

Elementary Preservice Teachers' Beliefs About the Nature of Science and the Influence
on Classroom Practice

by

Patricia Gayle Bright
B.Ed., University of Victoria, 1985

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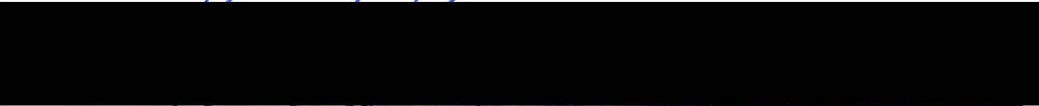
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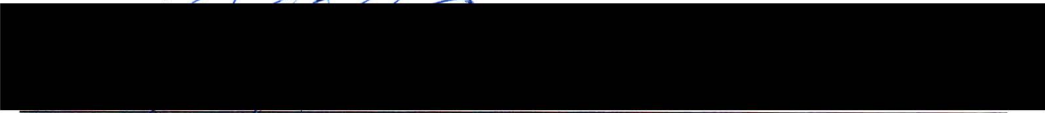
We accept this thesis as conforming
to the required standard



Dr. Larry D. Yore, Supervisor (Department of Curriculum and Instruction)



Dr. Robert H. Fowler, Departmental Member (Department of Curriculum and
Instruction)



Dr. John O. Anderson, Outside Member (Department of Educational Psychology and
Leadership Studies)



Dr. Eileen Van der Flier-Keller, External Examiner (School of Earth and Ocean Sciences)

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University of Victoria

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Supervisor: Dr. Larry D. Yore

ABSTRACT

This study was designed to examine preservice elementary teachers' beliefs about the nature of science, elucidate changes in beliefs through a science methods course, and assess the impact of preservice teachers' beliefs about the nature of science on their classroom practice. This study used a pre-test and post-test case study design to measure 50 elementary preservice teachers' beliefs about the nature of science prior to and after participation in an 18 week elementary science methods course and intervening teaching practicum. The design also employed qualitative methods of multiple classroom observations of a purposeful sample of six volunteer preservice teachers. During the classroom observations, an attempt was made to record the types of questions that the preservice teachers' asked, the responses the students gave to these questions, as well as handouts and assignments given by the preservice teacher. Further documentation of the study subjects' classroom practice included unit overviews, lesson plans, and assignments that were collected and analyzed to provide triangulation of the qualitative aspects of this design.

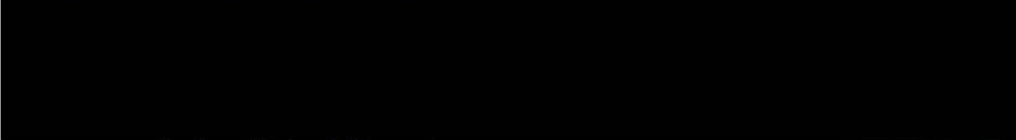
Significant gains were made between the pre-test and the post-test scores for the preservice teachers' beliefs on the creative, developmental, unified subscales, and the total score on the *Nature of Science Knowledge Survey* (Rubba & Andersen, 1978). The concepts of each of these three subscales had been explicitly addressed through a variety of instructional components associated with the subscales in the science methods class.

Results from the classroom observations indicated that the preservice teachers' beliefs about the nature of science were not clearly related to their classroom practice. Despite indications in their planning, the preservice teachers were unable to successfully implement the elements of a constructivist-based teaching approach (engage, explore, consolidate, and assess) and productive questioning strategies in their science lessons during their initial six week practicum.

Examiners:



Dr. Larry D. Yore, Supervisor (Department of Curriculum and Instruction)



Dr. Robert H. Fowler, Departmental Member (Department of Curriculum and Instruction)



Dr. John O. Anderson, Outside Member (Department of Educational Psychology and Leadership Studies)



Dr. Eileen Van der Flier-Keller, External Examiner (School of Earth and Ocean Sciences)

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CHAPTER 1

PROBLEM, OVERVIEW, SIGNIFICANCE, AND LIMITATIONS

Introduction to the Problem

An education in science in the 1950s was viewed as an accumulation of facts that were to be memorized, and science in the classroom was taught through teacher demonstrations, lectures, and textbook readings. The launch of Sputnik in 1957 by the Soviet Union focused public attention on science education and helped to initiate a major curriculum development initiative in the United States and many other English speaking countries (Ryks-Szelekovszky, 1993). Science education in the 1960s was no longer considered to be simply a list of facts but also the acquisition of skills that facilitated the discovery of science knowledge. The process of doing science rather than the memorization of the product became the focus of science education and the students did the activities rather than watching the teacher demonstrate the activity. The development of student's understanding of how scientific knowledge is developed and judged, the nature of science, was a goal of science education (Hogan, 2000; Lederman, 1992). Science education in the 1970s returned to a view of science as the acquisition of fact rather than embracing science as inquiry (Keys & Kennedy, 1999).

Science education reforms initiated in the 1980s and that continue today focus on science for all children and a balance of science knowledge, process, and habits of mind (Science Council of Canada, 1984). Although current science curricula may vary in the

science topics included, there is consensus on the importance of developing science literacy for all students and an understanding of the nature of science (Hogan, 2000; Lederman, 1992; McComas *et al.*, 1998). Documents like *Benchmarks for Science Literacy* (AAAS, 1993) and the *National Science Education Standards* (NRC, 1996) in the United States and the *Common Framework of Science Learning Outcomes* (CMEC, 1997) in Canada incorporate these ideas into the goals of science literacy and into teaching science through inquiry. The goal of science literacy cannot be achieved without first understanding the nature of science: the epistemology and ontology of scientific knowledge (Hogan, 2000; McComas *et al.*, 1998).

Teachers struggle to implement the current science reforms at the classroom level. Often science instruction encourages students to memorize isolated ideas rather than establish connections between concepts. In addition, science is taught too infrequently to be effective (Duschl, 1983; McDevitt *et al.*, 1993; Tobin *et al.*, 1990). Inservice instruction, such as workshops for teachers, is one way to address the current challenges of science teaching in elementary classrooms. Short-term approaches do not acknowledge that teachers' attitudes toward and methods of teaching science have been formed over a long period of time, and that changes in teaching behaviours do not occur with short-term intervention. Gabel and Rubba (1979) measured the attitudes of practicing teachers immediately after a science inservice workshop and measured their attitudes again one year later. They found that the majority of participating teachers reverted to their original ideas after one year. This would suggest that improving the current state of science instruction in the elementary must begin in preservice science methods courses prior to establishing practices that are difficult to change.

Description of the Study

This study examines preservice elementary teachers' beliefs about the nature of science prior to, and after participating in an undergraduate science methods course; and the impact that their beliefs about the nature of science have on their planning and teaching. The study involved 54 undergraduate elementary education students who were enrolled in their professional year of a five-year bachelors degree in education. The prerequisite courses for professional year entrance include two first year laboratory science courses in physics, biology, earth, or space science. The students have also completed educational foundation courses in psychology. Some students may have a prior undergraduate degree in other faculties. The professional year requires that the students complete methods courses in mathematics, science, social studies, and language arts. They are also required to complete a course in assessment and evaluation and participate in two six week practica in elementary classrooms (November-December and March-April). The students were asked to complete a 48-question survey to assess their beliefs about the nature of science prior to starting class instruction in September and were given the same survey at the end of the class in March prior to their second teaching practicum. Some volunteer participants were observed teaching science during their first practicum.

Research Questions

The following research questions framed this study:

- What are elementary preservice teachers' beliefs about the nature of science prior to completing an elementary science methods course?
- What changes, if any, occur to the beliefs of preservice teachers after explicit instruction on the contemporary view of the nature of science in an elementary science methods course?
- How do the preservice teachers' beliefs about the nature of science affect classroom practice?

Significance of the Study

A contemporary view describes science as a human endeavour that attempts to make sense of the natural world. Science is a process of successes and failures that is tentative and always changing based on further study and additional questions, and has elements of curiosity and creativity (Cross, 1990; McComas *et al.*, 1998; Vasquez, 1997). While this is the accepted view of the nature of science, elementary preservice teachers often have the preconception that science is a set of conclusions and knowledge to be acquired (Duschl, 1983; Zeitler, 1984). Science textbooks and science teaching

“emphasize the factual recall of science content to the near total exclusion of the knowledge-generation process” (McComas *et al.*, 1998, p. 4).

Teachers continue to rely on demonstrations, lectures, and textbooks to transmit facts and preservice teachers describe science teaching as imparting information to the students (Ryks-Szelekovszky, 1993; Zeitler, 1984). Preservice teachers’ beliefs about science and incomplete understanding of science concepts, the structure of science knowledge, and the scientific enterprise lead them to envision science teaching as disseminating or transmitting knowledge. Some research studies suggest that the lack of content knowledge is the cause of elementary teacher’s reluctance to teach science through inquiry (Sumrall, 1997). Increasing the number of content courses taken by preservice teachers, however, does not automatically increase the use of inquiry-based teaching strategies in the classroom (Chubin, 1990). Tilgner (1990) suggests that many content courses are taught with the view that a body of knowledge must be acquired and there is little emphasis on the processes of science. When the preservice teacher is presented with the view that science is more than a body of knowledge that includes skills, processes, attitudes, and habits of mind; a dilemma exists about how science should be taught in the elementary school (Duschl, 1983). While the need for a strong science content knowledge is important, the preservice teacher must also be shown the importance of science processes and the associated instructional methodology (Zeitler, 1984).

Elementary science methods courses should provide preservice teachers with the following: direct experience with hands-on, process oriented activities that can be used in their classroom and do not rely on a textbook, an understanding of the nature of learning

and knowledge in science, and an opportunity to practice what they have learned in their science methods course (Glass *et al.*, 1993; Ryks-Szelekovsky, 1993). Including the nature of science in preservice teacher education may be done in a variety of ways.

McComas (1998) proposes four approaches to teaching the nature of science: in science methods courses, as part of science content courses, through authentic experiences with scientists, or as a formal course required in teacher education programs. However “because a teacher has an understanding of the nature of science does not mean they know how to integrate forcefully such topics within instruction” (McComas *et al.*, 1998, p. 20). Knowing by way of rote memorization does not always lead to meaningful learning - making the connection between new knowledge and what is already known.

Researchers vary in their conclusions on the relationship between teachers’ beliefs about the nature of science and their planning and practice. Duschl (1987) suggests that teachers must have an understanding of the nature of science in order to incorporate inquiry-based or constructivist-based teaching methods. Lederman and Zeidler (1987) disagree, suggesting that preservice teachers’ beliefs about the nature of science do not influence teaching behaviour. According to Crawford (1999), the barriers to implementing inquiry-based learning in the classroom may not be influenced by preservice teachers’ beliefs about the nature of science but rather the inexperience of the preservice teacher “in several domains of knowledge of teaching, including pedagogy, pedagogical content knowledge, knowledge of students, and knowledge of classrooms” (p. 175).

This study continues to build on the research about elementary preservice teachers’ beliefs about the nature of science and the influence that these beliefs may have

on their teaching behaviours. This study also investigates the impact that explicit teaching about the contemporary view of the nature of science has on the beliefs of preservice teachers during an elementary science methods class using a pre-instruction and post-instruction survey.

Limitations of the Study

It is difficult to generalize the results of this research outside of the sample described in this case study (i.e., a single year cohort of volunteers from the University of Victoria). The selection of topics to be covered in the methods course and the strategies used to instruct these topics are specific to the instructors. The results should be considered in this context. The prior experiences and knowledge that each preservice teacher brings to the methods course differs and therefore the results may not be generalized to all elementary preservice teachers.

Attempts to address further limitations included using an established instrument that has been used in previous studies to measure of knowledge of the nature of science - the *Nature of Science Knowledge Scale*- NSKS (Rubba & Andersen, 1978). The limitation of observer bias was minimized by having the co-instructor teach and mark the assignments for the course in the first term prior to conducting the classroom observations.

CHAPTER 2

REVIEW OF LITERATURE

Introduction

Current science education reform documents focus on science literacy for all students, understanding the nature of science, and using constructivist based teaching approaches and authentic assessment (AAAS, 1993; CMEC, 1997; NRC, 1996). Science education courses should address each of these goals in order to adequately prepare preservice teachers (Glass *et al.*, 1993). This literature review focused on the interpretation of science promoted in science education reforms, the visions of constructivist-based teaching, the beliefs of preservice teachers about the nature of science, and the relationship between their science teaching and these beliefs.

The Ontology and Epistemology of Science

The nature of science has traditionally been of interest to philosophers and historians in terms of the ontology and epistemology. Recent challenges by cultural, philosophical and sociological groups have brought the nature of science to the forefront in science education (Matthews, 1998). Attempts to define the nature of science, document student's and teacher's beliefs about the nature of science, and explore the

implications of these beliefs on classroom practice have been prominent in science education literature. Some science educators believe that the nature of science influences teachers' decisions when planning what to teach and how to teach science (Palmquist & Finley, 1997). It is important then for science educators and researchers to clarify their common understandings and differences about what is science.

The definition of science that is useful to science teachers describes “the function, processes and limits of science rather than to engage students in the somewhat arcane arguments that occur among philosophers of science” (McComas *et al.*, 1998, p. 6). Hand *et al.* (2001) described traditional, contemporary, and postmodern views of science. These views address ontological and epistemological issues of how scientific knowledge develops, the assumptions inherent in the development, and the purpose of science knowledge.

The traditional (realist, absolutist) view of science suggests that science knowledge consists of true descriptions and explanations of the real world, epistemologically developed through inductive reasoning and validated through deductive reasoning. Facts are accumulated by making observations and these observations are interpreted and generalized to form a big idea or concept about reality. The traditional view of science proposes that the truth about nature (theory, law, principle, concept, or fact) is proven by the evidence gained through a series of observations using inductive reasoning. Ideas developed through inductive reasoning cannot be tested based on the same evidence used to create the generalization since this would result in circular logic. McComas (1998) suggested that sufficient evidence may be impossible to collect since the observations must hold true for all situations, past, present and future. The validity of a generalization

is tested through the process of deduction. Deductive reasoning occurs when a general rule exists and is used to explain other events and predict unwitnessed and future observations. Thomas Kuhn suggested that deductive reasoning is like a puzzle, rather than a problem, since the solution is already known from the outset (Jansen & Voogt, 1998). Scientific knowledge, according to traditional view, is a collection of absolute truths that is unchanging and that the scientific method is a linear, step-by-step process (Palmquist & Finley, 1997). The process itself provides validation to the generalization as this process is controlled and the scientist is objective. McComas (1998) suggested that objectivity for the scientist is a myth because the scientist most often comes to the process with prior conceptions and passions that affect what they look for, and see.

The contemporary (naïve realist, evaluativist) view of science proposes that science knowledge is set of temporary descriptions and explanations that best fits the existing evidence and current understanding of the real world within the limitations of peoples' sensory and intellectual abilities. Science knowledge epistemologically develops with a hypothesis (causation statement) and data that are collected which support or refute the hypothesis. Hypothetico-deductive reasoning relies on the absence of refuting evidence and the presence of confirming evidence as support for a hypothesis. Knowledge claims are not absolute, only supported or falsified. A hypothesis cannot be proven but increasing support leads to a greater level of certainty and one non-confirming observation may provide cause for the hypothesis to be rejected (Yore, 1992). Observed patterns of data that would either confirm or refute the hypothesis are predicted prior to data collection, and these predictions are then compared with the collected data to support or reject the original hypothesis (Yore, 1993). Ontologically these temporary

descriptions and applications are expected to change over time and more closely reveal more accurate insights about nature. The development of science knowledge may not begin with a totally untested hypothesis but may begin with questioning an established description, explanation or existing theory (canonical science). McComas (1998) suggested that since scientists have preconceptions about the outcome of an investigation most evidence the scientist collected would confirm or support the existing hypothesis rather than refute the hypothesis. Palmquist and Finley (1997) suggested that the scientific method, within the contemporary view of science, is not bound by a single, universal set of steps but the method employed by a scientist depends on the circumstances.

The postmodern (idealist, relativist) view of science proposes that science knowledge consists of multiple descriptions and explanations of the world and it is impossible to know which of the interpretations, if any, are accurate since observation and interpretation cannot be separated. Epistemologically people use multiple ways to construct these explanations in the context of their own personal beliefs. The ontological basis stresses that different explanations of the natural world are considered of equal value and are not questioned or judged by others since people can never know the truth about the natural world (Good *et al.*, 1999). Feminist science and multicultural science educators suggest that the epistemology of science is influenced by culture, language, and gender (Brickhouse, 2001; Snively & Corsiglia, 2001). In fact, postmodernists hold that the realist epistemology of science is so influenced by gender that it becomes a barrier to participation to women and people of other cultures because the language and ideas are created by mostly white males. Brickhouse (2001, p. 284) stated that “the construction of

alternatives to the conventional dualisms of objectivity/subjectivity, mind/body, masculine/feminine are part of what is necessary to create a science that is truly by and for everyone”.

The three views of science are presented in the research literature, and educators choose a view that in turn explicitly or implicitly guides their science teaching (Henriques, 1997). A review of international standards documents suggests that there is some agreement regarding the nature of science (Lederman, 1992; McComas *et al.*, 1998). McComas *et al.* (1998) stated that the following objectives characterized the nature of science common to many of the science curriculum standards documents:

Scientific knowledge while durable, has a tentative character.

Scientific knowledge relies heavily, but not entirely, on observation, experimental evidence, rational arguments, and skepticism. There is not one way to do science (therefore, there is no universal step-by-step scientific method). Science is an attempt to explain natural phenomena. Laws and theories serve different roles in science, therefore students should note that theories do not become laws even with additional evidence. People from all cultures contribute to science. New knowledge must be reported clearly and openly.

Scientists require accurate record keeping, peer review and replicability. Observations are theory-laden. Scientists are creative.

The history of science reveals both an evolutionary and revolutionary character. Science is part of social and cultural

traditions. Science and technology impact each other. Scientific ideas are affected by their social and historical milieu. (p. 6)

This consensus view of the nature of science suggests a contemporary middle-of-the-road view rather than a traditional or a post-modern view of scientific knowledge.

Contemporary science curriculum documents focus on science as inquiry, evaluation, and debate rather than the traditional view of a set of unchanging truths that result from step-by-step procedures interpreted by unbiased scientists, or the postmodern view that proposes all knowledge claims are equally valid. Science is a tentative explanation that attempts to describe and explain general patterns of events in the natural world. These descriptions and explanations are discussed and can be revised or supported within the scientific community.

Science educators need to clarify their views of the nature of science when faced with questions about the including multicultural, religious, and gender perspectives in the science curriculum. This debate centers around the ontological-epistemological question: What is the nature of science? Scientists resolve this conflict by acknowledging “that their science is based on reason and evidence from the natural world, whereas their religion is based on scriptures and faith” (Good *et al.*, 1999, p. 108). Science teachers can resolve whether to include Creationism in their science teaching by testing the tenets of Creationism against their definition of science. Documents like *Benchmarks for Science Literacy* (AAAS, 1993) and the *National Science Education Standards* (NRC, 1996) in the United States present a contemporary view of science that judges claims based on presented evidence and accepts that all knowledge claims are tentative and may be changed with successive rounds of testing and observations. This view of science is

inconsistent with Creationist Science. The authors of the *National Science Education Standards* (NRC, 1996, p. 201) acknowledge the other views of science but stated “Explanations on how the natural world changed based on myths, person beliefs, religious values, mystical inspiration, or authority may be personally useful and socially relevant, but they are not scientific”. The Canadian reform document *Common Framework of Science Learning Outcomes* (CMEC, 1997) is slightly different than its American counterpart in that it suggested that the components of science education include science, technology, society, and environment (STSE). The inclusion of technology and society suggests that this reform document can be interpreted as an evaluative view of science with a post-modern perspective.

The decision by teachers to include multicultural perspective in science classes or not, should be consistent with their views of science. If multicultural perspectives are to be included in science class, then the scientific community must have access to the evidence, claims and warrants associated with these multicultural ideas. In many cases, the multicultural scientific knowledge is supported by myth, folklore or stories which are difficult to test against further observations. Multicultural science aligns more closely with the postmodern view of science and is inconsistent with the contemporary view of science present in national and international science reform documents. The purpose of including multicultural perspectives of science focuses on issues of cultural sensitivity and inclusion rather than presenting an accurate view of the nature of science. Cobern and Loving (2001) suggested that to consider multicultural science in the same light as western science could possibly cause this indigenous knowledge to be de-valued. It is to

the benefit of indigenous knowledge to be separate and to be judged and valued on its own merits.

