inappropriate reinforcement to student misunderstandings. Therefore, a great challenge is faced by science teacher education institutions to undo the miseducation of secondary science teachers with regard to the nature of science. It is unlikely that science faculties are going to make any provision for courses in the history or philosophy of science in an already crowded science program. Besides, most practising scientists are not interested in educating their young fellow scientists about the nature of science (Gallagher, 1991). Therefore, it is recommended that teacher educators design and implement programs that challenge prospective science teachers' conceptions about the nature of science, and give appropriate exposure and experience for prospective science teachers to learn how to teach the nature of science. It may be beneficial for prospective science teachers that certain major science topics in K-12 science curriculum be used as the starting point for prospective teachers to examine their unconscious beliefs about the nature of science, and to acquire or develop skills to promote science learning and teaching that reflect the very nature of science.

Accordingly, it is recommended that Faculties of Education undertake to compensate for the lack of history and philosophy of science in the academic backgrounds of prospective and in-service science teaching by incorporating these topics into appropriate courses, so that science content is not taught independent of pedagogy.

References

Aguirre, J. M., Haggerty, S. M. and Linder, C. J. (1990). Student-teachers' conceptions of science, teaching and learning: a case study in preservice science education International Journal of Science Education, 12(4), 381-390.

Aikenhead, G. S. (1973). The measurement of high school students' knowledge about science and scientists. Science Education, 57(4), 539-549.

Anderson, H. O., Harty, H. and Samuel, K. V. (1986). Nature of Science, 1969 and 1984: Perspectives of Preservice Secondary Science Teachers. School Science and Mathematics, 86(1), 43-50.

Anderson, K.E. (1950). The teachers of science in a representative sampling of Minnesota schools. Science Education, 34(1), 57-66.

Behnke, F. L. (1961). Reactions of scientists and science teachers to statements bearing on certain aspects of science and science teaching. School Science and Mathematics, 61, 193-207.

Billeh, V., & Hasan, O. (1975). Factors affecting teachers' gain in understanding the nature of science. Journal of Research in Science Teaching, 12(3), 209-219.

Bloom, J. W. (1989). Preservice elementary teachers' conceptions of science: Science, theories and evolution. International Journal of Science Education, 11(4), 401-415.

Bohm, D., & Peat, F. (1987). Science, order, and creativity. New York: Bantam.

Brickhouse, N. W. (1990). Teachers' beliefs about the nature of science and their relationship to classroom practice. Journal of Teacher Education, 41(3), 53-62.

Carey, R. L., & Stauss, N. G. (1968). An analysis of the understanding of the nature of science by preservice secondary science teachers. Science Education, 58(4), 358-363.

Carey, R. L., & Stauss, N. G. (1970a). An analysis of the relationship between preservice science teachers' understanding of the nature of science and certain academic variables. Georgia Academy of Science, 148-158.

Carey, R. L., & Stauss, N. G. (1970b). An analysis of experienced science teachers' understanding of the nature of science. School Science and Mathematics, 70, 366-376.

Clark, C. M., & Peterson, P. L. (1986). Teachers' thought processes. In M. Wittrock (Ed.), Handbook of Research on Teaching, (3rd edition, p. 255-296). New York: Macmillan.

Donnelly, J. (1979). The work of Popper and Kuhn on the nature of science. The School Science Review, 60, (212), p. 489-500.

Duschl, R. A., & Wright, E. (1989). A case study of high school teachers' decision making models for planning and teaching science. Journal of Research in Science Teaching, 26(6), 467-501.

Fleury, S. C., Bentley, M. L., & SUNY-Oswego (1991). Educating elementary science teachers: Alternative conceptions of the nature of science. Teaching Education, 3(2), 57-67.

Gallagher, J. (1991). Preservice and practising secondary school science teachers' knowledge and beliefs about the philosophy of science. Science Education, 75(1), 121-133.

Gruber, H. E. (1963). Science as doctrine or thought? A critical study of nine academic year institutes. Journal of Research in Science Teaching, 1(2), 124-128.

Hodson, D. (1988). Toward a philosophy more valid science curriculum. Science Education, 72(1), 19-40.

Hodson, D. (1986). Philosophy of science and the science curriculum. Journal of Philosophy of Education, 20, 241-251.

Jackson, P. W. (1968). Life in classrooms. New York: Holt, Rinehart & Winston.

Kimball, M. E. (1968). Understanding the nature of science: A comparison of scientists and science teachers. Journal of Research in Science Teaching, 2(1), 3-6.

King, B. (1991). Beginning teachers' knowledge of and attitudes toward history and philosophy of science. Science Education, 75(1), 135-141.

Koulaidis, V, & Ogborn, J. (1989). Philosophy of science: An empirical study of teachers' views. International Journal of Science Education, 11(2), 173-184.

Kuhn, T. S. (1970). The structure of scientific revolutions (2nd edition). Chicago: University of Chicago Press.

Lantz, O., & Kass, H. (1987). Chemistry teachers' functional paradigms. Science Education, 71, 117-134.

Lavach, J. F. (1969). Organization and evaluation of an in-service program in the history of science. Journal of Research in Science Teaching, 6(2), 166-170.

Lederman, N. (1986). Relating teaching behaviour and classroom climate to changes in students' conceptions of the nature of science. Science Education, 70(1), 3-19.

Lederman, N. (1992). Students and teachers' conceptions of the nature of science: a review of the research. Journal of Research in Science Education, 29(4), 331-359.