Alters (1997) suggested that the nature of science is a major goal in science education and yet there is no single agreed upon view of science that has a philosophical basis. Science educators, however, have come to some agreement on the nature of science to establish workable foundations for decisions about what to teach and how to teach in the science classroom (Lederman, 2001). Much of this agreement centers on a contemporary evaluativist view of science. Although this contemporary view of science is not one used by some philosophers of science, it is a view that can guide teachers' decisions on instructional content and practice and is consistent with the constructivist learning and teaching theory endorsed by current science reform documents. Staver (1998, p. 517) stated that "the empirical character of science, as expressed in the thoughts and actions of scientists who seek to know, to bring coherence to our individual experiential worlds and collective knowledge through observation, experimentation, and the adjudication of results and theories needs no change within a constructivist framework".

Constructivist Learning and Teaching

The current foundation for knowledge and learning in science education is constructivism (Saunders, 1992; Yager, 1991). Constructivist learning theory is based on the premise that knowledge is constructed by learners in an attempt to make sense of the

world. Building on the ideas of Dewey, Piaget, Vygotsky and others, constructivists propose that in order for learning to occur it requires that students participate in activities that engage their minds and that students' previous experiences will influence the interpretation of new experiences (Phillips, 1995; Sterling, 1999). Furthermore, the constructivist view suggests that student engagement in activities that both challenge and build on prior experience is essential for learning.

When a student is introduced to a new experience there are four possible responses that the student can make (Appleton, 1993; Brooks & Brooks, 1993; Henriques, 1997; Saunders, 1992). The new experiences may confirm, strengthen or elaborate the student's preconceptions (whether correct or incorrect) and the student will assimilate the new experience into the prior conceptual network. Alternatively, the new experiences will be in conflict with what the student believes to be the best explanation of the phenomena resulting in one of three outcomes. The student may replace their inadequate prior ideas and create new ideas in a process of accommodation. The student may simply ignore the conflicting experience and make no attempt to reconcile the difference between the new experience and the existing explanation, in essence opting out. Finally, the student may wait for an authority to provide the 'right' answer and memorize this answer for future reference.

The Many 'Faces' of Constructivism

Many interpretations or 'faces' of the constructivist learning theory have been described in the research literature (Airasian & Walsh, 1997; Good, *et al.*, 1993; Phillips, 1995; Shymansky *et al.*, 1998). These individual perspectives on constructivism share

some common points, but have some critical differences. The individual perspectives differ on the ontological worldview or view of reality, epistemic view of science, locus of mental activity, pedagogical locus of control and structure, and the type and purpose of discourse (Shymansky *et al.*, 1998). The various interpretations of constructivism share the premise that knowledge is constructed by the learner within the context of his or her personal experiences, that the learners' prior knowledge plays a role in the construction of knowledge, and that this prior knowledge may contain misconceptions unrelated to age, intelligence, and culture (Airasian & Walsh, 1997; Shymansky *et al.*, 1998). This review briefly explores four constructivist approaches: Information Processing, Interactive-Constructivist, Social Constructivist, and Radical Constructivist. Differences in these interpretations of constructivism involve different assumptions about the nature of science and are likely to lead to differences in design and delivery of science instruction and it is therefore important to appreciate the contrasts. A teacher using an interactive-constructivist approach will implement strategies that are different than a teacher using an information-processing approach.

Information Processing

The information processing interpretation of constructivism proposes that students continually “fit” new experiences into their present understanding of the world. When a new experience does not fit into his or her prior understanding, the student revises his or her ideas and creates a new reality (Henriques, 1997). The metaphor of laying bricks has been used to illustrate how learning occurs in the information process approach (Good *et al.*, 1999). The view of science and scientific knowledge for information processing is a traditional or absolutist, realist view. The assumption is that the truth exists and the

verification of truth comes from nature. The construction of knowledge, enroute to discovering the truth, occurs privately within the minds of individuals. The presentation and design of the lessons and experiences is controlled by the teacher. The student's role is to react and move towards a common endpoint along with others in the class. The communication or discourse in an information processing approach can be described as one-way from teacher to student for the purpose of transmitting knowledge from the expert to the novice.

Instruction in an information processing classroom would have the teacher initially accessing prior knowledge about the topic. The students would complete a set of activities to increase their understanding of the topics and then apply this knowledge to a new situation. All of the students in the classroom complete the same activities in the same manner and arrive at the same understanding - the 'right' answer (Henriques, 1997).

Interactive-Constructivist

Interactive-constructivists "utilize a ecology metaphor to illustrate learning in which dynamic interactions of prior knowledge, concurrent sensory experiences, belief systems, and other people in a sociocultural context lead to multiple interpretations that are verified against evidence" (Shymansky *et al.*, 1998, p. 4). The view of science and scientific knowledge for the interactive-constructivist approach is a naïve realist, evaluativist view of science knowledge. Multiple interpretations are tested against current evidence and warrants, and either supported or refuted in attempt to gain insight into reality within the limitation of the observer (Yore, in press). Learning occurs in both a public and private domain often resulting in a variety of understandings across a group of learners. The students construct knowledge in the public domain through their

interactions with other people and their surroundings. Meaning is further developed and internalized when the student reflects on these interactions in the private domain. The teacher does not assume the role of expert but shares the control with the students. Students' initial ideas about a topic are the starting point for instruction. The teaching strategies maintain a focus on the students' ideas (Yager, 1991). The communications in an interactive-constructivist classroom are two-way negotiations to examine alternatives and to clarify thinking, rather than the one-way communications from the teacher to the students telling them what they need to know found in the information processing approach.

Henriques (1997, p. 22) proposed that interactive-constructivist approach has the following attributes:

- alignment among outcomes, instruction, resources and assessment;
- outcomes of conceptual change, conceptual growth, and metacognitive strategic learning;
- does not 'rule out' direct instruction embedded in a natural context of need;
- supports big ideas/unifying concepts (AAAS, 1993; NRC, 1996), science literacy and habits of mind needed to attain scientific literacy;
- requires students to gain ability to construct the construction, to think critically, and to communicate their constructions and persuade others of their value or utility;

- encompasses guided inquiry, learning cycles, conceptual change and generative approaches;
- and the teaching involves accessing, engaging, experiencing/exploring, justifying/rationalizing, consolidating/integrating old and new, and applying knowledge.

Social Constructivism

Social constructivists assert that knowledge is constructed “by an individual’s interaction with a social milieu in which he or she is situated, resulting in a change in both the individual and the milieu” (Airasian & Walsh, 1997, p. 445). The ontological premise for social constructivists is that knowledge and the world exists contextually. Science knowledge is evaluative but nonetheless relies on shared perceptions within a social or cultural group. Knowledge is created by individuals and differences in interpretation are subsequently resolved by consensus. The process of evaluating multiple interpretations of observations is similar to the evaluativist view of the science and science knowledge. However, the role of consensus as a way of validating interpretations sets the views of social constructivists apart from the scientific community (Henriques, 1997). The mental activity is public and the locus of control is derived from the group. There are two way communications for the purpose of negotiation that leads to consensus within the group.

A social constructivist classroom does not have an agenda with outcomes and objectives that are specified at the beginning of the class. The problems to be studied, the

methodology to be used, and the acceptable solution is determined by the group, not by the teacher (Brooks & Brooks, 1993; Henriques, 1997).

Radical Constructivism

Radical constructivist approaches are based on a postmodern, multicultural, or relativist view of science and science knowledge. Radical constructivists propose that all ideas are equally acceptable and “no group or groups are able to posit ideas which are more expert or more acceptable” (Henriques, 1997, p. 25). Phillips (1995) suggested that this interpretation of constructivism would not use terms like ‘misconceptions’ to describe students prior ideas, as this implies that there is one set of correct conceptions that all students should possess. A fundamental difference between radical constructivists and interactive-constructivists is that the latter group holds that, while there may be several correct interpretations, there are also most certainly incorrect ones. The radical constructivist interpretation proposes that “interpersonal deliberations and inner speech lead to equally valid unique interpretations that are internally assessed for personal consistency” (Shymansky *et al.*, 1998, p. 4).

A radical constructivist classroom would provide students with a number of experiences which would allow students to actively construct their own ideas, but would not require consensus between individuals or groups (Henriques, 1997; Phillips, 1995). The teacher would have a variety of learning outcomes rather than a specific outcome for the class. Each student would have their own understanding and would assess the viability of this understanding through using the idea to predict or explain other events or phenomena.

The various interpretations of the constructivist theory can be viewed on a continuum that emphasizes different aspects of ontology and epistemology (Henriques, 1997). The information processing view assumes a truth exists suggesting an absolutist, realist view of science. The interactive-constructivist interpretation suggests that it is possible to have multiple interpretations of a set of evidence and each interpretation must be judged on the claims, evidence, and warrants. This suggests an evaluativist, naïve realist view of science. Social constructivists also accept that multiple interpretations of one set of evidence will exist but cultural influences and social consensus provide the basis for judging the validity of the interpretations. Radical constructivism is based on a postmodern, idealist view of science that accepts all interpretations and these interpretations are judged within the context of the culture and the consistency with other culturally accepted interpretations. It is hard to envision a radical constructivist approach in British Columbia with Integrated Resource Packages, provincial examinations, and teachers as agents of the state (Yore, in press).

Constructivist Teaching Approaches and Strategies

Airasian and Walsh (1997) proposed that teachers should not use one particular constructivist-based teaching method exclusively. Philips (1995) viewed the interactive-constructivist approach as a ‘middle ground’ in the constructivist continuum. Yager (1991) suggested that teachers subscribing to the constructivist model may not have to completely overhaul their teaching methodology but merely reorganize and shift the emphasis of their current teaching. Some teachers, in particular the ones that stand out in student’s minds as their best teachers, have used constructivist-based teaching strategies

intuitively. Teaching approaches such as the learning cycle, four-part guided inquiry, open-ended inquiry, and cooperative learning are consistent with constructivist theory. Other teaching strategies that encourage students to construct knowledge include: demonstration teaching, student journals, concept mapping, and questioning. These strategies are useful in the science classroom but may extend to other disciplines.

Learning Cycle

One teaching approach that is consistent with the interactive-constructivist interpretation is the learning cycle. Through a process of exploration, concept development, and application the students are able to “disclose and discuss conceptions and then construct patterns and relationships” (Schulte, 1996, p. 27). The basic premise of the learning cycle is that learning is more effective when activity precedes direct instruction. The learning cycle may be divided into four phases: explore, explain, expand, and evaluate (Martin *et al.*, 1998). During the explore phase of the learning cycle the students have the opportunity to manipulate materials distributed by the teacher with or without teacher guidance. During the explain phase of the learning cycle, the students use experiences derived from the activity in the explore phase along with the direct teaching and questioning by the teacher to construct new ideas (Colburn, 1998; Martin *et al.*, 1998). Student involvement increases during the expand phase as the students apply their new ideas to prior situations or new situation. The evaluation phase examines what the students have learned but is not necessarily a paper and pencil test.

Modified Learning Cycle (Engage, Explore, Consolidate, Assess)

It may also be helpful to utilize a modified learning cycle called four-part guided inquiry with four phases: engage, explore, consolidate, and assess (Yore & Beugger,

1989). This teaching approach is flexible and at the same time provides structure for the teacher and student. The modified learning cycle or four-part guided inquiry, may be used with all types of inquiry (inductive, deductive, semi-deductive, hypothetico-deductive) while at the same time providing a scaffold for thinking skills.

The engage phase of the lesson is intended to motivate and focus students on the subsequent lesson and to access and challenge a student's prior knowledge. This is consistent with the constructivist premise that students come to the science lesson with knowledge rather than an empty container waiting to be filled with knowledge. Accessing prior knowledge assists both the student and the teacher. Students' prior knowledge provides an activated foundation from which to build understanding when presented with new experiences. The teacher accesses student prior knowledge to assist him or her in adjusting a lesson to meet the needs of the student (Ausubel, 1968). Should the students' prior knowledge contain misconceptions, the lesson activity will need to challenge these misconceptions and set the stage for conceptual change. Colburn (1998) suggested that a question or challenge be posed by the teacher to engage student ideas and increase motivation. Student initiated questions provide a rich source of information to assist the teacher in assessing prior knowledge and promoting student focus and motivation (Yager, 1991). Other teaching suggestions for this phase include demonstrating discrepant events and using children's literature as springboards into inquiry.

The implications of building knowledge through the interaction of prior knowledge and concrete experiences in the sociocultural context of a science classroom is the central focus of the explore phase. If science learning is to be more than memorizing

a set of facts, and involves the active building of knowledge through participation in activities and discussion with others, then science teachers must provide a variety of experiences. The explore phase encourages students to “collect and process data to develop understanding by thinking, doing, seeing, talking, and reading” (Yore & Beugger, 1989, p. 12). The activities or experiences can include investigations/inquiries, debates, role plays, readings, videos, and simulations. The teaching focus is on providing an experience that matches the intended learning outcomes, students’ cognitive abilities, and teachers’ abilities and preferences.

Although constructivists believe that students construct their understanding from their experiences, Martens (1999) suggested that few students develop a conceptual understanding by simply completing an activity. Colburn (1998) suggested that once students have been exposed to new experiences and ideas by doing an activity, then the students need to synthesize that information and use the resulting ideas in a new context to solidify their understanding. Yager (1991) also proposed some form of integration and application in a constructivist-based lesson that would include sharing information, constructing new explanations, explaining models, applying new knowledge and skills, and asking new questions. The consolidate phase of a four-part guided inquiry lesson allows students to share their experiences in a group or whole class setting. The discussion is guided by the teacher through a series of questions or tasks that begin with the most basic of sharing information, and progresses to analyzing that information, making a ‘rule’ or generalization about the information, and finally applying this generalization to a new situation or to the ‘real world’.

Assessment in constructivist-based teaching should follow from and reinforce a teaching approach that encourages the students to access prior knowledge, establish problem focus, design and conduct inquiries, collect and interpret data, and construct their own knowledge. Traditional assessment focuses on assessment as a motivator, a control strategy, and a measure of the accumulation of knowledge by the student (Tobin & Tippins, 1993). Constructivists place greater value on the use of ongoing or formative assessment to allow students to construct understandings not just reproduce understandings, to empower the students' learning and to inform the teachers' teaching methods (Colburn, 1998). The assessment must be better matched to the goals and instructional strategies used by the teacher; in other words the assessment must be authentic (Brooks & Brooks, 1993).

Assessment in a constructivist context should not be simply a final event. The fourth part of a guided inquiry lesson suggests that assessment is distributed across the learning experience. During the engage phase, the teacher assesses for the purposes of finding out what the students already know and to inform the design of appropriate instruction that is tailored to their prior knowledge. If the students prior knowledge contains misconceptions, the teacher needs to ensure that the learning activities in the explore and consolidate phases challenge and monitor the misconceptions. Assessment during the explore phase of the lesson provides the teacher with the opportunity to adapt instruction for individuals or small groups by crafting questions and tasks that encourage attention, data collection, analysis, action, problem-solving and thinking. There is also an opportunity for the teacher to observe the process skills, cooperative group skills, and habits of mind for individual students and document this information for the summative

evaluation. Assessment during the consolidation phase of the lesson allows the teacher to evaluate whether the conceptual goals of the lesson have been achieved. The assessment may be based on student responses to a scaffolded questioning sequence, student responses to embedded evaluative questions, or a task completed by the students during the explore phase. The teacher may ask the students to revise a completed task or apply the knowledge gained from the activity to a different situation. The teacher may then use this information for both student assessment and as a guide for instruction.

Both the timing and the purpose of assessment during an engage, explore, and consolidate lesson is distinctly different than traditional assessment, in that it occurs throughout the lesson and is directly intended to empower learners and inform teaching. Formative assessment may occur when the teacher notes student responses to questions during ‘engage’ and ‘consolidation’, makes observations of students during the ‘exploration’, and views the progression of understanding using writing assignments such as concept maps, student journals, and portfolios in order to make judgments about student performance. Summative assessment may still include paper and pencil tests. Objective tests need to be redesigned to facilitate the continuation of learning, the application of understanding to new situations, and the demonstration of student thinking which transcends simple acquisition and recall of facts. Formative assessments and culminating tasks form the basis of the summative assessment.

Structured versus Open-Ended Inquiry

Colburn (2000) suggests that there are different inquiry teaching approaches on a continuum ranging from confirmation-type activities to more open-ended activities. The structured, confirmation-type activities are often referred to as a ‘cookbook’ activities.

This type of activity involves a high degree of teacher direction designed simply to verify a predetermined outcome. The students are provided with a worksheet or study guide that provide the directions for completing the experience, the data table to be filled out, and a set of questions pertaining to what happened as the students were mindlessly carrying out the instructions. During this type of activity, the students are often on autopilot simply carrying out instructions instead of challenging and using their prior ideas, plausible reasoning and debate with other students to help them make sense of the experience and transform observations and measures into knowledge claims. Although this type of experience is a step towards constructivist-based teaching in that it provides concrete experiences, the lack of interaction between prior knowledge and new experiences does not further building understanding.

An alternative to the cookbook investigation, and closer to being an interactive-constructivist teaching approach, is the inquiry-based or investigative activity (Clough & Clark, 1994; Colburn, 1998; Saunders, 1992). This type of experience encourages the student to use his or her prior knowledge to formulate a plan for investigation. The students investigate the problem in a variety of ways unique to each individual or small group. The teacher's role is to facilitate and guide the process but not prescribe the method. Clough and Clark (1994) provided an example of how a cookbook type activity can be modified to be a more inquiry-based activity (Table 2.1). The original activity described for the students prior to completing the activity what evidence is confirmatory of a chemical change, whereas the modified activity required that students research and list evidence to support the claim that a chemical reaction took place. Changing the focus

question reorients the logical demands for verification toward knowledge building involving claims, evidence and warrants.

Table 2.1: Revising a ‘Cookbook’ Activity from Clough and Clark (1994, p. 36)

‘Cookbook’ Activity	Inquiry-based Activity
In this activity you will carry out a chemical reaction and capture the new chemicals which form. The experiment will be carried out in a zipper-lock plastic bag. this way you can be sure that no chemicals "slip out" before you have a chance to notice them. You have learned earlier that good chemists are also good detectives. They gather evidence by making careful observations. When a chemical reaction occurs, a chemical detective should be on the lookout for four kinds of evidence: 1. a color change 2. a temperature change 3. a solid forming 4. a gas forming A good chemist must be careful to take the time to look for each of these kinds of evidence. What evidence have you gathered that a chemical reaction has happened? What would happen if you tried the experiment again, but left out one of the ingredients? Try this. Make careful observations of the changes you see. Be sure to write down what you have added to the bag.	In this activity you will determine whether or not a chemical change has taken place. You will also examine how the mass of the "system" after mixing the chemicals compares to the mass of the "system" before mixing the chemicals. Careful observations are important in gathering evidence. A chemist must take the time to look for the kinds of evidence that indicate a chemical change. 1. Before beginning the experiment, write down what evidence would indicate the occurrence of a chemical reaction? What did you observe happening in your plastic bag that would indicate a chemical and/or physical change? Briefly describe how you would determine what happens to the mass of the “system” after you have mixed the chemicals. After having checked with the instructor, perform this procedure Predict what would happen if you tried the experiment again, but left out one of the ingredients. Try this (above). Record what you added together, and what you observed.

Demonstrations

The demonstration teaching strategy involves the teacher showing the students an activity. This may not sound like a constructivist-based activity, but the teacher encourages student thinking through questioning. The teacher asks the students to make

observations, make predictions, and answer analysis and synthesis questions throughout the demonstration or possibly afterwards in their journals. Demonstrations can give the teacher a picture of the prior knowledge that the student has about the concepts covered, and may also provide a 'springboard' to further investigation. Discrepant events are common demonstrations. The outcome of these demonstrations are counter-intuitive or unexpected, for example pushing a needle through an inflated balloon without it popping. The discrepant event often causes some disequilibrium or cognitive dissonance amongst the students, which in turn provides motivation and focus (Martin *et al.*, 1998).

Student Journals

Student journals can be used as a teaching, learning, and assessment tool (Shepardson & Britsch, 2000). Science journals from a constructivist perspective are a place wherein the student can write down their prior knowledge, record information from their science activity, transform raw data into knowledge claims, react to the new ideas, and reflect on how these ideas fit together. Lehman (1994) suggested that reflective journals can guide instruction by providing teachers with insights into misconceptions as well as topics for future lessons. Student journals may be used for a variety of assessment purposes (Shepardson & Britsch, 1997). Assessment of conceptual understanding "cannot be accomplished by looking at single sentences or words, but rather by analyzing the entire journal over time" thereby following the changes in student understanding (Shepardson & Britsch, 1997, p. 15). Teachers may use student journals to assess process and procedure by noting the level of detail in the observations, comparisons between observations, and the use of plausible deductive reasoning and hypothetico-deductive reasoning. However, Shepardson and Britsch (2000) cautioned

teachers not to over-interpret the content of student journals. It is important that teachers do not infer from a student's representation of the activity that there is conceptual understanding. Teachers must determine what evidence needs to be present in a student journal that will indicate conceptual understanding.

Concept Mapping

Concept mapping has its foundation in constructivist learning theory (Martin *et al.*, 1998; Novak, 1996). Concept mapping helps students to establish the relationships between concepts derived from prior knowledge, from new experiences, or both (Schulte, 1996). Each student may construct a different concept map depending on his or her understanding of the subject and reasoning. A concept map is not meant to be memorized but to provide an overall picture of the main ideas and the relationships in the conceptual network. A concept map is meant to encourage meaningful learning which implies that an individual, after instruction, is able to relate new concepts to knowledge that has previously been acquired or apply new concepts to a new situation. In other words, a student views the new knowledge in the context of what he or she already knows and as a result finds new meaning. If the connections between old and new knowledge are missing the student may see the new knowledge as isolated and useless bits of information.

Questioning Strategies

Questioning strategies can often be the key to a successful constructivist-based lesson during engage, explore, consolidation and assessment phases. Questioning is an effective way for a teacher to find out what ideas or preconceptions the student is bringing to the lesson (Colburn, 1998). Questioning can also help students to stimulate,

redirect, extend, and develop their thinking. Productive questions scaffold or encourage students to build their own understandings and help teachers to guide students toward a desired understanding (Martens, 1999). When a teacher is attempting to implement interactive-constructivist teaching and students are not moving towards understanding of the concept being explored, the teacher does not need to resort to telling the students what they need to do or to know. Martens (1999) suggested six types of questions (attention-focusing, measuring and counting, comparison, action, problem-posing, and reasoning) that will move the student forward in the thinking process during the explore phase of a four-part guided inquiry lesson. Many of the types of questions that Martens suggests are useful in the strategies already mentioned (Table 2.2). The questions are not meant to be sequential but rather the selection of the type of question is driven by the needs of the student and asked just-in-time to promote knowledge building.

Table 2.2: Productive Questions

Question Type	Purpose	Examples
Attention-focusing	Draw student attention to significant details	Have you see...? What have you noticed about...? What are they doing? What does it feel/smell/look?
Measuring and counting	Encourage students to be more precise about their observations	How many...? How often...? How long...? How much...?
Comparison	Encourage students to analyze and classify	How are these the same or different...? How do they go together...?
Action	Encourage students to make predictions or observations based on events	What happens if...? What would happen if...? What if...?
Problem-posing	Assist students to plan and implement solutions to problems	Can you find a way to...? Can you figure out how to...?
Reasoning Questions	Encourage students to think about experiences and help them make sense of these experiences	Why do you think...? What is your reason for...? Can you invent a rule for...?

(Martens, 1999, p. 26)

These questions are often asked both by teachers and other students during the explore phase or activity part of a lesson and are meant to keep students “on track” in terms of thinking and behaviour. The timing of these questions is important since the type of question asked by the teacher can either stimulate or discourage student thinking. The type of question that the teacher asks, as well as the timing, is critical to stimulating students to complete the activity. The attention-focusing questions can help those groups getting behind to become interested and involved again. On the other hand, the groups who are finished early are ready for the reasoning type questions that further their thinking and help them consolidate isolated ideas and build understanding.

Portfolios

Portfolios have been proposed as an alternative to traditional assessment methods and are in alignment with constructivist-based teaching strategies (Tobin & Tippins, 1993). A portfolio can be defined as a collection of evidence and student work completed during a unit (Collins, 1992). The portfolio may contain evidence of “having mastered and organized facts, or the mastery of some process skill such as the ability to design an experiment” (Collins, 1992, p. 25). The evidence may include student data tables and conclusions derived from the data, student reflections on an activity, self and peer assessments, diagrams, or other artifacts that demonstrate a student’s growth over time.

The amount of evidence to be included in a portfolio is a decision that is made by the teacher and student. A portfolio may contain a selection of materials that represent the student’s choices of what they think represents their learning, and teacher’s choices of items that are important to their instructional goals. The student may simply present an

overall description of the portfolio, in written or oral format, that provides a summary of the work in the portfolio rather than all of the pieces of evidence. A portfolio with numerous pieces of evidence should have a label on each piece with the reasons for the students' or teachers' selections (Collins, 1992). Proper planning and design make a portfolio an effective tool that may serve many purposes.

Current Reforms and Teaching

An understanding of the nature of science coupled with the ability to construct understanding (constructivism) establishes a basis for science literacy (Bingle & Gaskell, 1994; Demers, 2000; Van Driel *et al.*, 2001). National reform documents in Canada and the United States propose that the central goal of science education is scientific literacy for all students (AAAS, 1993; CMEC, 1997; NRC, 1996). A scientifically literate person knows “the characteristics of scientific knowledge and the way it is constructed, ... and will be better able to recognize pseudoscientific claims, distinguish good science from bad, and apply scientific knowledge to their everyday lives” (Bell & Lederman, 2000, p.1). However, this process of “mapping out what it means to be scientifically literate is only the beginning of a long journey through the reform process. The most difficult task in an education reform effort of this nature is implementation” (Shaka, 1997, p. 2). A key resource in the successful implementation of the current science education reforms is well trained and knowledgeable teachers (King *et al.*, 2001).

The achievement of scientific literacy by students will require teachers who are able to provide instruction that enables students in their science classrooms to experience the knowledge, skills, and attitudes associated with science inquiry. The national reform documents suggest that a science program should focus on science as an active process using hands-on and minds-on activities, depth versus breadth (less is more), interdisciplinary connections, and applying science content to the world of the learner and society. However, science is still often taught through lectures and verification-type laboratory work that is focused on cookbook-style exercises and encourages students to view “the processes of knowledge building in science as unproblematic, leading unambiguously and inevitably to proven science.” (Bencze & Hodson, 1999, p. 522). This type of instruction is contrary to a contemporary view of science, and the constructivist teaching and learning promoted by the science education reforms.

Beeth and Hewson (1999) studied the classroom practice of an exemplary elementary science teacher, Sister Gertrude Hennessey. Sister Hennessey has implemented many principles of the current science reform in her classroom and her students’ performance has “captured the attention of science educators, scientists, and cognitive psychologists” (Beeth & Hewson, 1999, p. 738). Researchers attempted to identify the successful teaching practices used by Sister Hennessey in order to isolate a set of skills or behaviours that could be taught to science teachers struggling to implement current science education reforms in their own classrooms.

Sister Hennessey’s teaching provides activities that acknowledge students’ prior ideas and encourage the students to talk about their emerging ideas. The lessons include a teacher-centered introduction moving to student-centered activities. The key features of

instruction include: (1) units and lessons designed by the teacher with the students' ideas in mind, (2) instruction that focuses on students' conceptions of science, views of learning, and their ability to apply aspects of scientific epistemology, (3) goals of learning that are known to students through the hands-on experiences selected by the teacher, her responses to student discussion during instruction, and modeling of the inquiry practice by the teacher, (4) individual, small group, and large group activities whereby the teacher monitors the process and intervenes only when the students become 'blocked' and can go no further in the discussion, and (5) sufficient time is allotted for students to complete the learning process.

These key features of interactive-constructivist instruction cannot be implemented effectively without understanding the underlying constructs. First, this type of instruction takes a larger amount of time to accomplish than other alternatives. A teacher has to make the decision that "less is more" and that the criteria for quality science curriculum should be depth of coverage rather than breadth of coverage. Second, the student's conceptions of science content, science learning, and science epistemology are not independent of one another but intertwined. Unlike traditional science teaching, Sister Hennessey "requires that her students learn to express their ideas; talk about why they are attracted by them; examine them for consistency; realize they may need to change for good reasons; and identify and discuss the status, in conceptual change terminology, that these ideas have for them" (Beeth & Hewson, 1999, p. 754). Sister Hennessey also insists that the students judge their own ideas and those of fellow students using the same criteria as the scientific community does. The students, therefore, require some familiarity with the epistemological criteria of the scientific community. Third, the role

of the teacher during a lesson shifts from proactively selecting activities that will encourage learning to a responsive role that monitors students' actions during the activity. Sister Hennessey intervenes in student discussion only to clarify student ideas or instructions. Fourth, both private and public components are critical for learning. Students are encouraged to think about the supporting rationale for their ideas, and to speak to these reasons when presenting their ideas to a large group. Fifth, consensus on the ideas explored in Sister Hennessey's classroom is not determined by a majority vote but rather by using epistemological criteria. When the idea is not the scientifically accepted view, the canonical science is presented as another idea to be judged along with other ideas using the criteria used by the scientific community. This is in contrast to the presentation of canonical science as the 'right' answer. The model of effective science instruction provided by Sister Hennessey results in a learning environment that encourages students to "speak about their ideas, offer justifications for those ideas, recognize the limitations of an idea, and negotiate knowledge claims in ways that were similar to some of those in the scientific community", a model that is consistent with current science education reform efforts and evaluativist view of science (Beeth & Hewson, 1999, p. 757).

Teacher Beliefs and Teaching

A necessary first step toward implementing reform in science education is to define the desired image of instruction. However, this desired image must also be

realized in actual practice. Haney *et al* (1996) suggested that reforms are destined to fail if implementation efforts do not consider the role of teachers' beliefs, intentions, and attitudes in addition to developing the desired teaching skills. Many teachers are already implementing classroom practices consistent with current science education reform (science literacy for all, understanding the nature of science, and using constructivist-based science teaching). Other teachers agree with the reform ideas and accompanying classroom practice but contrary to personal beliefs may not be implementing the appropriate changes in their classrooms. Some classroom observations have shown, contrary to many teachers' stated beliefs, that the science instruction taking place in the classroom is not inquiry-based science (King *et al.*, 2001; Mellado, 1998; Simmons *et al.*, 1999). Simmons *et al.* (1999) conducted a three-year study to explore the beliefs of beginning secondary science teachers and the connection to their actual classroom practice. The teachers in the study were observed in their first year of teaching and again in the second and third years of teaching. The first year teachers described their instruction as student-centered. However, the classroom observations of these same teachers indicated that teacher-centered instruction was taking place. These science classrooms presented the teacher in the dominant role of dispensing knowledge to the students. This study indicated that as the teachers "gained experience (i.e., teachers in their third year), their beliefs and actions became more congruent - albeit more teacher-centered" (Simmons *et al.*, 1999, p. 947).

King *et al.* (2001, p. 106) also found a "great disparity between what the teachers stated was their practice and the reality of the situation". The teachers in this case study included novice and experienced elementary teachers. The teachers felt that they taught

with an inquiry-based approach; however, inquiry teaching was not evident in any of the cases. In each case, the teacher relied on the textbook and instruction that was described as expository or traditional in its approach, in spite of the fact that the teachers in this study had been provided with staff development programs to encourage the use of inquiry-based science instruction. The staff development was described as the occasional afternoon workshops to help the teachers to make science more “hands-on”.

Previous research has shown that preservice teachers have adequate conceptions of some elements of the contemporary view of the nature of science, but misconceptions about other elements (Abd-El-Khalick *et al.*, 1998; Lederman, 1992; Lederman & Zeidler, 1987). These beliefs, adequate or not, are not translated into classroom practice (Abd-El-Khalick *et al.*, 1998; Brickhouse, 1990; Lederman, 1992; Lederman & Zeidler, 1987). The research into the relationship between beliefs and classroom practice has revealed several issues that may impede the translation of beliefs into practice.

Overcoming the Barriers to Implementation

Bencze and Hodson (1999) suggested that it is unrealistic to expect teachers to implement constructivist teaching strategies and a contemporary view of the nature of science in their classroom when their own experiences as students were based on a traditional, absolutist view of science and a lecture-verification laboratory approach to science teaching. Although preservice teachers may show an interest in the nature of science they often have misconceptions about the ontology and epistemology of science, are not aware of their importance to science education, and do not have strategies that will assist them in incorporating these ideas into instruction (Clough, 1998).

Although teachers hold certain beliefs about the nature of science, they often perceive that the nature of science is a less important outcome than outcomes associated with science process and content (Abd-El-Khalick *et al.*, 1998). Further constraints such as preoccupation with classroom management, lack of resources and experience in the nature of science, pressure to cover content, and lack of time for planning are barriers to the implementation of the nature of science in the classroom (Abd-El-Khalick *et al.*, 1998; Bell *et al.*, 2000). Additional barriers have been identified by preservice teachers in their attempts to translate their beliefs about the nature of science into classroom practice. Bell *et al.* (2000) reviewed several studies and listed concerns for student abilities (assuming more responsibility for learning), institutional constraints such as lack of mentoring, and lack of teaching experience as possible constraints to preservice teachers efforts to implement the nature of science into their classroom practice.

Many of the barriers that interfere with the translation of nature of science into practice also impede the implementation of constructivist teaching. One of the barriers to implementation of constructivist-based teaching strategies may be the lack of experience that teachers and the students have with this type of learning and teaching. Constructivist teaching and learning require teachers and students to assume unfamiliar roles. The teachers need to assume the role of guiding and facilitating, and the students need to become more self-regulated and active in their own learning. The purpose of assessment has to be viewed as a learning opportunity for both students and teachers to empower and inform. Furthermore, the pressures of having to spend extra time in planning and teaching, classroom management difficulties, coupled with the lack of curriculum materials present additional barriers to implementing constructivist strategies for teachers

of all levels (Beck *et al.*, 2000). The implementation of constructivist-based teaching strategies is not an automatic and short-term goal. Hand (1996) suggested that teachers progress through stages beginning with no knowledge of constructivist-based teaching, moving to a mechanical, almost structured application of constructivism, to finally completely focusing on student-directed learning. Louden and Wallace (1994) suggested that the shift of teachers and students to constructivist-based teaching and learning may involve a conceptual change approach and the implementation of strategies through the gradual accommodation and assimilation of these new strategies by both students and teachers.

Inquiry science activities that are consistent with an interactive-constructivist and the contemporary view of science are often difficult for teachers to implement in the classroom. Inquiry-based activities encourage the student to use their prior knowledge to formulate a plan for investigation. The students investigate the problem in a variety of ways unique to each investigator many of which may not be fully productive, controlled experiments. The teacher's role is to facilitate this diversity and to guide the process but not determine the method nor overly confine the learning experience. The expectation that preservice teachers whose priority is on the unfamiliar tasks of classroom management, relating to students, and the organizational structure of teaching can implement complex inquiry strategies in an elementary science classroom may not be feasible considering their developmental stage in pedagogy (Bell *et al.*, 2000; Lederman, 1999). Crawford (1999) concluded that there were six factors that assisted preservice teachers in their efforts to implement an inquiry-based classroom. The factors included: prior experience with this type of exploration, experience with an inquiry-based

classroom, a clear vision of the unit goals, developing a trust relationship with the classroom teacher, collaboration with experts outside of the classroom, and reflective practice.

The first factor, prior experience with inquiry, relates to the experience that the preservice teacher has as a student in their elementary school, secondary school, and university courses with inquiry-based activities. In other words, the preservice teacher will be more open to trying inquiry-based activities if he or she has participated in this type of activity previously. In Crawford's study, the preservice teacher worked as a laboratory technician, had successfully designed experiments, and in turn felt that it was something that the students in her class could try and benefit from. The second factor is that the preservice teacher in Crawford's study had seen another teacher implement the inquiry approach in the classroom over the course of her clinical experiences. The preservice teacher had a role model from whom she could pattern her inquiry teaching behaviours in her own classroom. The preservice teacher was also able to observe how successful the inquiry strategy was for both the teacher and the students. The third factor was that the preservice teacher had a clear understanding of the goals that she wanted to achieve by the end of the unit. She not only knew the knowledge that she wanted the students to understand but also the products and the processes that were to be a part of the student's learning. In other words, she knew that she wanted the students to design their own experiment and to produce a technical report at the end of the investigation. The fourth factor that facilitated the implementation of the inquiry approach by the preservice teacher was the supportive relationship with the sponsor teacher. In Crawford's study, the classroom teacher was flexible in allowing the preservice teacher's choice of topic

and teaching strategy. This level of support encouraged the preservice teacher to take risks such as implementing the inquiry approach. A fifth factor that allowed the preservice teacher to use the inquiry approach was the support system she had for equipment and supplies. The inquiry approach may require additional time for the teacher to get the materials that the students need for their individual investigations. A resource person from within the school system can assist in providing the equipment is helpful in preparing for inquiry lessons. The sixth factor that facilitated the success of the inquiry approach for the preservice teacher was that she would reflect on the success and failures of the lessons and implement changes based on the reflections.

Promoting Nature of Science and Constructivist Approaches in Preservice Methods Courses

Translating the current science education reforms into classroom practice has required considerable resources to be expended on the professional development of teachers. The attention is now beginning to focus on improving teacher education. Preservice teacher education “needs to prepare teachers who will enter the profession recognizing that they will continue to learn throughout their careers, as well as understanding and having competence in the ways of teaching called for in the current reform movement” (Hewson *et al.*, 1999, p. 374). Two ideas come to the forefront in discussions about reforming teacher education - constructivism and reflective practice (Hewson *et al.*, 1999; Mellado, 1998; Meyer *et al.*, 1999; Staver, 1994).

Teachers can no longer be considered technicians who mechanically apply instructional strategies to achieve a desired result. Teachers should be considered as constructivists who process information based on their prior experiences in order to make instructional decisions and generate routines in their classrooms (Mellado, 1998). However, teachers' prior experiences as students are as passive receivers of information. Many teachers were taught by the traditional transmission model wherein the concept was explained and the teacher and the textbook were the resources. This traditional approach has been reinforced throughout their school years including university and creates a stable belief system about how science is taught. Teachers often draw on their experiences as students to guide their teaching (Hewson *et al.*, 1999). Unfortunately, these prior beliefs about science teaching are in conflict with the current ideas on teaching and learning science and unless these prior ideas are addressed during the preservice methods course, they will not necessarily change or be replaced by new beliefs (Jasalavich & Schafer, 1994). The conceptual change approach to teaching science in the elementary classroom becomes a useful approach in teaching a preservice methods course (Hewson *et al.*, 1999; Staver, 1994).

Mellado (1998) suggested that knowledge of preservice teachers' prior conceptions about teaching and learning is not enough to change teaching behaviour. A preservice methods course must also provide opportunities for the teacher to "redefine their teaching strategies, contrast them with their previous beliefs, and again put them into practice" (Mellado, 1998, p. 210). The idea of encouraging reflective practice in preservice teachers is important not only in developing their beliefs but also in developing their professional practices (Akerson & Abd-El-Khalick, 2000; Hewson *et al.*

1999; Mellado, 1998). Elementary science methods courses must provide more than the underlying theories of learning. The instruction of preservice teachers should provide the strategies and procedures to use in the classroom that exemplify the theory and should be taught in a manner that is consistent with the theories of learning and teaching that are being promoted.

There has been much research into how to develop preservice science teachers' understanding of the nature of science including how to change their prior conceptions (Lederman, 1992). Many options have been considered when thinking about how to teach the nature of science to preservice teachers. Instruction about the nature of science could be provided in a separate course in the history and philosophy of science, in undergraduate science courses, or within a science methods course. However, taking a course on the history of science outside the context of classroom applications may provide information on the subject, but does not provide explicit connections to science teaching and does not approach the nature of science from the same perspective as science educators (Clough, 1998; McComas *et al.*, 1998). Providing nature of science instruction to preservice teachers in an undergraduate science course may not be an appropriate option either. Most science experiences at the first and second year undergraduate level focus on acquiring content and completing cookbook laboratory experiments. These types of courses do not provide preservice teachers with an understanding of "the thinking and behavior of scientists" (Matson & Parsons, 1998, p. 223). Although there is general agreement that the nature of science should be taught within the context of a science methods course, there is some debate about the value of implicit versus explicit teaching methods (Lederman, 1999; Palmquist & Finley, 1997).

The explicit method of teaching combines inquiry activities with explicit instruction on the nature of science. Implicit instruction presents science process skill instruction without direct instruction on components of the nature of science. This type of instruction assumes that the various aspects of the nature of science will be realized as a result of completing process skill activities. Palmquist and Finley (1997) suggested that this was an effective method since the preservice teachers' traditional conceptions of the nature of science changed after implicit teaching of the nature of science in their science methods course. Lederman (1999) alternatively suggests that in the Palmquist and Finley (1997) study, the changes in students understanding were only in areas where explicit instruction was provided. Overall however, there appears to be some agreement among researchers that teaching the nature of science is best achieved through explicit instruction within the context of a science methods course (Abd-El-Khalick *et al.*, 1998; Akerson *et al.*, 2000; Clough, 1998).