Lederman, N. and Zeidler, D. (1987). Science teachers' conceptions of the nature of science: do they really influence teaching behaviour? Science Education, 71(5), 721-734.

Lucas, A. M. (1975). Hidden assumptions in measures of 'knowledge about science and scientists'. Science Education, 59(4), 481-485.

Mayer, R. H., & Goldsberry, L. (1987). The development of beliefs/practice relationship in two student teachers. Paper presented at the annual meeting of the American Educational Research Association, Washington, DC.

Miller, P. E. (1963). A comparison of the abilities of secondary teachers and students of biology to understand science. Iowa Academy of Science, 70, 510-513.

Schmidt, D. J. (1967). Testing on understanding science: A comparison among school groups. Journal of Research in Science Teaching, 5(4), 365-366.

Stinner, A., & Williams, H. (1993). Teaching science in the secondary school: A modern perspective. University of Manitoba.

Welch, W. W., & Walberg, H. J. (1968). An evaluation of summer institute programs for physics teachers. Journal of Research in Science Teaching, 5(2), 105-109.

Appendix A

Letter

Sandra P. M. Liu

Winnipeg, Manitoba
R3L 0M5 ( )

March 1994

Dear Prospective Secondary Science Teachers:

Most studies of science teachers' conceptions about the nature of science have focused on experienced science teachers. As a graduate student in the Department of Curriculum: Mathematics and Natural Sciences in the Faculty of Education, I have chosen to study prospective secondary science teachers' conceptions about the nature of science and how these conceptions relate to the planning of science lessons.

Your input is important because the Faculty of Education is currently re-examining the undergraduate program. Your responses may assist in the planning of future science teacher education programs.

There are three components to my study. In the first component, I have a questionnaire to gather your conceptions about science and science lessons. The questionnaire will take you approximately 30 minutes to complete. You need not sign the questionnaire and you are assured that your response will remain confidential.

In the second component of the study, you will be interviewed. The interview is expected to take 20 minutes, and will be done at a time convenient for you. I will tape the interviews, and transcribe them for analysis. All tapes made will be destroyed upon the completion of the study.

The third component involves the collection of lesson plans. The plans will be collected after your student teaching experience, and again at a time convenient for you. Your name will not be used in any way in this study.

Your participation in this study is voluntary. I hope you continue participating in this research once a commitment has been made. However, you have the right to withdraw from this study at any time. Your participation or non-participation in my study will not have an effect on your grade in either coursework or student teaching.

The findings of the study will be used in a Master's of Education thesis for the University of Manitoba and will be available to you upon request. You may contact me at the address or telephone number given above.

Thank you for taking the time to assist me in my research.

Yours truly,

Sandra Liu

Appendix B

Consent Form

Consent Form

Teachers' Conceptions and Science Lesson Study

I have read the description of the study and understand the procedures involved. In particular, I understand that I will respond to a 30-minute long questionnaire, and will attend a follow-up interview that requires 20 minutes. In addition, I understand that I will submit lesson plans.

I understand that my participation in this study is voluntary and that I may withdraw from it at any time. I also understand that my assessment or grade in either coursework or student teaching will not be affected by participating or withdrawing from the study.

****

Please check your response.

(1) I agree to complete the questionnaire. YES_________ NO_________

(2) I agree to be interviewed. YES_________ NO_________

(3) I will submit lesson plans YES_________ NO_________

I would like to have a summary of the major findings of the study. YES_________ NO_________

_________________________________ SIGNATURE OF PARTICIPANT

_________________ PHONE NUMBER

_________________________________ NAME OF PARTICIPANT

_________________ DATE

Appendix C

Questionnaire

I) Background Information

Most items can be answered by placing a check (✓) mark in the space provided. Please respond as indicated for ***other*** *questions.*

1) What degree(s) do you hold, if any?
____B.Sc. ____M.Sc.
____other (specify): ____________________

2) In what subject field(s) do you hold your degree(s)?
____Biology ____Chemistry
____Physics ____General Science ____Computer Science
____other (specify): ____________________

3) What is your background in science?
(check as many as you wish)
____University or College degree/certificate in science
____Five or more science courses taken in University
____Three to five science courses taken in University
____Less than three science courses taken in University

4) What is your gender?
____Female ____Male

5) What grades did you qualify to teach?
___K-6 ___7-9 ____10-12

6) What is your major teaching area?
___General Science ____Biology ___Chemistry
___Physics ____Computer Science
___other (specify): ______________________

7) What is your minor teaching area?
___General Science ____Biology ____Chemistry
____Physics ____Computer Science
___other (specify): ______________________

II) Questionnaire Items

Please write short paragraphs to respond to each of the following:

1. What is science? (or what is science about?)

2. Give examples of scientific theories, and then discuss their role.

3. How does a scientific theory become an accepted theory?

4. How does a scientist go about doing science?

5. How do you think science advances/progresses?

6. Name a conception or unit in science you plan to teach. Describe how you would plan to incorporate the ideas about science that you have just described above into the lesson plans for the named science conception or unit.

Appendix D

Interview Questions

Interview Questions

1. How did you go about planning lessons for a particular topic that you have assigned to during your student-teaching?

2. How did you incorporate the nature of science into your planning?

3. Why do you think it is important to incorporate the nature of science into science lessons?

4. What activities did you plan for your students?

5. What material or resources did you use?