The relative successes and failures of explicit and implicit teaching have lead to the consideration of a conceptual change approach to help teachers develop adequate views of the nature of science. Conceptual change theory proposes that in order for ideas to change, the student must be dissatisfied with his or her existing ideas and the new idea must be plausible, acceptable, and powerful. Akerson and Abd-El-Khalick (2000) used a conceptual change approach and direct explicit instruction with reflective components to change preservice teachers' conceptions of the nature of science in an elementary science methods course. This approach included questionnaires prior to discussing the nature of science in class. The class was then made aware of their conceptions and were given readings and activities that would assists them in confronting their misconceptions. The

activities were not content specific and were “followed by a whole class discussion that aimed to explicitly highlight the target aspect of nature of science” (Akerson & Abd-El-Khalick , 2000, p. 6). The instructor asked the students to describe how the science content and pedagogy related to the nature of science through verbal discussions and papers that were written in reaction to specific readings and videotapes. The effect of this conceptual change-reflective activity approach showed that participants made significant gains in their understandings of the target aspects of the nature of science. However, this was a one semester course and participants indicated that their understandings of nature of science were still tentative and required further development. The study did not address the issue of whether the teachers’ ideas about the nature of science were successfully translated into the classroom practice.

The goal of science literacy, including an understanding of the nature of science, should not be limited to students in kindergarten to Grade 12. Elementary science methods courses should also consider science literacy as a goal for preservice teachers. A teacher who is able to make informed decisions about information based on the epistemological criteria of science (claims, evidence, warrants) will be better able to make professional decisions throughout his or her career. Achieving this goal with students and teachers will continue to be a focus of science education in the near future. The conceptual change approach is gaining acceptance as an effective teaching approach in the elementary classroom. The emergence of using this same approach for teaching elementary science methods is becoming a focus for reform in preservice teacher education. There appears to be little research that examines the relationship between the use of the explicit conceptual change instruction in a science methods course and the

effect this approach has on the degree to which a preservice teacher translates constructivism and the nature of science ideas into their classroom practices.

CHAPTER 3

METHODOLOGY

Introduction

A combination of quantitative and qualitative research methods best served the purposes of this case study. The quantitative portion of this study included a pre-test and post-test of two sections of elementary science methods students. These elementary preservice teachers completed a nature of science survey prior to and after completion of an 18 week elementary science methods course. The methods course took place over eight months beginning in September and ending in March. The course instruction was interrupted by an initial six week practicum in November and December. The pre-test took place in September prior to the beginning of the course, and the post-test took place in March after completion of the methods course and the initial six week practicum. The survey measured the preservice teachers' beliefs about the nature of science knowledge. The qualitative portion of this study was comprised of multiple classroom observations to document the teaching behaviour of six volunteer preservice teachers who had also participated in the survey. This combination of the data from the qualitative and quantitative research methods was intended to document beliefs about the nature of science, elucidate changes in beliefs through a science methods course, and assess the impact of preservice teachers' beliefs about the nature of science on their classroom practice.

Design

This study used a hybrid pre-test and post-test case study design to measure two cohorts of preservice teachers' beliefs about the nature of science prior to and after participation in an elementary science methods course and intervening teaching practicum. The design also employed qualitative methods of multiple classroom observations of a small purposeful sample of volunteer preservice teachers from the two cohorts. Further documentation of the study subjects' classroom practice included unit overviews, lesson plans, and assignments that were collected and analyzed to provide triangulation of the qualitative aspects of this design. This research design was selected to provide insights into the beliefs of preservice teachers' of the nature of science and the potential influence of these beliefs on their classroom practice within the limitations of a non-random intact group.

Setting and Sample

The research took place in the Faculty of Education at the University of Victoria and at five elementary schools and one middle school in urban, suburban, and rural areas of Victoria, BC, Canada. The preservice teachers were enrolled in an elementary science methods class in the Department of Curriculum and Instruction. According to the calendar description, the course is “a study of the curriculum organization and techniques

of instruction in elementary science. The course will include consideration of both the content and strategies for teaching elementary science education” (University of Victoria, 2000, p. 272). The fifty-four students in this study were enrolled in two sections of the course; all of them voluntarily participated in the survey portion of the study. The students were in the 4th and 5th year of a five year B.Ed. degree and had a variety of science backgrounds. Thirty-seven of the preservice teachers had completed the basic 3-unit laboratory science course requirement to enter the Faculty of Education, 15 had completed additional science courses such as second year or additional first year biology, physics or earth science courses (the areas or strand of the elementary science curriculum), and two had completed a degrees in biology and biochemistry. As is typical in many elementary teaching programs there were more female students than male students in the sample; 45 females and 11 males. Of the 54 participants in the survey portion of the study, 27 preservice teachers volunteered to be observed in their science teaching during their six week November-December practicum. At the time of completing the pretest, the participants had not been assigned a specific topic to teach for science but had visited their assigned classrooms for three days. The participants indicated on the initial survey whether or not they would like to participate in the classroom observation part of the study.

The Elementary Science Methods Course

The science methods course was co-taught by the researcher and the supervisor with six years and 30 years experience respectively teaching this course. The 54 participants were taught the same material in two separate cohorts. The course was one

of five courses that the preservice teachers were required to complete in the professional year (a year that includes two practical experiences schedule in six week blocks - November/December and April/May). The goals of the science methods course included:

- define the nature of science and technology, describe the intellectual, physical and sociocultural nature of the learner, outline the intellectual, economic and multicultural needs of the society, and state how these factors should be reflected in the elementary school science goals, curricula and instruction;
- demonstrate proper use of the science applications (skills, processes, thinking strategies, habits of mind) and state how these are learned by children;
- demonstrate knowledge about, sensitivity toward and application of elementary school science curricula and instructional resources;
- develop and apply instructional approaches, teaching strategies, assessment techniques, and support materials that are compatible with the nature of science and technology, interactive-constructive learning model, intellectual, physical and socio-cultural nature of the learner, intellectual, economic and multicultural needs of society and IRP outcomes (science content and applications);
- demonstrate conceptual understanding of the nature of science and technology, major themes, science applications, and socio-cultural considerations involved in elementary school science program;
- demonstrate knowledge about and applications of creative problem solving, plausible reasoning, writing-to-learn, and content reading strategies in elementary school science.

Nature of science was a central theme of the course (goals 1, 2, 4, and 5) and students were expected to provide a strong rationale for the instructional decisions that were implicitly or explicitly included in their assignments, examinations, and teaching.

The course content was presented to the students by providing in-class activities (Appendix A) and readings from science teaching journals such as *Science and Children* and *Science Scope* (Appendix B). The instructors modeled teaching behaviours consistent with interactive-constructivist teaching methods during instruction.

The content of the course in the first term focused on providing students with an introduction to the nature of science, basic process skills, four-part guided inquiry teaching method, and basic assessment methods (Table 3.1). Prior to instruction about the nature of science, the students were asked to provide a list of words and phrases that they associated with the discipline of science. These beliefs were examined and discussed in the context of two articles on the nature of science (McComas, 1996, Ten myths of science: Re-examining what we think we know about the nature of science; Cross, B., 1990, A passion within reason: The human side of process). Two activities (Baggie Science; Science in a Bag) showed the tentative nature of science and the inductive reasoning characteristic of the contemporary, evaluativist view of science and science knowledge. Any discrepancies between the students' ideas and the ideas presented in the two articles were discussed and attempts were made to resolve any misconceptions that the students may have held. Throughout the rest of the methods course, the students were explicitly taught aspects of the nature of science and these were reinforced using in-class activities that could be used with elementary students (Appendix A). The assignments for the first eight week term were designed to prepare the

Table 3.1: Science Methods Course Schedule

Week	Topic/Activity
1	Scientific Literacy LAB: Nature of Science
2	B.C. Science (K-7) Integrated Resource Package (1995) Constructivism: View of Science Teaching and Learning LAB: Instructional Resources
3	Science Process Skills/ Habits of Mind/Planning a Science Unit LAB: Observing and Inferring <u>Assignment Due:</u> Topic/Classroom description
4	Basic Teaching Strategy: 4-Part Guided Inquiry LAB: Classifying and Measurement
5	<i>Thanksgiving Holiday</i> LAB: Predicting <u>Assignment Due:</u> Unit Overview
6	Pre-experience (Engaging students; introduction ideas) Experience Phase (Exploring ideas, role of teacher, management) LAB: Communicating
7	Post-Experience Discussion (Consolidating ideas: explain, extend, apply) LAB: Post-Experience Questioning <u>Assignment Due:</u> Lesson #1
8	Assessment (empowering learning and informing instruction) PRACTICUM
9	Critical Attributes of Effective Science Teachers LAB: Interpreting Data
10	Formulating Models LAB: Fair Tests-Experimenting, Controlling Variables, Hypothesizing <u>Assignment Due:</u> Reaction Paper
11	Teacher On Call Activities LAB: Creative Problem Solving
12	Teacher On Call Activities LAB: Jigsaw Approach
13	Authentic Assessment and Scoring Rubrics LAB: Performance Assessment
14	Science Learning Centers LAB: Computer Applications
15	Science in our Communities <u>Reading Break</u>
16	Reading to Learn LAB: Science Inquiry and Popular News <u>Assignment Due:</u> Portfolio
17	Writing to Learn LAB: Pillbugs and Writing Genre
18	Nature of Science Revisited PRACTICUM

preservice teachers for their initial six week practicum and encouraged them to incorporate the four-part guided inquiry lesson format and hands-on exploration in their required science teaching. These assignments included a classroom description, unit overview and one four part guided inquiry lesson plan (Appendix C).

The second term was 10 weeks followed by a second six week practicum. The focus of this part of the course was on the integrated process skills and on expanding and refining the repertoire of teaching strategies consistent with interactive-constructivist teaching model. There was explicit instruction on the nature of science and how the teaching strategies presented portrayed the consensus view of the nature of science. The consensus view (McComas, 1998) was presented to the students. The assignments for the second term included reflections on their science teaching experience in the first practicum, a reaction paper for an article from a science teaching journal, and a science professional development portfolio that included a section that required students to define the nature of science (Appendix C). The portfolio assignment was intended to provide an opportunity for students to synthesize the course goals and to provide an opportunity “to document and describe their teaching; articulate their professional knowledge, and reflect on what, how and why they teach” (Moseley, 2000, p. 39). The first part of the portfolio assignment required the preservice teachers to write a one to two page summary of their beliefs about the nature of science, their science teaching philosophy and their thoughts on how children can best learn science (learning theory). They were encouraged to consider some key words for this section (nature of science, scientific literacy, constructivism, hands-on/minds-on). The summary was also to include specific examples

of teaching strategies that they would use in their science class and that also align with their stated beliefs.

The class schedule for the science methods course included one 50 minute class and one 100 minute class per week. The 50 minute class was taught in a lecture format and at times included a small group discussions. The 100 minute class featured a laboratory activity pertaining to a process skill and teaching strategy under consideration. The instructors taught the methods classes using a four-part guided inquiry approach that represented interactive-constructivist teaching and a form of inquiry teaching that could be achieved by most elementary preservice teachers. A typical lesson such as the class on predicting (week 5) would begin with engaging the preservice teachers. This lesson began with a challenge of how to fix a grandfather clock that was not keeping accurate time and was running slowly. The preservice teachers first described what a grandfather clock looked like and then provided suggestions on how to fix the clock, thereby providing insights into their prior knowledge as well as motivate and focus the students toward the activity. Many preservice teachers revealed the common misconception about the mass of the pendulum bob affecting the swing of the pendulum. A demonstration using a pendulum hung from the ceiling was used to negotiate the basic expectations of the exploration (defining a 'swing', the height of release). The preservice teachers were given their own pendulum (a length of string with a washer attached) to find out how many swings the pendulum made in 10 seconds. They were asked to tape their pendulum on a number line on the chalkboard underneath the number of swings that their pendulum made in 10 seconds. This created an inverted graph showing the relationship of the length of the pendulum to the number of swings in a set period of time. The instructor

modeled questioning, supervision, and equipment distribution techniques during this experience phase. The instructor asked a sequence of questions during the consolidating phase relating to the activity to demonstrate consolidation of the lesson. The sequence of questions included: What happens to the pendulums as they get shorter? Is this the same for every pendulum? Ask the students to explain pendulums that do not follow the pattern and possibly retest those pendulums as a whole class. What kind of 'rule' might we be able to make about pendulums from looking at this graph?; Let's test this rule with another pendulum. (use a new pendulum placing it on the graph to fit the pattern and predict the number of swings that the pendulum will make); How would you adjust the broken grandfather clock? What would happen if you made the pendulum heavier? The last question was meant to serve as a problem focus for the next lesson which would explore the effect of mass on a pendulum.

Setting and Sample for Classroom Observations

The classroom observations completed by the researcher occurred during the initial six week November-December practicum and focused on questions and responses of teachers and students and the type of assignments given by the teacher. The initial 27 classroom observation volunteers were reviewed using the first assignment for their science methods course - a class description (Appendix D). One of the original 27 volunteers discovered at this stage that their practicum did not include a science teaching assignment and as a result was eliminated from the sample. Other volunteers were removed from the sample for reasons such as: placement in a French immersion classroom (the researcher is, unfortunately, unilingual), an assignment that involved team

teaching, a science teaching assignment that was not a topic in the BC Ministry of Education's Integrated Resource Package, Science K-7 (1995), the traveling distance to practicum school for the researcher was too far, or the practicum was at an alternative school. This resulted in a pool of 13 preservice teachers as possible subjects for participation in the classroom observations. The teaching assignments of the remaining 13 volunteers were in classrooms from grades one to seven and included topics from the physical science, life science, and earth and space science strands (Appendix D). The second assignment for the science methods course, an unit overview, was used to select a purposeful sample of six preservice teachers. The criteria that were used in this selection included: presence of science content, opportunities to teach constructivist-based lessons, a balance of primary (K-3) and intermediate (4-7) grades, a balance of all the science strands (physical science, life science, earth/space science), and a representation from both sections. There were three volunteers from each cohort in the final selection (Table 3.2). All six of the final volunteers were female. This situation was not a purposeful decision on the part of the researcher but was a consequence of a skewed ratio toward females in the original pool of volunteers, as well as the selection criteria. The names used in Table 3.2 and subsequently are pseudonyms.

Table 3.2: Volunteers for Classroom Observations - names, grade level, topic and school

Susan	Mary	Kara	Linda	Julie	Kelly
Grade 7	Grade 4/5	Grade 4/5	Grade 3	Grade 1	Grade 1
Ecosystems	Light & Colour	Skeletal System	Earth's Composition	Weather & Seasons	States of Matter
School B	School E	School F	School G	School J	School F

Susan was a 5th year student in the elementary education program. She had completed lower and upper level courses in the history of science as well as the basic three units of laboratory science course requirement for entrance into the elementary education program. Her practicum assignment was in a grade seven class at a suburban middle school (grades 6-8). The class had 30 students; 14 girls and 16 boys. Susan was required to modify the assignments to accommodate the following students: three students with learning difficulties, one student with severe behaviour difficulties - attention deficit disorder, and one student with learning difficulties and severe behaviour difficulties. Susan provided the following description of the class:

The group has good energy and dynamics. Students are cooperative, well focused and respectful. Collaboration is a useful method as students work well together with partners and in small groups where discussion and constructive criticism are valued. On an individual basis, several students require direct attention from the instructor for comprehension and completion. Some students are unable to work together or near each other. These students have a tendency to distract each other which leads to a lack of focus and eventually behavior problems and disruptions for the entire class.

The classroom that Susan taught science in was designated as an art room. The room had tables and chairs instead of desks and a sink at the back of the room. The sponsor teacher assigned an ecology unit to teach in science and suggested a chapter of a science textbook to guide Susan in identifying the concepts that she would be teaching. Science classes

occur four times a week and are 45 minutes in duration. Three of the science blocks occurred immediately after lunch and the fourth science block occurred after morning recess.

Julie was a 5th year student in the elementary education program. She had completed the required basic laboratory science courses. Julie's practicum assignment was a grade one class of 22 students; 11 boys and 11 girls. Julie stated in her class description that one student in this class had "significant learning difficulties in the areas of listening, comprehension, and small motor control" and was seated next to an above average student who helped him with his work. There were six students who were "performing significantly above the other students on a continual basis, however would not be considered gifted". Julie described the physical arrangement of her classroom as follows:

The students are seated in desks arranged in groups of four, with the exception of one group of six. There are three other work tables besides the classroom desks that are situated in the classroom, however these tables are not very big so the majority of all work done in the classroom is done so at the students' desks. There is one sink situated in the classroom.

There were limited resources, books and equipment, for Julie to use to teach her weather and seasons unit. Science periods were scheduled twice a week in 25 minute blocks.

Mary was a 5th year student in the elementary education program. She had completed the basic three units of laboratory science courses required for entering into the elementary education program. She was assigned to teach a split class of grade four

and five students in an urban elementary school for her practicum. There were 27 students; 16 students in grade 5 and 11 students in grade 4. There were 15 girls and 12 boys in the class. There were no designated special needs students in the class that would require modified assignments. The students in this class had been taught several life science topics and Mary was teaching a physical science unit on light and colour. Mary expressed some concern in her class description that science was taught in the mid-afternoon:

This is a time when many students are showing signs of tiredness and can have trouble staying on task. With this in mind, I realize I will have to make science as exciting as possible by using materials that are manipulative, visual, and involve the students in self-discovery.

The classroom was arranged in rows and each row had two desks pushed together side by side. There was a table at the front of the room for demonstrations and a sink at the back of the room. There was no designated science program that the school subscribed to and the equipment for a light and colour unit was minimal. Science was taught for forty minutes three times per week.

Kelly was a 4th year student in the elementary education program. She had completed the basic laboratory science course requirement. She was assigned to teach a grade one class in an elementary school in a suburban area close to the University of Victoria, the same school as Kara. There were 20 students in the class; 11 boys and 9 girls. Some of the students are not yet able to read but there are no designated learning difficulties. Kelly described the classroom set-up as follows:

Students' desks are arranged in groups of four to six (there are four of these such groups). This arrangement is ideal for teacher-guided hands-on activities which invite discussion amongst peers.

Students are familiar with the large carpeted area in the center of the room for which they engage in 'Group'. 'Group' is a time where students share their knowledge with the teacher and other students by sitting in a circle and participating in a discussion. The carpeted area presents an excellent venue for the introduction of activities, demonstrations, and KWL discussion.

There was limited science equipment for use in teaching her unit on solids, liquids, and gases. The class periods for science were only 30 minutes long.

Linda was a 4th year student in the elementary education program. She had completed the basic laboratory science courses as well as first year courses in geology and astronomy. Linda's practicum assignment was a grade three class in a rural elementary school. There were 22 students in the class; 9 boys and 13 girls with no learning or physical disabilities. Linda described her classroom as follows:

The classroom has a sink at the back of the room, which is accessible to all students. The classroom is set up with student desks in pods of four. This will make experiments and hands on activities with limited resources easy to work with. There is also a table at the front of the room for class demonstrations, which all students can see clearly from their desks.

The sponsor teacher provided a new science textbook series and a rock and fossil kit for Linda to use in her earth's composition unit. The science periods were twice a week in one hour and two hour blocks.

Kara was a 4th year student in the elementary education program. She had completed the basic laboratory science course requirement. She was assigned to teach a skeletal and digestive system unit to a grade four class in an elementary school in a suburban area close to the University of Victoria. There were 30 students in this class; 22 boys and 8 girls. Kara stated that "there are a couple of IEPs (individual education plans), some reading comprehension difficulties, and one hearing impaired student". The desks in the classroom were organized in rows. There was a small table near the front of the classroom and a carpeted area at the side of the room. Kara's sponsor teacher provided some books to help Kara plan her unit. There were no models or kits in the school related to the skeletal and digestive system. Science classes were scheduled each day for 40 to 45 minutes.

The Instrument

The *Nature of Scientific Knowledge Scale* (Rubba & Andersen, 1978) was used to assess the preservice teachers' beliefs about the nature of science prior to and after taking the science methods course (Appendix E). The classroom observations were done by the researcher in an observer-participant role with no evaluation responsibilities for the practicum (Gall *et al.*, 1996). The researcher was primarily an observer and

entered the classroom setting to gather data and interacted with individuals in the setting indirectly. The researcher provided feedback on teaching behaviours only when requested by the participant. The feedback was not directly related to nature of science issues. The classroom observations required that the researcher was familiar with classroom observation techniques. This familiarity was developed by the researcher while completing an apprenticeship in Spring 2000 during a science internship for elementary science education majors.

Assessment of Preservice Teachers' Conceptions

The *Nature of Science Knowledge Scale* (NSKS) purports to be an objective measure of secondary students' beliefs of the nature of science described earlier (Rubba & Andersen, 1978). A detailed description of the content selection, validity, and reliability can be found in the original study (Rubba & Andersen, 1978). The NSKS was selected to provide an established marker to other studies and to aid in the generalization of this case study results (Firestone, 1993; Yore, in press). Lederman *et al.* (1998) in a review of assessment instruments for the nature of science includes the NSKS in a list of 12 instruments that are the most valid and reliable of assessment instruments that use a paper and pencil format. One weakness of the NSKS is that there are identical pairs of items except that one is phrased negatively which creates some redundancy. This "redundancy could encourage respondents to refer back to their answers on previous, similarly-worded items" and "result in inflated reliability estimates" (Lederman *et al.*, 1998, p. 339). Lederman and Zeidler (1987), in a study similar to this research, used the NSKS as a pre-test and post-test assessment instrument that measured high school

teachers' beliefs about the nature of science. The indices for internal consistency for each subscale and the overall score on the pretest and posttest were a minimum of $r = 0.70$ and a maximum of $r = 0.92$ (Lederman & Zeidler, 1987).

The NSKS contains 48 statements based on six subscales and has a Likert scale response format with five choices (i.e., strongly agree, agree, neutral, disagree, strongly disagree). Rubba and Andersen (1978) describe the subscales as follows:

Amoral: Scientific knowledge provides people with many capabilities, but does not instruct them on how to use them. Moral judgment can be passed only on people's application of scientific knowledge, not on the knowledge itself.

Creative: Scientific knowledge is a product of a person's intellect. Its invention requires as much creative imagination as does the work of an artist, a poet, or a composer. Scientific knowledge embodies the creative essence of the scientific inquiry process.

Developmental: Scientific knowledge is never "proven" in an absolute and final sense. It changes over time. The justification process limits scientific knowledge as probable. Beliefs which appear to be good ones at one time may be appraised differently when more evidence is at hand. Previously accepted beliefs should be judged in their historical context.

Parsimonious: Scientific knowledge tends toward simplicity, but not to the disdain of complexity. It is comprehensive as opposed to specific. There is a continuous effort in science to develop a

minimum number of concepts to explain the greatest possible number of observations.

Testable: Scientific knowledge is capable of public empirical test.

Its validity is established through repeated testing against accepted observations. Consistency among test results is a necessary, but not a sufficient condition for the validity of scientific knowledge.

Unified: Scientific knowledge is born out of an effort to understand the unity of nature. The knowledge produced by the various specialized sciences contributes to a network of laws, theories, and concepts. This systemized body gives science its explanatory and predictive power. (p. 456).

There were eight items assigned to each subscale, four of the items were stated in the negative and four of the items were stated in the positive (Table 3.3). The respondents received one to five points on each NSKS item. A response of ‘strongly agree’ on a positive item would receive five points and a response of ‘strongly disagree’ would receive one point. The negative items were scored in the reverse (‘strongly agree’ would receive one point and ‘strongly disagree’ would receive 5 points). Overall scores for the NSKS vary from a minimum of 48 points to a maximum of 240 points. Subscale scores vary from a minimum of eight points to a maximum of 40 points. The more consistent a respondent’s view is with the view presented by each subscale, the higher the point total. Pre-test and post-test results were examined for evidence of changes in the NSKS and in each subscale.

Table 3.3: NSKS Item-to-Subscale Key

NSKS Subscale	Positive Item Numbers	Negative Item Numbers
Amoral	4, 5, 8, 48	7, 18, 21, 36
Creative	17, 20, 28, 32	1, 23, 34, 41
Developmental	16, 26, 37, 42	25, 27, 31, 43
Parsimonious	2, 6, 29, 46	14, 15, 39, 40
Testable	12, 22, 38, 45	9, 11, 13, 33
Unified	3, 30, 35, 47	10, 19, 24, 44

Classroom Observations

The researcher conducted observations on two different visits to each of the six preservice teachers' science classes. The researcher was unaware of the preservice teachers' performance on the initial NSKS while making the observations. During the observations, an attempt was made to record the types of questions that the preservice teachers' asked, the responses the students gave to these questions, as well as handouts and assignments given by the preservice teacher.

Timeline and Data Collection

The science methods course encompassed 18 weeks of instruction divided by a six week practicum experience and followed with another six week practicum experience.

The NSKS survey was administered by an external research assistant during the first class of the science methods course in the first eight weeks of instruction. The same survey was given again in the last class of the final 10 weeks of instruction. Survey results were sealed and stored until the study was completed and student grades were submitted in April. The classroom observations were completed during the first six week practicum (Table 3.4).

Table 3.4: Timeline of Study

First Term Instruction (8 weeks)	Initial Practicum (6 weeks)	Christmas Holidays (2 weeks)	Second Term Instruction (10 weeks)	Final Practicum (6 weeks)
↑ 1 st NSKS (September, 2000)	↑ Classroom Observations (November-December, 2000)			↑ 2 nd NSKS (March, 2001)

Data Analysis

Systat 6.0 (1996) was used to complete the quantitative portion of this study. A factor analysis was completed on the individual questions for the pre-test and post-test. A Cronbach's alpha was used to assess the internal consistency of the individual items in each of the six subscales. The pre-test and post-test subscale scores and overall scores were compared using a paired sample t-test to determine if significant changes had occurred over the period of the methods course.

The classroom observations from the two visits to each volunteer preservice teacher were reviewed focusing on the types of questions asked by the preservice teacher, the types of assignments that were given in class, and the response by the students. The questions types were identified using the same categories used by Martens (1999). The assignments were analyzed for the degree of open-ended inquiry that was present. This analysis technique involved comparing the results of the classroom observations with patterns that were currently described in theory or literature (Cresswell, 1994).

CHAPTER 4

RESULTS

Introduction

This study attempted to document elementary preservice teachers' beliefs about the nature of science and changes in their beliefs over the duration of a science methods course. The study further examined the impact of preservice teachers' beliefs about the nature of science on their classroom practice. These elementary preservice teachers completed a nature of science knowledge survey (NSKS) prior to and after completion of an 18 week elementary science methods course. Multiple classroom observations were employed to document the classroom practice of six preservice teachers selected from the larger cohorts.

Analysis of Instrument Reliability

The NSKS measured the preservice teachers' beliefs about the nature of science knowledge. Student responses to the pre-test and post-test items were analyzed using a *Cronbach's alpha* to determine the internal consistency of the items within assigned subscales and within the entire survey. The pre-test alphas for the six subscales and the total survey ranged from 0.40 to 0.84 (Table 4.1). An alpha of greater than 0.60 is often

considered to be a threshold for acceptable internal consistency of a set of questions in low risk research studies (Yore, pers. com.). The post-test alphas for five of the six subscales and the total score increased from the pre-test and ranged from 0.61 to 0.85 (Table 4.1). The Creative subscale alpha decreased from 0.83 to 0.74 but is still within the acceptable limit. These analyses demonstrated acceptable indices of internal consistency for the post-test scores. The alphas for the parsimonious and developmental subscales on the pre-test were lower than the acceptable limit, and the underlying questions, therefore, are suspect.

Table 4.1: Pre-test and Post-test Cronbach's Alpha (n=50)

	Pre-test	Post-test
Amoral	0.75	0.78
Creative	0.83	0.74
Developmental	0.47	0.61
Parsimonious	0.40	0.63
Testable	0.69	0.73
Unified	0.73	0.78
Total	0.84	0.85

A principal components analysis (PCA) was conducted to confirm the structural validity of the six subscales and the relationships among the 48 questions. It was expected that the factor analysis of the 48 questions would reflect the six subscales already established in the NSKS. Before rotation, the first six factors of the PCA on the pre-test surveys captured a total of 49.4% of the variation found in the original data set (Appendix F). Overall, the pre-test PCA results confirm that there were at least six independent (orthogonal) constructs underlying the 48 questions. Based on this

information, the PCA was conducted using a varimax rotation in order to partition the variance explained and the underlying variables more equally across the six factors.

Most questions (67%) within subscales tended to load on the same factors. Six subscales did not have all eight designated questions loading entirely on the same factor (loadings > 0.30). The amoral subscale had all eight questions load on factor one. The creative subscale had all eight questions load on factor two. The testable subscale had five of eight questions load on factor five. The unified subscale had three of eight questions load on factor six while three other questions loaded on factor one. The parsimonious subscale had three of eight questions load on factor four.

The pre-test factor analysis partially reflected the structure of the original NSKS survey. Items from the developmental and unified subscales loaded on the same factor (factor one). A PCA assumes that the survey scores are based on an informed decision rather than random selection. Pre-test results from the preservice teachers prior to instruction were not assumed to be well-behaved, therefore the results of the NSKS pre-test principal components analysis were not surprising.

The post-test factor analysis utilized a six factor solution with a varimax rotation of the NSKS questions revealed that 77% of the questions loaded on appropriate factors with no two subscales loaded on one factor (loadings > 0.30). The structural validity of the post-test results for the subscales increased. Six questions in the amoral subscale loaded on factor two, seven questions in the creative subscale loaded on factor one, six questions in the testable subscale loaded on factor three, four questions in the developmental subscale loaded on factor four, seven questions in the unified subscale loaded on factor five, and seven questions in the parsimonious subscale loaded on factor

six. The developmental subscale questions did not consistently load onto a single factor. Overall, the PCA of the post-test surveys more closely approximated the structure of the original NSKS survey than the pre-test data did. The results of the PCA on the post-test results support the use of the NSKS for low risk research studies.

Descriptive Statistics

The pre-test and post-test minimum scores, maximum scores, means, and standard deviations were calculated for the total NSKS and the six subscales to provide an overview of the results of 50 students who completed both the pre-test and the post-test (Table 4.2). Four students did not complete both the pre-test and post-test because of late entry into the course or illness at the end of the year. The deletions of these four students did not appear to change the characteristics of the two cohorts.

The preservice teachers generally expressed more distinctive beliefs about the nature of science on the post-test than they did on the pre-test. Informal observations suggested that there were more strongly agree and strongly disagree responses on the post-test than on the pre-test. The mean performances on the pre-test and post-test were judged to be good (> 168 on the NSKS and >28 on the subscales). The pre-test performance on the testable subscale was judged to be very good (> 32). The mean total score and the mean score for each subscale increased from the pre-test to the post-test. The largest gain in mean score for a subscale was made on the creative subscale. The range (actual maximum - minimum) of the scores increased on three subscales (amoral,

parsimonious, unified), decreased on two subscales (creative, testable), and stayed the same on one subscale (developmental).

Table 4.2: Descriptive Statistics of Pre-test and Post-test Subscale Scores (n=50)

NSKS Scale	Administration	Min	Max	Mean	SD
Total	Pre-test	150	201	172.10	13.89
	Post-test	154	226	181.62	14.81
Amoral	Pre-test	19	38	27.10	4.51
	Post-test	14	39	27.82	5.07
Creative	Pre-test	11	35	26.94	5.20
	Post-test	22	39	31.34	4.29
Developmental	Pre-test	25	37	30.66	2.72
	Post-test	27	39	32.86	3.19
Parsimonious	Pre-test	16	32	23.68	3.25
	Post-test	16	37	24.48	4.05
Testable	Pre-test	25	40	32.60	3.60
	Post-test	26	39	32.66	3.67
Unified	Pre-test	24	39	31.12	3.40
	Post-test	19	39	32.46	3.90

A Pearson correlation matrix was completed between the students' NSKS total scores (pre-test, post-test) and their marks received on assignments within their science methods course, including a unit overview, lesson plan, portfolio assignment, and the midterm and final examinations (Table 4.3). The strongest correlation was between the NSKS pre-test and post-test scores ($r = 0.64$). Correlation coefficients between the pre-test NSKS scores and the marks for the assignments or examinations in the methods

course ranged from -0.07 to 0.14. The correlation coefficients between the post-test NSKS scores and the marks for the assignments and examinations in the methods course ranged from -0.02 to 0.32. Only one of these correlation coefficients was greater than the critical correlation coefficient of 0.28 ($n=50$, $p \leq 0.05$). However, it was disappointing to find the negative correlations between students' pre-test NSKS scores and their planning to teach inquiry science.

Table 4.3: Correlation Matrix for NSKS Total Score and Course Assignments and Examinations ($n=50$)

NSKS	Unit Overview	Lesson Plan	Midterm Exam	Portfolio	Final Exam
Pre-test	0.04	-0.07	0.07	0.14	0.02
Post-test	-0.19	-0.02	0.32*	0.10	0.16

*significantly greater than r_{crit} ($p \leq 0.05$) = 0.28

Pre-test and Post-test Changes

A paired sample t-test was used to determine if gains between pre-test and post-test scores on each subscale and the overall total scores were greater than what would be expected by chance. There were significant ($p \leq 0.05$) differences between the pre-test and post-test scores for the overall total score, and three of the six subscales - creative, developmental, and unified (Table 4.4). There were non-significant ($p \geq 0.05$)

differences between the pre-test and post-test scores for the other three of the six subscales - amoral, parsimonious, and testable.

Table 4.4: T-test Analysis of Pre-test and Post-test Differences (n=50)

NSKS Subscales	Mean Difference	t	df	p-value
Total Score	9.52	5.53	49	0.00
Amoral	0.72	0.97	49	0.34
Creative	4.40	5.74	49	0.00
Developmental	2.20	5.56	49	0.00
Parsimonious	0.80	1.54	49	0.13
Testable	0.60	0.12	49	0.91
Unified	1.34	2.55	49	0.01

Descriptions of Classroom Observation Cases

Six preservice teachers were selected as a non-random cohort for the qualitative component of this study that attempted to explore whether their beliefs about the nature of science influenced their classroom practice. A description of these preservice teachers was provided to facilitate limited generalization deemed appropriate. The classroom observation cohort mean total score and means for each subscale was higher than the class total score mean and the means for all six subscales (Table 4.5). Pre-test scores were used in this part of the study since they most closely approximated the timing of the classroom observations.

Table 4.5: Mean and SD of Class and Case Study Cohort Total and Subscale Pre-test Scores

NSKS Subscale	Class (n = 50)		Case Study Cohort (n = 6)	
	Mean	SD	Mean	SD
Total Score	172.10	13.89	181.33	9.20
Amoral	27.10	4.51	30.33	4.76
Creative	26.94	5.20	29.00	4.43
Developmental	30.66	2.72	31.33	2.58
Parsimonious	23.68	3.25	24.33	2.66
Testable	32.60	3.60	34.50	3.39
Unified	31.12	3.40	31.83	3.25

Each member of the case study cohort had scores that varied in their relationship to the class and cohort means (Table 4.6). Each case will be discussed individually according to: pre-test survey scores and comparisons to the class and cohort scores, and summary of the classroom observations. The analysis of the observations focused on the unit plans, implementation of constructivist teaching (engage, explore, consolidate, assess), types of questions posed by the teacher, types of assignments, responses by students, and general comments about the practicum situation.

Table 4.6: Individual Case Study Subject Pre-test Scores

	Susan	Julie	Mary	Kelly	Linda	Kara
Total	191	190	184	182	173	168
Amoral	29	38	34	29	26	26
Creative	35	23	29	32	25	30
Developmental	35	28	32	31	33	29
Parsimonious	25	25	28	20	25	23
Testable	33	40	33	36	35	30
Unified	34	36	28	34	29	30

Susan

Susan's total score on the NSKS was higher than the class and case study cohort means (191 out of a possible 240). Her scores on all subscales were also higher than the class means and case study cohort means. Susan's strongest subscale scores were in the areas of creative and developmental beliefs and her weakest subscale score was on amoral beliefs. Susan was classified as having a high NSKS total score in the classroom observation cohort.

The unit overview and lesson plans prepared indicated that Susan was planning to use a modified learning cycle. The activities that she had planned for the engage phase included: using literature as a springboard, picture and quote to stimulate brainstorming on the topic, and concept mapping. The unit overview indicated that Susan would be using a variety of explorations. Students would be making posters, creating food webs, building models, and writing a summary based on watching a video. The lesson plan included sequenced questions beginning with sharing information and ending with an application question. Susan used the completed student assignment sheets after each lesson as her formative assessment.

Observations of her teaching revealed that the engage phase of her lessons was a review of the previous lesson concepts. Susan did not provide an activity to focus, motivate or assess prior knowledge during this phase. The explore phase of one lesson consisted of a video as planned. Susan asked the students to take notes while watching the video. The notes were to focus on particular pieces of information that was determined by Susan. During another observed lesson, Susan provided an introductory lecture to the class on the components of the nitrogen cycle and listed them on the board.

The exploration required students to make a diagram of the nitrogen cycle during the explore phase. Individually the students drew the nitrogen cycle using the components listed. The consolidation phase focused on sharing information rather than constructing generalizations. Although the topics in this unit would lend themselves to real world connections and applications, they were not part of the lesson. Formative assessment included collecting and marking the nitrogen cycle and the video notes created by the students.

Susan often used questioning as a classroom management tool rather than an instructional scaffolding. The questions were asked in quick succession and directed to students who were not paying attention. Most of her questions were attention-focusing or measuring and counting type questions and began with phrases such as: *what is...?*; *where does ...?*; *how do ...?* (Martens, 1999). A few of the questions that Susan asked were action type questions (i.e., *what would happen if...?*) and a few were comparison type questions (i.e., *what do they have in common...?*). Susan did not use reasoning or problem-posing type questions.

The students enjoyed Susan's energetic, structured teaching style and her methods seemed to be familiar to the students. The students responded to Susan's teaching by answering questions with little elaboration and many times providing one word answers. The students provided little elaboration on the assignments as well. The drawings done by the students contained the terms that were listed on the board. The video notes contained the information that was required by Susan. During the discussion after the video individual students modified their notes to reflect other ideas. The students' drawings and their notes from the video were all similar in content.

Susan's science classes were in two different rooms during the week and these rooms were used by multiple teachers for several subjects. Consequently Susan felt that it was not possible to create any science displays that remained up during other teachers use of the room. Science in the second block of the week was in a classroom with rows of desks and Susan felt this did not lend itself well to hands-on science. She felt that her classroom management skills were weak and was concerned about the class getting out of control during experiments and fieldtrips. Susan's sponsor teacher was specific about the chapters that he wanted Susan to cover during her practicum. Susan was concerned about this and felt that it was critical that she cover this material as assigned.

Julie

Julie's total score on the NSKS was higher than the class and cohort means. Her scores on the amoral, parsimonious, testable, and unified subscales was higher than the class and cohort means, but her scores were below the class and cohort mean for the creative and developmental subscales. Julie had the highest subscale scores in the cohort. Her highest score was on testable subscale and her lowest score was on the creative subscale. Julie was classified as having a high NSKS total score in the classroom observation cohort.

The unit overview and lesson plans that Julie prepared indicated that she planned to use a modified learning cycle. She had planned to use the following activities in the engage phase: outdoor walk, children's literature as a springboard, identifying mystery wind speed and direction symbols, and a demonstration of the effect of weather on plants. The explorations for the students were planned to include: observing changes in

temperature and changes in the states of water, experimenting with wind speed and pinwheel movement, describing the appearance of an outdoor item during each season, and experimenting with different clothes used to keep warm. The consolidating phase of sequenced questions was included on Julie's lesson plan. Julie planned to collect and review completed student assignment sheets after each lesson for her formative assessment.

Observations of Julie's teaching showed that the engage phase of the lessons was often a review of the previous lesson or an explanation of what the students would be doing for the current lesson. Julie did not spend anytime in the engage phase identifying and assessing students' prior knowledge or providing focus and motivation for the lesson. The explore phase of the lessons had students completing an activity. One lesson involved the students cutting out a pinwheel and then experimenting with its movement by waving it in the air or blowing on it. The majority of the explore phase for the students was making the pinwheel with the assistance of the sponsor teacher and Julie. In another lesson the activity involved Julie reading a book to the class about the seasons. The students then drew a picture of their favourite season with an explanation why they liked that season. The consolidation phase was either missing or abbreviated to include sharing information about what happened in the activity, but not creating a generalization or applying the knowledge to a new situation. The drawings of the favourite seasons were collected for review by Julie as the formative assessment. There was no evidence of formative assessment for the pinwheel lesson.

The students in Julie's class were attentive for the pinwheel activity and were focused on decorating their pinwheel, its general movement and how to make it move.

The students were less focused on the concepts of wind, wind speed, and the relationship to weather which were Julie's original lesson goals. Students enjoyed drawing of the favourite seasons picture but were not focused on the concept of weather differences in the seasons. They were more focused on the fun activities that they were able to do during the selected seasons.

All of Julie's questions were related to logistics and control, (i.e., *what do you need to do first?; what are you suppose to be doing right now?*). She rarely used questions in whole class discussions. A lecture-style format was primarily used to elaborate the lesson concepts.

Julie felt that her sponsor teacher did not approve of a hands-on approach to science and preferred her to do activities like the drawings of the seasons. Julie was not comfortable or happy with her weather and seasons unit or what the students were doing in terms of actual science but was at a loss as to how to fix the problem given her practicum placement. She felt that since this was not her classroom that she should not depart from what her sponsor teacher requested.

Mary

Mary's total score on the NSKS was the same or higher than the means of class and case study cohort. Her subscale scores for amoral, creative, developmental, parsimonious were the same or higher the class and cohort means; below the class and cohort means for the unified subscale; and higher than the class mean and below cohort mean for the testable subscale. Mary's strongest subscale score was on amoral questions

and her lowest subscale score was on parsimonious questions. Mary was classified as having a mid-range NSKS total score in the classroom observation cohort.

The unit overview and lesson plans indicated that Mary was planning to use modified learning cycle. The activities that Mary planned for the engage phase of her unit included: classifying pictures of light sources, creating a rainbow with a prism, and matching a shadow with the object. Students would be involved in the following explorations: making a pinhole camera, experimenting with different reflective materials, creating a spectrum, and experiment with bending light. The consolidating phase in the lesson plans was a complete set of scaffolded questions. Mary planned to review and mark the completed student assignment sheets after each lesson for her formative assessment.

When Mary began an actual lesson with the engage phase, she used a demonstration to show how light travels in a straight line. Mary asked the students to make a conclusion about light from what they had just seen her demonstrate. Mary's teaching of the engage phase allowed her to assess the prior knowledge of her students and they found her demonstration very motivating. Further observations suggested that Mary did not make use of this information later in the lesson or the unit.

The explore phase was activity-based for students. The activity had a predetermined procedure and outcome. There were two parts to the activity and the students were required to get approval from the teacher before continuing with part B. Students were meticulous in their completion of the procedure and worked to fulfill the instructions. As groups of students finished the activity, Mary asked them to read certain passages from their science textbook that related to the concept that they had just covered

in the activity. There was no stated purpose for the assigned reading and it was not covered in the following class discussions. Mary later mentioned that the reading was an effective way of occupying students who finished early. Consolidation of the lesson did not follow a scaffolded questioning sequence from sharing information to creating a generalization. Mary collected the assignment sheets after the lesson for review and marking and used this information for formative assessment of the students.

Mary relied on attention-focusing (i.e., *what can you say about...?*; *what is happening....?*; *what is....?*; *what did you see....?*) and comparison (i.e., *what is the difference between...?*) questions in her teaching. She did not use reasoning or problem-posing questions to further understanding. Mary's questioning sequences were limited to whole class situations. While her students were completing their activity Mary circulated amongst the groups but did not use questioning as a way to direct and enhance learning.

Mary found that the activities were very time-consuming and they took longer for the students to complete than she had anticipated. Mary was concerned that she would be unable to complete her unit before the practicum was finished as her sponsor teacher had requested. Mary also expressed her frustration that this unit required equipment that was not available in the school or district resource center. This situation required that Mary spend extra time and money to get the equipment for teaching hands-on science. The existing class schedule was also a frustration for Mary. She was teaching science at the same time as a small group of students went to a music class. The students returned to the class in the middle of the explore phase at a time when the other students were finishing the activity. This created confusion and disruption for everyone in the class and Mary had concerns about the ability of the music group to catch up on the material that

they had missed. She stated that since the activities were hands-on and she did not want the equipment to go home with the students, it was difficult for the students to complete missed the exploration.

Kelly

Kelly's total score on the NSKS was higher than the class and cohort means. Her scores on the creative, developmental, testable, and unified subscales were higher than the class and cohort means. Her score on the amoral subscale was higher than the class mean but below the cohort mean. Her score on the parsimonious subscale was below the class and cohort mean. Kelly's strongest subscale score was on the unified subscale and her lowest score was on the parsimonious subscale. Kelly was classified as having a mid-range NSKS total score in the classroom observation cohort.

The unit overview and lesson plans that Kelly prepared indicated that she planned to use a modified learning cycle. Kelly had planned to use the following activities for the engage phase of her lessons: mystery objects in the various states (solid, liquid, gas), predicting the outcome of an ice cube experiment, and demonstrations. She had planned that the students would be involved in explorations such as: observing and recording the characteristics of various solids, liquids and gases, condensation experiment, and exploring the reaction of popcorn, alka-seltzer, and water. Kelly planned a sequential set of questions for the consolidate phase of the lessons. The completed assignment sheets were to serve as her formative assessment of the students.

Observations of Kelly's teaching revealed that the engage phase of her lessons often began activities that would provide focus and motivation for the lesson. These activities also assessed the prior knowledge that the students were bringing to the class.

In one lesson, Kelly asked the students to look around the classroom for examples of solids, liquids, and gases. She made a list on the board and then expanded the list to include examples that the students could think of from home. This strategy allowed Kelly to assess the students' prior knowledge on solids, liquids, and gases. Further observations indicated that Kelly did not make use of this information. Another lesson began with a demonstration. Kelly put a rock in a glass of water and asked the student if they noticed anything as she did this. Students responded that the water level went up. Kelly asked "*why did the water level rise?*" and the students responded that it was because of the rock. Teacher asked "*Why would a rock make the water rise?*". This sequence in the engage phase not only assessed the prior knowledge of the class but also provided motivation and focus for the coming lesson.

The explore phase of Kelly's lessons often involved a student activity that was guided by a set of questions on an accompanying worksheet. For example, the students were given zip-lock bags with a rock, water, or air in each bag to explore the properties of matter. The accompanying worksheets had the following questions and task for each bag: Can you change the shape of the matter in this bag?; Does this matter take the shape of the bag? Does this matter fill the whole bag up to the top?; Draw the matter and the bag. Another exploration involved a demonstration with a plastic glass with a piece of paper towel in the bottom. Kelly told the students that she would be turning the glass upside down in a bowl of water and pushing it down until the water covered the bottom of the upside down glass, but the glass would not be touching the bottom of the bowl. The students were asked to make "predictions" about what would happen to the paper towel and these predictions were graphed (get wet, stay dry, partly wet). The

demonstration was performed and Kelly asked the students why the paper towel had stayed dry. There were a variety of answers from the students and Kelly asked their reasons for their answers. Kelly then asked the students for suggestions on how she could get the paper towel in the bottom of the glass wet while still placing it upside down in the bowl. One student suggested that she tip the glass “to let the water in”. Kelly demonstrated this suggestion and asked the students about the bubbles that they were seeing and the origin of the bubbles. One student responded that the bubbles were made of air and that was because the “air had to get out for the water to be able to get in”. Students were asked to draw a picture of what happened during this demonstration. This sequence had not been planned ahead of time by Kelly, but she was able to build on the students ideas spontaneously.

The consolidation phase of the lesson was attempted many times but was incomplete. Kelly questioned the students on the information on their worksheets and concentrated on having the students share this information with the rest of the class. Kelly did not compare experiences or make generalizations from the shared or pooled information. She did not attempt to apply, extend, or reinforce the concepts covered in the lessons. The students had a music class with another teacher immediately after science. Kelly was rushing to finish the lesson so that the students would not be late and the consolidation of the lesson was missed as was the case with the air and glass demonstration. The assignment sheets for the lesson were placed in a science folder and were reviewed and marked for the purposes of formative assessment.

Kelly often used a variety of questions in whole class discussions. She used fewer questions in small group or individual instruction. She used each of the following

types of questions: attention-focusing (i.e., *what is in here?*; *what do you notice about....?*), measuring and counting (i.e., *how much..?*), action (i.e., *what happened when...?*), and reasoning (i.e., *why does this happen?*; *why do you think..?*). Kelly did not use comparison type questions in her teaching.

Kelly's practicum experience was different than the other five members of the classroom observation cohort. Kelly was able to collaborate with another preservice teacher completing a practicum in the school. Kelly and another preservice teacher (from another University of Victoria cohort with a different science methods instructor) were teaching the same unit to the same grade level in this school. The two teachers worked on each lesson plan together and shared the equipment and preparation that was required. They would work on the lesson plan the night before and decided on the questions and possible student responses at all stages of the lesson. Kelly taught the lesson first and then was able to reflect on the successes and failures of the lesson with the other teacher. Together they made adjustments that would be implemented by the other preservice teacher. Kelly often talked about the careful planning of questions she needed to ask in order to get to the understanding of the concept while still avoiding just telling the students the answers. She was pleased with the results that she was getting from the students and the high level of thinking that the students were accomplishing. She also said that she thought some of her success had to do with the small class size (17 students).

Linda

Linda's total score on the NSKS was higher than the class means and below the cohort means. Her score on the developmental, parsimonious, and testable subscales was higher than the cohort and class means. Her score was below class and cohort means for amoral, creative, and unified subscales. Linda's highest subscale score was on testable questions and her lowest subscale score was on amoral questions. Linda was classified as having a low NSKS total score in the classroom observation cohort.

Linda's unit overview and lesson plans indicated that she was planning to use a modified learning cycle to teach her earth's composition unit. The unit plan indicated that Linda had planned to use the following engage activities: explaining the difference between rocks and minerals using a chocolate bar analogy, explaining how metamorphic rocks form, explaining the Moh's hardness scale, and explaining the role of a geologist. The explorations phase had the students completing the following activities: breaking earth materials to determine if it is a rock or a mineral, creating a poster explaining the different rock types, and testing rock hardness. Linda's lesson plans included a partial sequence of questions for the consolidate phase. Formative assessment utilized the completed student assignment sheets after each lesson.

Observation of her teaching showed that the engage phase of the lesson was often a review of the previous lesson. The explore phase consisted of hands-on activities such as completing a scratch test of various rocks and analyzing and separating soil. The activity instructions were very specific and teacher-directed. Linda provided information to the students on the components of soil (rocks, water, animals) and the students identified the individual components in a soil sample. The consolidation phase of the

lessons was partially completed and confined to sharing the results but not creating a generalization. The consolidation of the lesson testing the hardness of rocks did not have common rock samples for every group. The lack of common samples did not allow for comparisons to be done between groups and looking at group variations to demonstrate the difficulties in using the Moh's hardness scale. The students were also asked to apply their knowledge using a rock that they had brought from home. Linda collected and reviewed student worksheets each day for formative assessment. The worksheets were then placed in the student science portfolios that they called their 'Rock booklets'.

Linda used questioning as a classroom management tool rather than an instructional scaffolding. Most of the questions that Linda asked were attention-focusing type questions (i.e., *what is...?; what did you find?; is all soil the same?; who has something that.....?*). Often her questions required recall of information or a yes or no answer. Linda did not use problem-posing or reasoning type questions in her teaching.

The students often responded to the Linda's questions with one word answers and no elaboration. The students did not provide any reasoning for their answers verbally or on their worksheets. They were interested in the subject and in completing the activities. The students tended to focus on each activity as a single event with no connections to previously studied material.

Linda was very focused on the logistics and safety of an activity. When she was circulating among the groups during the explore phase she focused on these issues rather than extending the students thinking. She was concerned about classroom management and behaviour issues and the science activities were very tightly controlled. Linda's classroom was carpeted and Linda had been told that she was to be very careful

especially during science not to get anything on the carpet. This situation also caused Linda to focus more on the logistics of the lesson than on student thinking.

Kara

Kara's total score on the NSKS was below the class and cohort means. Her score on the creative subscale was higher than the cohort and class means but her scores were below the means of the cohort and class means on all other subscales. Kara's strongest scores were on creative, testable, and unified subscales. Her lowest subscale score was amoral. Kara was classified as having a low NSKS total score in the classroom observation cohort.

Kara's unit overview and lesson plans indicated that she intended to use a modified learning cycle to teach her science lessons. Her unit plans indicated that the engage phase included: showing a skeleton and discussing the purpose of the skeleton, using children's literature as a springboard, and a song about the skeletal system. Kara had the following explorations for the students: building a model of the bones and muscles of the arm, building a model of the different types of joints, drawing x-rays of various bones, and writing a song about the skeletal system of an animal. The consolidate phase of the lessons was a sequence of questions beginning with sharing information and ending with an application question. The planned formative assessment often used the students' completed worksheets.

Observations of her science classes indicated that the engage phase for lessons was review of previous days concepts with a focus on recalling terms and reviewing the worksheet. One of her lessons showed some evidence of creating focus and motivation

during the engage phase. At the beginning of the day, Kara wrote on the board that she would need someone who can stand on their head for science. The students talked about why she might need someone to do this and what it might have to do with the human body unit that Kara was teaching. When the science period began with the actual demonstration there was no attempt to access the student's prior knowledge about the central concept.

The explore phase of the lesson had varying degrees of student activity. One of the lessons on the strength of the bones required the students to create two different bones out of paper - one shaped like a tube and the other shaped like a cube. The students tested the strength of each type of bone by placing books on top of the 'bone' until it collapsed. There was no right answer (the number of books the 'bones' would hold), and no procedure for placing the books on the bones. Similar sized and shaped books were provided. A second lesson had a video and demonstration for the explore phase. Kara used a sock (esophagus) and a tennis ball (bolus of food) to show peristalsis. She used this model to help to explain why the student could drink upside down. She showed a video which reinforced this concept and students were to indicate when they saw peristalsis on the video.

The consolidation phase for the bone strength lesson was a sequenced scaffold of questions leading to a generalization and addressed some of the differences in the answers given by individual groups. The questions included: *What were your results?; Why are everyone's numbers different?; Were everyone's books the same?; What pattern do you see when you compare the bone shapes?* The consolidation of demonstration and video lesson focused on a review of the terms and defining any terms

covered in the lesson that were still outstanding. There was no scaffolded questioning sequence. Kara collected and marked the worksheets the students completed each day for her formative assessment. She also had quizzes at regular intervals throughout her unit.

Kara used questioning as part of her teaching with whole class rather than with individuals or small groups. Most of the questions that Kara asked were attention-focusing and measuring and counting type questions (i.e., *what is the name of.....?*; *can you tell me...?*). She made use of action type questions several times (i.e., *what will happen when...?*). She used reasoning (*What makes you think that ...?*) and comparison (*What pattern do you see...?*) once during the observed lessons. Kara did not use problem-posing type questions although the opportunity was there to use them.

The students were challenged by Kara's approach to teaching science. When faced with an action type question (prediction), the students were concerned with not knowing the answer (i.e. "*What if I don't know?*"; "*How do I know what will happen?*"). The students were very attentive during science class and were excited on the days that they were having a science class. The students were excited and surprised at the number of books the different types of bones held and the class had a feeling of discovering something new and unique. They were also uncomfortable that whole class did not have the same number of books (the same answer). The students wanted to know the 'right answer' for the number of books that each bone could hold.

This was an unusual class because there was not an even number of boys ($n=22$) and girls ($n=8$). The energy level was very high and Kara mentioned that she had to have good classroom management techniques if she was doing hands-on science. She did not mind the elevated noise level and was able to recognize the difference between noise that

was productive and part of the activity from noise that was a problem. She was concerned that her sponsor teacher liked a quieter classroom. Kara was very enthusiastic with the way that the hands-on lessons were working and the knowledge the students were gaining. Kara had created a bulletin board with interesting information that built on what the students were learning in science class.

Assertions

A summary of the results of the relationship between the preservice teachers' beliefs about the nature of science (NSKS scores) and the classroom observations of their science teaching are reported using several assertions. The assertions constructed from these data are expressed in bold face type, supporting quotes from the classroom observations are expressed in script type, while the researchers' elaborations are expressed in normal type.

1. It is unrealistic to expect preservice teachers to adequately implement the complex elements of inquiry teaching during their first practicum experience.

The first eight weeks of science methods instruction focused on inquiry and their assignment marks indicated that the six preservice teachers had a good understanding of the elements of a modified learning cycle (engage, explore, consolidate, assess).

However, none of the six preservice teachers observed demonstrated all elements of the modified learning cycle at an adequate level. All six preservice teachers in the classroom observation cohort achieved good (80%) to excellent (95%) on their instructional

planning activities for science (see Appendix C for description of assignments). The marks for the unit overviews ranged from 12.5 to 13.5 out of a possible 15 marks. The marks for the lesson plan ranged from 8.0 to 9.5 out of a possible 10 marks. Classroom observations that focused on evidence and quality of the engage, explore, consolidate and assess phases of the modified learning cycle indicated that only two of the six preservice teachers demonstrated satisfactory performance of all four phases over the two lessons observed.

2. A high NSKS score does not imply effective implementation of the phases of a modified interactive-constructivist learning cycle by preservice teachers.

The desired image of the interactive-constructivist learning cycle suggests that teaching involves engaging students, providing opportunities for exploring and experiencing science events, promoting consolidation and application of the experiences and prior knowledge, and assessing student inquiry, habits of mind and science understandings (Beeth & Hewson, 1999; Colburn, 1998; Henriques, 1997; Schulte, 1996; Shymanksy, 1998; Yore & Beugger, 1989). The following sections provide insights into what was expected and what was observed for the four phases of the modified learning cycle.

Engage

During the engage phase teachers should motivate, establish problem focus, and access and assess prior knowledge. The teacher's questioning should encourage divergent responses and allow for unanswered questions that set the central purpose for the exploration. The preservice teachers with high NSKS scores used traditional introductory strategies, while preservice teachers with lower NSKS scores used more

inquiry-oriented engagement strategies. Susan (high NSKS score) and Julie (high NSKS score) used traditional strategies in the engage phase of their observed lessons. Both preservice teachers began their lessons with a review of a prior lesson reinforcing facts and lower-level ideas and provided teacher-directed instruction to establish purpose, procedures and behaviour expectations for the coming lesson. During one lesson, Susan stated:

Let's review yesterday. Tell me about the water cycle. What makes it a cycle? Today we are going to cover one more cycle, the nitrogen cycle. Where does the nitrogen cycle exist? (Observation Notes, December 7, 2000)

Julie began her lesson using the following statement:

This morning we watched a video on weather and wind was part of weather. Now we are going to make a pinwheel and use it with different types of wind. (Observation Notes, December 11, 2000)

Kelly (mid-range NSKS score) also reviewed the previous lesson in the engage phase. After the review, she performed a demonstration related to the current lesson concept that involved putting a rock in a glass of water. She asked the students the following:

Watch what happens when I put this rock into a glass of water. What did you notice? Why do you think this happens? Does anyone think that air takes up space? (Observation Notes, December 14, 2000)

Linda (low NSKS score) accessed prior knowledge during the engage phase after a review of the previous lesson concepts. She began the lesson with the following:

What do you think soil is made of? The word 'soil' is printed on the board. Connections were made to the student suggestions. Student suggestions included: dead animals, worms, manure, garbage, dirt, leaves, roots, minerals, compost, and vegetables. (Observation Notes, December 13, 2000)

Explore

The ideal explore phase is characterized by open-ended investigations that involve collecting evidence used to construct a knowledge claim. The teacher should act as facilitator and use a variety of questions to stimulate action and extend thinking. The selection of the type of question is driven by the needs of the student and asked just-in-time to promote inquiry, data collection and knowledge building (Martens, 1999). The preservice teachers with high NSKS scores appeared to use more structured explorations than the preservice teachers with lower NSKS scores. Susan (high NSKS score) asked her students to make a drawing of the nitrogen cycle. She stated:

Draw the nitrogen cycle. Fold your paper in half, use the top half of the paper for your drawing. Let's review the parts of the nitrogen cycle that you need in your drawing. (Observation Notes, December 7, 2000)

Mary (mid-range NSKS score) encouraged her students to collect evidence to support a claim about the central research question of the inquiry using the following instructions on their worksheet:

What could you see when the tube was bent at right angles? What could you see when the tube was straight? What does this tell you about how light travels? (Observation Notes, December 12, 2000)

Kelly (mid-range NSKS score) used a variety of questions during a demonstration to stimulate and extend student thinking. She used the following questions:

What will happen to the napkin if I put the glass upside down in the bowl of water? (Student responses included: Stay dry, get wet, disintegrate, absorb all of the water in the bowl); What happened to the paper towel? Why do you think the paper towel stayed dry? How could I get the paper towel in the bottom of the glass wet if I put it upside down in the water? (Student response: Tip the glass) Did anyone notice what happened when I did that? Where did the bubbles come from? (Observation Notes, December 14, 2000)

Kara (low NSKS score) provided materials for designing and testing the strength of two different bone types and then directed the students to collect evidence and make a claim based on that evidence. She stated:

Build the different bones, stand the bones up on a flat surface. Put one book at a time on top of the bone. Should you be able to hold the bone? Why not? (Student response: Holding the bone will add strength). Decide which bone type you think is the strongest and why you think that. (Observation Notes, November 16, 2000)

Consolidate

The ideal consolidation phase should scaffold student's construction, integration and application of science understanding. Consolidation may occur in individual students, small groups or whole class settings and may involve both public and private dimensions. This phase is characterized by pooling information from the explore phase (evidence) which leads to a generalization (claim). The pooled information may contain conflicting ideas and may be examined for procedural differences and sampling or observing errors. The claim is then integrated into the students' conceptual network and connected to a real world application. A scaffolded sequence of questions (share, organize, analyze, generalize, verify, and apply) is used to support knowledge construction, integration and application. All of the six preservice teachers regardless of their beliefs about the nature of science (NSKS scores) had their students pool or share their information but did not complete the sequence of scaffolded questions to ensure construction, integration and application. Susan (high NSKS score) asked the following questions in the consolidation phase:

What did you see on the video? What is a population? What are some of the different populations that you saw on the video? How do various species cope with crowding? (Observation Notes, December 11, 2000)

Mary (mid-range NSKS score) used the following questions to encourage the students to share their information from their experiences:

What did you see? Students response: I could see part of the man. I could see none of the man. Why couldn't you see the man? What can you say about light? (Observation Notes, December 12, 2000)

Kara (low NSKS score) in one observed lesson began a sequence of questions for the consolidation phase that had potential, but did not complete the sequence:

What were your results - how many books did each type of bone hold? Why are these numbers different? Was everyone's book exactly the same? Does the length of the bone make any difference? Is there any pattern to the number of books each bone held? (Observation Notes, November 16, 2000)

Linda (low NSKS score) completed the following questions during the consolidation phase that was more typical of the preservice teachers:

Who had a sample that could be scratched by pencil lead? Student X found one sample and that means it is really soft. Who has something that could be scratched by a nail? (Observation Notes, November 24, 2000)

Assess

Assessment should ideally encourage students to demonstrate active inquiry and construct knowledge rather than recall or represent information. It should be authentic and focus on the process as well as the product and utilize a variety of information sources and assessment techniques. None of the six preservice teachers regardless of the NSKS scores implemented authentic formative assessment strategies and only

demonstrated traditional assessment techniques in the lessons observed. They marked their students' worksheets and recorded the mark for the purpose of providing a grade.

Susan (high NSKS score) stated at the end of a lesson:

Please hand in your drawings of the nitrogen cycle. I will be marking them and handing them back. (Observation Notes, December 7, 2000)

Kara (low NSKS score) stated:

You did well on the sheet from yesterday. Most of you were able to give the scientific name for each bone. Many of you got As and Bs on that assignment (Observation Notes, November 16, 2000)

3. The NSKS scores (high, mid-range, low) do not predict preservice teachers' use of questions that promote an evaluativist view of the nature of science.

Questions such as problem-posing and reasoning encourage students to think about the evidence that supports their claims and the creativity involved in scientific inquiries.

None of the six preservice teachers consistently used problem-posing to extend and redirect inquiry (can you find a way to...?; can you figure out how to...?) or reasoning questions to promote critical think and make the claims-evidence evaluations explicit (why do you think...?; what is your reason for...?; can you invent a rule for...?) in their teaching. They primarily used attention-focusing (have you see...? ; what have you noticed about...?; what are they doing?; what does it feel/smell/look?) and measuring and counting questions (how many...?; how often...?; how long...?; how much...?) to

control and manage the specified tasks assigned or expected. Susan (high NSKS score) used the following questions in her lesson:

What are the different spheres? What is the lithosphere? What is the biosphere? What were the cycles? What is common about all of the cycles? (Observation Notes, December 11, 2000)

Kelly (mid-range NSKS score) posed the following questions during a lesson:

What are some examples of solids? What are some example of liquids? What are some examples of gases? What do you notice about what is inside this bag? (Observation Notes, November 23, 2000).

Linda (low NSKS score) asked the following questions:

Where does soil come from? What is in soil? What animals did you find? What is in the rock and mineral pile? Are all the rocks the same size? (Observation Notes, December 13, 2000)

CHAPTER 5

DISCUSSION AND IMPLICATIONS FOR FUTURE RESEARCH

Introduction

This study was designed to examine preservice elementary teachers' beliefs about the nature of science prior to, and after participating in an undergraduate science methods course. This study used a pre-test and post-test case study design to measure two cohorts of preservice teachers' beliefs about the nature of science. The study also examined the impact that the preservice teachers' beliefs about the nature of science have on their planning and teaching. The study involved 50 undergraduate elementary education students who were enrolled in their professional year of a five-year bachelors degree in education and completed all data collection tasks. The students were asked to complete a 48-question, *Nature of Science Knowledge Survey* (Rubba & Andersen, 1978), to assess their beliefs about the nature of science at the beginning of the course instruction in September and prior to their initial practicum. They were given the same survey at the end of the course in March prior to their second teaching practicum.

Nature of science was a central theme of the course and students were expected to provide a strong rationale for the instructional decisions that were implicitly or explicitly included in the assignments, examinations, and teaching. The course instruction included explicit instruction on several aspects of the nature of science. The instructors modeled teaching behaviours consistent with an interactive-constructivist teaching approach.

The study's design also employed qualitative methods of multiple classroom observations of a small purposeful sample of volunteer preservice teachers from the two cohorts. During the classroom observations, an attempt was made to record the types of questions that the preservice teachers' asked, the responses the students gave to these questions, as well as handouts and assignments given by the preservice teacher. Further documentation of the subjects' classroom practice included unit overviews, lesson plans, and assignments that were collected and analyzed to provide triangulation of the qualitative aspects of this design.

Results from the pre-tests showed that preservice teachers held a traditional, realist view of the nature of science on all NSKS subscales (amoral, creative, developmental, parsimonious, testable, unified) with the exception of the testable subscale. The testable subscale pre-test scores indicated that the preservice teachers' predominantly held a evaluativist, naive realist view of the nature of science.

Significant gains ($p \leq 0.05$) were made between the pre-test and the post-test scores for the preservice teachers' beliefs on the creative, developmental, unified subscales, and the total score on the NSKS. No significant gains were made from the pre-test to the post-test scores on the testable, amoral or parsimonious subscales. The high pre-test scores for the testable subscale appear to have created a ceiling effect for the post-test results; in other words, there was little room for improvement between pre-test and post-test results.

There was no significant ($p \leq 0.05$) correlation between the preservice teachers' NSKS total scores (pre-test, post-test) and their marks received on planning and professional assignments within their science methods course, which included a unit

overview, lesson plan, and portfolio assignment. Surprisingly, there were negative associations between the NSKS scores and the unit and lesson planning tasks.

Results from the classroom observations indicated that the preservice teachers' score on the NSKS were not clearly related to their classroom practice. Despite indications in their planning, the preservice teachers were unable to successfully implement the elements of a constructivist-based teaching approach (engage, explore, consolidate, and assess) and productive questioning strategies in their science lessons during their initial six week practicum.

Discussion

This study provided qualified support for the assertion made by previous researchers that explicit rather than implicit instruction is effective in changing nature of science beliefs (Abd-El-Khalick *et al.*, 1998; Akerson *et al.*, 2000; Clough, 1998). The gains made in the creative, developmental and unified subscales appear to be, in part, due to the method of instruction provided in the science methods course for each subscale. The concepts of each of these three subscales had been explicitly addressed through a variety of instructional components associated with the subscale in the science methods class.

The greatest mean difference between the pre-test and post-test on the NSKS was on the creative subscale. Creative subscale questions on the NSKS focused on the belief that science knowledge is a product of human creativity and intelligence (Rubba &

Andersen, 1978). There was direct discussion, activities, readings and an assignment that specifically addressed this aspect of the nature of science, as captured in the subscale.

The preservice teachers completed an activity that addressed the concept of the creativity involved in designing an experiment, a ‘fair test’ (Appendix A).

The developmental subscale on the NSKS exhibited the second greatest overall improvement after the students’ had completed the science methods course. The developmental subscale questions were related to the concept that scientific knowledge was tentative and “is never proven in an absolute and final sense” but is evaluated as further evidence becomes available (Rubba & Andersen, 1978, p. 456). The ideas underlying the developmental subscale were discussed directly at numerous times throughout the methods course. The preservice teachers also addressed this concept in the “Science in a Bag” activity (Appendix A). The debriefing of this activity included a discussion of how each new piece of evidence either refuted or supported the guess that the students had made. The connection to the procedures of science was made during the debriefing of this activity.

The unified subscale had the next greatest mean difference on the NSKS. The unified subscale questions were designed to address the idea that science knowledge is the result of an effort to understand nature and this knowledge “produced by the various specialized sciences contribute to a network of laws, theories and concepts” (Rubba & Andersen, 1978, p. 456). The concepts associated with the unified subscale were addressed in the methods class during a specific discussion of the nature of science at the beginning of the first term. These beliefs were examined and discussed in the context of two articles on the nature of science (Appendix B).

The absence of pre-test versus post-test changes in student beliefs on the amoral and parsimonious subscales might be due to the implicit teaching methods employed in the course in those aspects of the nature of science captured by these subscales. The amoral subscale question focused on the idea that science knowledge cannot be judged as good or bad, only the application of the knowledge may be judged. The parsimonious subscale questions were designed to examine the belief that science knowledge attempts to “develop a minimum number of concepts to explain the greatest possible number of observations” (Rubba & Andersen, 1978, p. 456). In contrast to the creative, developmental, and unified subscales, the parsimonious and amoral subscale concepts were not explicitly addressed during the instruction in the science methods course. It is possible, however, that the preservice teachers were able to indirectly discern some aspects of each of these subscales through discussions and activities associated with instruction about the process skills, teaching strategies, and science literacy.

The lack of correlation between the NSKS total scores and the planning assignment marks was disappointing but not unexpected. This result was consistent with prior expectations that preservice teachers’ beliefs about the nature of science might not be correlated with either their level of motivation to achieve high grades in a university course by satisfying the evaluation criteria. The evaluation rubrics for these assignments used in the science methods course could perhaps be modified to better reflect acquisition of an understanding of the theoretical aspects and practical implications of evaluativist view of science and interactive-constructivist views of science teaching.

Regardless of preservice teachers’ beliefs about the nature of science, the expectation that preservice teachers are able to successfully implement the elements of a

modified learning cycle (engage, explore, consolidate, assess) in an initial practicum experience is unrealistic. The choice between using constructivist and inquiry teaching approaches and the traditional teacher-directed approach is influenced by their experiences as students and the approach used by their classroom sponsor teachers. The model of science teaching that preservice teachers have experienced as students, the model of science teaching that they see in the classroom, and the perceived expectations placed on them by sponsor teachers or university supervisors are in most cases contrary to the model of interactive-constructivist science teaching presented in the science methods course. Crawford (1999) observed the same barriers to preservice teacher's implementation of inquiry teaching strategies as seen in this study.

Preservice teachers have often experienced science in the traditional stand-and-deliver approach (lecture followed by a verification laboratory) as a student in science courses at the elementary, secondary, and post-secondary levels. The preference of this traditional teacher-directed approach is frequently reinforced by their sponsor teacher during the preservice teachers' practicum experience. The preservice teacher is then faced with a dilemma of choosing between an approach to teaching science that they have experienced as students and have seen implemented by their sponsor teacher and the model of inquiry teaching presented in their science methods class. Faced with the pressures of wanting to impress the sponsor teacher and facing judgment from the practicum supervisor, and further complicated by a lack of experience and concern about survival and desire to succeed, the preservice teacher is likely to adopt the teacher-directed approach over the inquiry approach, at least initially.

Finally, many preservice teachers are in the early developmental level of concern about self and subject matter and have not evolved to levels of concern about students and learning. The interactive-constructivist approach requires comfort with self, content knowledge, classroom management and basic teaching strategies which then allows preservice teachers to shift their focus to their students' prior knowledge and their students' struggles to construct and apply science understandings.

Implications for Preservice Teacher Education

Teacher education programs need to provide content science courses that not only educate preservice teachers about the concepts necessary to teach science at the elementary level, but also model inquiry teaching strategies. The traditional academic science courses simply reinforce the stand-and-deliver model of science teaching, especially during the first and second undergraduate years. Lectures and verification laboratory activities do little to assist preservice teachers in understanding inquiry from the point of view of a student and to establish a hypothetico-deductive logic and evaluativist view of science, since real scientist have authorized its use and demonstrated its application. Experiencing inquiry as a learner is essential to implementing the interactive-constructivist approach as a teacher. From a conceptual change perspective, the preservice teacher will begin to see the shortcomings of the traditional approach and the power of the new approaches through experience with the successes of learning by inquiry.

The selection of sponsor teachers is a critical step in the successful implementation of inquiry science by the preservice teacher. The sponsor teachers ideally should be implementing inquiry science in the classroom prior to the arrival of the preservice teacher, since the preservice teacher has an unclear picture of what inquiry science looks like in a classroom. The sponsor teacher becomes a model for the preservice teacher to follow. The students in this classroom will also be familiar with the processes and habits of mind needed for inquiry science. Preservice teachers cannot successfully implement constructivist-based teaching approaches that are unfamiliar to them and at the same time provide for their students who are also uncomfortable and unfamiliar with this approach.

Teacher education programs need to develop practicum placements and teaching environments that recognize the preservice teachers' concerns and reflective practice. Peer mentorship between two preservice teachers placed in the same classroom or same grade level of a school may provide a solution to this problem. The benefits of such peer-pairs were observed during a special Year 5 science internship (Yore, 1997) and again in one case during this study. Preservice teachers can be invaluable to one another as a source of feedback and as non-threatening partners in reflections on practice. Kelly was assisted in implementing inquiry-based teaching strategies by another preservice teacher from another University of Victoria science methods course. These preservice teachers were both familiar with the elements of the modified learning cycle and both had similar levels of concern and came together to assist each other in planning lessons and evaluate areas of improvement and success.

Preservice teachers need to have practicum supervisors who are familiar with the elements of science inquiry. This is necessary not only in terms of evaluating success in the practicum but also for providing feedback to the preservice teacher. The practicum supervisor needs to be familiar enough with the individual elements of the desired image of science teaching to be able to identify problem areas and make suggestions for change. The current evaluation rubric used by practicum supervisors appears not to be consistent with the interactive-constructivist approach to science teaching. The evaluation rubrics currently used by practicum supervisors are used for all subject areas not just science teaching. This type of generalist evaluation rubric does not provide the guidelines that reflect the interactive-constructivist approach and the evaluativist view of science. A rubric needs to be designed that will reflect inquiry teaching approaches in science but that could also be used in other subject areas using inquiry approaches such as social studies.

Future Research

Future research endeavours might include a longitudinal study of the classroom practice of a cohort of preservice teachers through their first five years of elementary school teaching. This type of study has not been possible in the last several years, since preservice teachers were unlikely to get permanent teaching positions after they graduated. The intervening years of substitute teaching (teacher-on-call) did not provide a suitable classroom environment or predictable schedule for developing teaching

effectiveness. With the pending teacher shortage, however, preservice teachers in North America are more likely to get permanent employment directly upon graduation and this would allow for a long term study of their professional development in science teaching. It would also be worthwhile to repeat this study and include not only the initial practicum experience but also the final practicum experience to study any changes in the implementation of the modified learning cycle in a second teaching experience after many of the self, subject content knowledge, classroom management and basic teach strategies were of lesser concern.

Recent changes to the elementary education program at the University of Victoria provide the opportunity to repeat this study. The elementary science methods course will take place over a shorter period of time and will not necessarily take place immediately prior to the practicum experience. The study could be repeated in an effort to assess the impact of the reduced time allotted to the course and the existence of an intervening practicum on preservice teachers' beliefs about the nature of science and the implementation of inquiry approaches during their science teaching.

Concluding Remarks

This study implicates the role of the sponsor teacher and larger educational community as an influence on whether new teachers are likely to implement inquiry-based teaching strategies early on in their careers. The results indicate that preservice teachers' beliefs about science and knowledge about interactive-constructivist science

teaching can be improved during the university-based component of a teacher education program. But the impact of the field-based component of a teacher education program may have over-riding contrary influence. As perceptions about appropriate educational practice change, there is also an expectation of inter-generational changes among teachers. Positive change, however, may be stymied if the practices encouraged by universities in preservice educational offerings are contradicted by the earliest classroom experiences and by mentorship within the teaching community. This points to a need to reach practicing teachers to a much greater degree, so that sponsor teachers and colleagues are capable of supporting, not undermining the implementation of inquiry-based, interactive-constructivist methods toward the goals of science literacy.

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APPENDIX A

SCIENCE METHODS COURSE STUDENT ACTIVITIES

- Nature of Science: Science in a Bag/Baggie Science
- Observing and Inferring
- Classifying
- Measuring
- Predicting
- Communicating
- Interpreting Data
- Fair Test: Hypothesizing, Controlling Variables, designing an experiment
- TOC Activities: Cat's Meow, Penny Science, Poppin' Rockets
- Jigsaw Approach - Floating and Sinking
- Performance Assessment - Mystery Powders

SCIENCE IN A BAG

For this activity you are to work together as a team of scientists to determine the contents of the brown paper bag.

Your team will use one sense at a time to collect data about the contents of the bag. Using this data, you will make a guess about the contents of the bag. As you collect more data using each sense, you will confirm or revise your 'guess' based on the new data.

<i>SENSE</i>	<i>CONTENTS OF THE BAG</i>
Smell * smell the top but don't touch the paper bag!	
Hearing * but don't squeeze the paper bag!	
Touch * open the paper bag but don't look inside!	
Sight * you can open the bag now!!	

BAGGIE SCIENCE

1. Observe and record your observations of Calcium Chloride (CaCl_2), Baking Soda (NaHCO_3), Bromothymol Blue.
2. Put 1 teaspoon of Baking Soda into a zip lock bag.
3. Put 2 teaspoons of Calcium Chloride into the same bag.
4. Measure 5 ml of Bromothymol Blue and 5 ml of water and pour into a vial.
5. Put the vial into the bag (standing upright) and make sure the bag is well sealed.
6. Tip the vial of Bromothymol Blue and water.
7. Observe and record your observations on the back of this sheet.
8. Why do you think this happened?

ED-E 745

OBSERVING & INFERRING

Observing: involves obtaining information about objects, situations, or events using one or more of the senses, may qualitative or quantitative.

- common misconception limits observing to looking.
- uses sense directly or indirectly, sometimes with aid of a simple or complex instruments.
- describes changes in terms of actions, patterns, and relationships; i.e. bounces, rolls.
- Development of observing:
 - using five senses separately
 - using 2 or more senses simultaneously
 - making comparative descriptions; i.e. 'like, greater than, less than
 - making quantitative descriptions
 - noting changes; i.e. before, after, etc.

MAPPING THE TONGUE

Use the solutions of salt, sugar, lemon juice, and coffee to dab on your partner's tongue at the tip, edges, and top back. *Use a clean Q-tip for each solution.* Record results on the map of the tongue.

DETECTING TOUCH

Use the 5 plastic forks for the back of your partner's hand, upper arm, and neck. Ask your partner to determine how many points of pressure. *Check your partner' is guessing by using a single point once in awhile.* Record results.

DESCRIBING AND MATCHING TEXTURES

Using a single texture card, ask your blindfolded partner to describe the texture. Using two texture cards (matched or mismatched), determine if your partner can detect same or different textures.

DESCRIBING AND MATCHING SMELLS

Using a single smell bottle ask your partner to describe the smell. Using two bottles (matched or mismatched), ask your partner to determine if smells are the same or different. *Check your results by using the code on the bottom of the bottle.*

DESCRIBING AND MATCHING SOUNDS

Using a single tuning fork, ask your partner to describe the sound produced by the fork. Using the set of 6 tuning forks, ask your partner to match the sounds. Strike the fork lightly and harder, describe the differences in sound. *Check your results by using the number code on the side of the forks.*

DESCRIBING GEOMETRIC SHAPES

Describe a 2- or 3-D shape using its characteristics (not its name) and ask your partner to identify the shape. Hint: consider points, edges, texture, colour, and size.

DETECTING SHAPE & COLOUR AT THE EDGE OF THE VISUAL FIELD

This activity is from Sight and Sound (HAP) and is designed as a small group activity to explore peripheral vision. Follow the directions on the direction card.

Inferring: suggesting more about a set of conditions than is observed, and can be based on observed data and past experience. Inferences may evolve from both direct and indirect evidence and are modified on the basis of new evidence.

- the first level of speculation i.e. making guesses using observable data and intuitive patterns.
- provides explanations or reasons for events that are based on limited facts.
- relies on personal judgment.
- speculation is constrained to limited cases (not generalized like a hypothesis).

TRACKS

Use the handout to make inference about the tracks shown in each picture. Examples are from Tracks Picture Books (ESS), “Tracks Picture Story” from Teacher’s Guide for Tracks (ESS), and “Be A Tracking Detective” (Owl magazine, Winter 1991).

INFERENCE BOXES

Also called mystery boxes. Shoe boxes contain an assortment of materials and obstacles. (See Pat for key to contents.) Use the sound and touch observations to infer the type and number of objects and lay-out inside the sealed box.

INFERENCE BOARDS/CIRCUITS

Also called mystery circuits. Using the battery, wire and bulb infer the circuit pattern through testing and observing the bulb lighting up.

LARGE GROUP ACTIVITIES

OPTICAL ILLUSIONS

Baum, Arline and Joseph. Opt: An Illusionary Tale. (Explorations in Science Library 2) Puffin Books, 1987.

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Cobb, Vicki. How to Really Fool Yourself: Illusions for All Senses. Lippincott, 1981.

Liem, Tik L. Invitations to Science Inquiry. 2nd. ed., Ginn Press, 1987.

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SOUND

This activity is from Sight and Sound (HAP) and is a whole class activity designed to show the progression from observation to inference.

The following equipment is needed for the activity:

- blindfold and cotton balls (for ears)
- 5 small pill bottles (with lids) with 5 smallest washers inside

Procedure:

Blindfold one person. Place 5 other people with pill bottles in front of the blindfolded person. Have each of the 5 people shake their pill bottle once (at separate times). The blindfolded person then points to the direction of the sound. Repeat the procedure having the blindfolded person plugging one ear then the other with cotton.

What was different between detecting the sound and “guessing” the direction of the sound? What allowed the “observer” to be such an effective “inferer”?

ED-E 745

CLASSIFYING

Classifying: involves grouping objects, concepts, or events on the basis of observable properties to show similarities, differences and interrelationships.

Development of classifying:

- class inclusion
- binary classification
- multi-stage binary classification
- using a classification key to identify an object

LAB ACTIVITY:

- Using the ziplock bag of junk.
 - a. Are there more yellow objects or are there more objects? Use a Venn diagram to illustrate your answer.
 - b. Pick one item out of the bag and set it aside. Discuss the idea of physical properties (texture, color, shape, size, etc) and the function of the items. Devise a binary classification system (2 groups) for the bag of items. Draw your classification system on the chart paper.
 - c. When all the groups have finished, take a "gallery walk" around to look at the other group's classification system. Try to determine the 'definition' of their classification system. Decide where the one item that was set aside at the beginning of the activity would fit in your own classification system and in another group's classification system.
- 2. Do ***Creature Cards*** (Cards #1 to 15). Define the creatures in group 1 and identify the creatures in group 3 for each card. Use union and intersection symbols to illustrate your definitions.

from: Attribute Games and Problems (1966)
- 3. Sort junk materials into two groups using a magnet. Name and describe the two groups formed. Define the composition (the material the object is made of) for each group.
- 4. Discuss the classification system for living things; plants, animals, monera, protista and fungi. Why do children have difficulty with the classification system? Where do dead (once living) things go in this classification system?

ED-E 745

MEASURING

Measuring: observations are quantified using non-standard and then standard units. Length, area, volume, mass, time intervals, speed, and temperature are among the measurements used. Appropriate measurement instruments and units within the metric system are selected.

Development of Measuring:

- need for comparison i.e. setting a problem
- introduction of reference object - arbitrary, uniform, standard
- experience in using measurement tools and limiting observer error
- estimating
- abstract conversions

LAB ACTIVITY:

1. Measure and compare—
 - using ticker-tape, measure and compare your head's circumference to your partner's head's circumference
 - your finger spread to your foot's length
 - your lower arm's length to your head's circumference
2. Use your pace length to measure the length of the front desk. Compare your results to your partner's results.
3. Use the un-marked dowel rod to measure the length of your table. Then use the unmarked and marked meter sticks to measure the table's length. Compare the three measurements.
4. Compare the volume of a cone, pyramid, cube and cylinder. How many of one shape fits into the other shape?
5. Estimate the length, area, volume, mass and time of an object or recurring event. Check your estimate against a measurement of the object or event.
6. Using non-uniform objects (beans), uniform objects (counters or cubes) and a plastic grid, determine the area of the drawing provided.

ED-E 745 PREDICTING

Predicting is a forecast made about future events on the basis of ordered data. Predictions on the basis of ordered data (within a data set) is interpolation, and beyond observed patterns of event is extrapolation.

ACTIVITY 1—WASHER PENDULUMS

Equipment:

- folder containing 30 metal washers attached to varying lengths of string
- masking tape (enough for each pendulum to be taped to the number line on the chalk board)

Each pair of students test their ‘pendulum’ to see how many swings it makes in 10 seconds. The student then tapes the actual pendulum on the number line at the place equal to the number of swings in 10 seconds. The graph formed on the chalk board is an inverted bar graph. This graph can be used to predict missing information within the data boundaries (interpolation) or beyond the boundaries (extrapolation).

ACTIVITY 2—DIFFERENT PENDULUM BOBS

Equipment:

- small plastic bags containing 3 pendulum bobs the same size but different weights (i.e. aluminum, wood, lead or brass)
- adding machine tape (3 pieces per group)
- rulers
- clear bulletin board with maptack.

Determine the number of swings in 10 seconds for the three different pendulum bobs. Record your findings on the adding machine tape labelled weight (heavy, medium, light) and number of swings in 10 seconds. Put your results on the bulletin board with map tacks.

Determine the mass of each pendulum bob and graph the results.

ED-E 745 COMMUNICATING

Communicating is the process of organizing and processing data that occurs between the observation stage and the interpretation or generalization stage. It usually involves organizing "rough" data in a more compact and meaningful way (ordering, rearranging, comparing), depicting the data pictorially or graphically, and processing it mathematically (finding slopes, tangents) to facilitate interpretations.

Charts and Tables

Activity—complete the chart of your personal traits and compare them to the most common traits in the class.

	YOUR TRAIT	CLASS TRAIT
Sex		
Eye Colour		
Vision		
Hair Colour		
Widow's Peak		
Roll Tongue		
Earlobes		
Handedness		
Fingers		

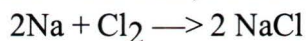
Graphs

Bar, pie, line, etc.

Activity—Place a coloured card in appropriate space to represent your eye colour (brown or blue), hair colour (dark or light), tongue rolling (yes or no), earlobes (attached or unattached) and handedness (right or left) on the wall chart.

Symbolic Communication

(Chemical statements, formulas, symbolic diagrams):



$$\text{IR} = \text{E}$$

Maps and Blueprints

Charts and Tables

Pictorial Diagrams

Children's art can be a rich source of information. How can you use pre-instruction and post-instruction pictures to demonstrate understanding?

ED-E 745

INTERPRETING DATA

Interpreting data is the process by which students organizes, analyzes, draws conclusions and make judgements on information usually expressed in a table or graph. The assumptions and conclusions that are made have limitations based on the method of data collection.

MASS TECHNIQUE

- Estimate the number of red beans in the container by using the balance scale.
- Clearly identify your assumptions and procedures

VOLUME TECHNIQUE

- Estimate the number of white beans in the container by using the small plastic cup. Use the cup only once. Identify assumptions and procedures.
- Using the red and white bean mixture, estimate the number of red beans (red beans only) in the container using the small paper cup. Use the cup only once. Identify assumptions and procedures.

MARKED AND RE-CAPTURE TECHNIQUE

The 88 speckled beans in the container represent individuals that have been captured, marked and released back into the 'population'.

- Randomly select (re-capture) 30 beans from this container.
- Record the number of these which were previously captured and marked. The total population can be found by using the formula below.

$$\frac{\text{\# of marked individuals in the 2nd capture}}{30} = \frac{88}{\text{total population}}$$

What is the estimated size of the population? _____

What assumption about the population and the procedure were made which could have an effect on the estimate?

Imagine this was a real population of mice which was being captured in small cages. What population factors could influence the accuracy of this type of population estimate?

DESCRIBING POPULATIONS OF TOOTHPICKS

Simulating for Protective Coloration

- Provided are three containers, each with a sample of insects (represented by different coloured toothpicks) collected from three different habitats.
- The insects were collected by hand. The collectors randomly chose a square meter plot in each habitat, and took all of the insects that they saw.
- The habitats were: a sandy shore, a grassy hill, and a lake.
- For each container sort the insects by colour. Create a data table and record your data in the table. Remember well designed data table must reflect the problem and are the first phase of effective interpretation.
- Communicate the data in a graphical format.

What conclusions can you safely draw about the distribution of these insects?

Where might there be hidden biases in the collection and interpretation of the data?

ESTIMATING THE PROPORTION OF OBJECTS IN A MIXED COLLECTION

- One partner wears a blindfold, reaches into the dish and scoops up a handful of objects. both partners then count the number of each object and record the results in a data table that you designed. Return the objects to the dish.
- repeat step #1 two more times, for a total of three samples.
- Record the data for each trial and determine a single set of information.
- From the data in the table, estimate the relative proportions of the objects.
- What conclusions can you draw about the relative proportion of each object? How important is it to have multiple samplings to get your estimate? How would more samples affect your results?

ED-E 745

HYPOTHESIZING

DESIGNING EXPERIMENTS

CONTROLLING VARIABLES

HYPOTHESIZING is an "educated guess" made about an expected relationship between two variables in an attempt to explain a cause-and-effect relationship. A hypothesis is based on observations and inferences and should be testable. It is usually expressed as an "if.....then...." statement.

DESIGNING EXPERIMENTS is the process of establishing cause-and-effect test between two variables. All processes may be involved. This can begin with setting a problem to be solved, identifying the variables, devising a test to be carried out, and following the prescribed procedure.

CONTROLLING VARIABLES involves deciding which variables or factors will influence the outcome of an experiment and deliberately controlling all recognized variable in a systematic manner.

Test Flight

Purpose: To test and redesign paper airplanes in order to come up with a 'successful' prototype.

Criteria: Best prototype = flies the furthest distance.

1. Form an airplane company consisting of 3 people. Give your company a name and a logo. Each person will assume a role in the company.

ROLE	RESPONSIBILITIES
President	Reads instruction, leads group discussions, facilitates participation and consensus within the group, keeps production on track, watches where plane lands on test flight
Material Engineer/Recorder	Collects and returns equipment, keeps materials in good shape for design and construction, keeps accurate records on design and test flight
Pilot	Maintains flight consistency for each test flight. Launch suggestions: bend elbow and keep elbow close to your body, hold plane with thumb/index/middle fingers, keep nose straight, gently push plane out with wrist action only.

2. Build a paper airplane of your own design or a copy from one of the books on the front table.
3. Run a test flight in the hallway (keep in mind the roles in your company!).

Trial 1	Trial 2	Trial 3

4. What could your company do to make your design fly better? Keep in mind the criteria.

Action	Purposeful Change Independent variable	Response to Change Dependent variable	Remained Constant Constant

5. Write a hypothesis for the redesigned airplane. Write the hypothesis as a “if.....then” statement. (Hint: use the action and the criteria).

6. Run a test flight of your redesign and record the data.

Trial 1	Trial 2	Trial 3

7. What conclusions can you draw from this experiment?
8. What made this a “fair test”?
9. Write a report and include: purpose, hypothesis, data presentation (graph/table), conclusions, recommendations for further study (supported by observations).

TOC ACTIVITIES

A teacher on call (TOC) is often provided with a lesson to complete by the teacher. However, the TOC may need to rely on their own activities in order to provide the students with a productive day while their teacher is absent.

The following should be considered when choosing TOC science activities: easy to access equipment, safety, unknown student prior knowledge/skills, certainty of activity occurrence, can complete in a short period of time or be extended to fill a longer period of time, flexibility for grade levels, possibility for cross discipline connections, and provides information for the returning teacher (data sheet, journal entry, etc).

CAT'S MEOW

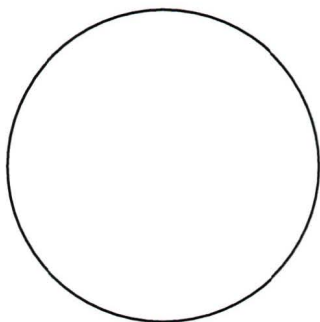
Materials:

Whole milk
food colouring (blue & yellow)
toothpicks
liquid soap (full strength)
aluminum pie plates

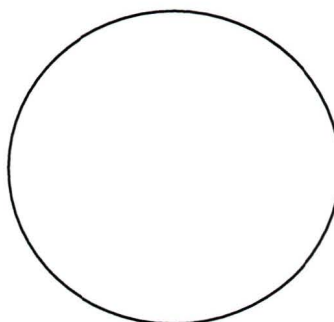
Procedure:

- pour milk onto the aluminum pie plate
- place drops of blue and yellow food colouring at the points indicated
- put a plain toothpick into the milk at the 'X' and observe what happens
- dip the toothpick into the full strength soap and put it into the milk at the 'X'.
Observe what happens

OBSERVATION SHEET/WORKSHEET



BEFORE



AFTER

EXTENDING THE ACTIVITY

- written component onto the worksheet
 - (i.e.) list 10 observations about the experiment,
 - list 5 “I wonder” questions
 - create a science journal entry - “Today I learned/I experienced...”
- design an experiment that relates to this activity
 - (i.e.) what happens with different types of milk (2%, skim)
 - what happens with dilute vs. full strength milk
 - what happens with different types of soap

PENNY SCIENCE

Materials:

Plastic glasses

Eye droppers

Pennies

Paper towel

1. Make at least 10 **observations** for the 'tail' side of a penny.

2. **Infer** how many drops of water you can put on the 'tail' of a penny before it spills over the side. Support your inference with your **observations** and **prior knowledge** (what do you know about pennies, water,.....)

3. How close was the actual number of drops of water to your inference? Why might this happen?

4. Look at the 'head' of a penny and **predict** how many drops of water will fit on this side of the penny.
What is the basis of your prediction?

5. Was your prediction more accurate or less accurate than your inference? Why?
6. List at least **5** '*I wonder.....*' questions that relate to pennies, water, etc.....

Poppin' Rockets

Materials:

Film canisters
Vinegar
Baking soda
Aluminum foil

- Using about 2cm X 2cm of aluminum foil, make a small aluminum foil 'boat'.
- Place a spoonful of baking soda in the boat.
- Fill the film canister half full of vinegar.
- Float the boat with the baking soda on the vinegar. Make sure that the boat does not sink!
- Carefully place the lid on the film canister, making sure that the boat is still floating! Turn the canister upside down (lid on the ground) and stand back!

ED-E 745
FLOATING AND SINKING JIGSAW

Jigsaw: A cooperative learning strategy that involves individuals within a cooperative group becoming experts on a particular topic or concept. Each expert provides a piece of the ‘puzzle’ that forms the big idea or concept.

POPCORN FLOATERS (A)

Materials:

Popcorn
 Plastic glass and water
 Alka-seltzer tablet

Procedure:

Place popcorn and alka-seltzer in the glass of water.

ALUMINUM BOATS (B)

Materials:

aluminum foil
 pennies
 bucket or aquarium with water

Procedure:

Float all the materials on the surface of the water.

CARTESIAN DIVER (C)

Materials:

plastic pop bottle with lid
 water
 eye dropper
 plastic cup with water

Procedure:

Place the dropper in the pop bottle filled with water. Squeeze the dropper so there is some water in the dropper. Place lid on the pop bottle and tighten; squeeze the sides of the bottle.

ICE CUBE FLOATERS (D)

Materials:

1 plastic cup filled with water
 1 plastic cup filled with alcohol
 1 plastic cup filled with vegetable oil and water
 3 ice cubes

Procedure:

Explore what happens when an ice cube is placed in each of the 3 cups containing the different liquids.

JIGSAW ACTIVITY

- Get into groups of four (your "home" group) and you will be assigned a number for your group
- Label this worksheet 'a', 'b', 'c' 'd' along with your home group's number, i.e. 1a, 1b, 1c, 1 d
- Your group will now split up and go to individual activities. Each member of the group will become "experts" on their particular activity along with people from other "home" groups. Example: 1a,2a,3a,4a are all investigating

the Pop Can Floaters. There will be "expert" groups of 3 to 4 students. The three "expert" groups will explore each activity independently and pool their understandings.

- Use a recording sheet to make detailed observations about your activity. Offer an explanation for your observations.
- Discuss the activity with your fellow "experts" from the other "expert groups" to make a tentative explanation of what is going on in the activity.
- Return to your "home" group and inform the other members of your group about your findings that the tentative explanation.

Consider the following questions in your discussion:

- What causes the floating and sinking of the objects in all four activities?
- What general 'rule' could you use to explain what was happening in all four activities?

PERFORMANCE TASK

Performance assessment is designed to evaluate science process skills and thinking skills and provide an opportunity for students to demonstrate their ability to successfully complete an activity using concrete manipulatives.

 Student Name

 Number of Unknown

Commonly Accepted Results

Substance	Heat	Water	Vinegar	Iodine	Hand Lens & Touch
Baking Soda	No Change	Dissolves	Fizzes	Yellow	Irregular
Corn Starch	Browns	Turns Milky	Turns Milky	Blue-Black	Smooth
Flour	Browns	Turns Milky	Turns Milky	Blue-Black	Rough
Salt	No Change	Dissolves	Dissolves	Yellow	Cubes
Sugar	Melts and Burns	Dissolves	Dissolves	Yellow	Rectangular

Experimental Results

Substance	Heat	Water	Vinegar	Iodine	Hand Lens & Touch
Unknown					

FINDINGS			EVIDENCE
<i>Powder</i>	<i>Present</i>	<i>Not Present</i>	<i>Description</i>
Baking Soda			
Corn Starch			
Flour			
Salt			
Sugar			

APPENDIX B

COURSE READINGS

NATURE OF SCIENCE

Cross, B. (1990). A passion within reason: The human side of process. Science and Children, 27(4), 16-21.

McComas, W.F. (1996). Ten myths of science: Reexamining what we think we know about the nature of science. School Science and Mathematics, 96(1), 10-16.

Spurlin, Q. (1995). Put science in a bag. Science and Children, 31(4), 19-27.

CONSTRUCTIVISM

Schulte, P.L. (1996). A definition of constructivism. Science Scope, 34(3), 25-27.

PROCESS SKILLS

Sumrall, W. J. & Sumrall, C.A. (1994). Process skills used effectively. Science and Children, 32(3), 41 - 42.

OBSERVING AND INFERRING

Padilla, M.J. and Pyle, E.J. (1996). Observing and inferring promotes science learning. Science and Children, 33(8), 22-25.

PREDICTING

MacDonald, D. (1993). Predictions and pedagogy. Science and Children, 30(7), 16-19.

EXPERIENCE (MANAGING HANDS-ON INQUIRY)

Schulte, P.L. (1999). Lessons in cooperative learning. Science and Children, 36(7) 44-47.

POST EXPERIENCE QUESTIONING

Martens, M.L. (1999). Productive questions: Tools for supporting constructivist learning. Science and Children, 36(8), 24-27 & 53.

ASSESSMENT

Foster, G.W. & Heiting, W.A. (1994). Embedded assessment. Science and Children, 32(2), 30 - 33.

Lehman, J.R. (1994). Assessment for preservice teachers. Science and Children, 32(2), 48-51.

INTERPRETING DATA

Matthews, C.E. (2000). The cormorant controversy. Science Scope, 23(7), 17-21.

FAIR TEST: HYPOTHESIZING, CONTROLLING VARIABLES, DESIGNING EXPERIMENTS

Colburn, A. (2000). An inquiry primer. Science Scope, 23(6), 42-44.

CREATIVE PROBLEM SOLVING

Chahrour, J. (1994). Perfecting the question. Science Scope, 18(2), 9-12.

Authentic Assessment, Scoring Rubrics, Performance Assessment

Demers, C. (2000). Beyond paper and pencil assessments. Science and Children, 37(2), 24-29 & 60.

Joyce, B & Farenga, S. (2000). Preparing for parents' questions. Science Scope, 23(6), 12-14.

Luft, J. (1997). Design your own rubric. Science Scope, 20(5), 25-27.

LEARNING CENTERS

Jones, I. (1999). A workshop approach. Science and Children, 37(3), 26-30 & 55.

SCIENCE IN OUR COMMUNITIES

Bodzin, A. & Gehringer, M. (2001). Breaking science stereotypes. Science and Children, 38(4), 36-41.

READING TO LEARN SCIENCE

Breger, D.C. (1995). The inquiry paper. Science Scope, 19(2), 27-32.

Huber, R.A. & Walker, B.L. (1996). Science reading dos and don'ts. Science Scope, 20(1), 22-23.

Misulis, K. (1997). Textbook comprehension strategies. Science Scope, 21(1), 39-43.

WRITING TO LEARN SCIENCE

Rillero, P., Zambo, R., Cleland, J., & Ryan, J. (1996). Write from the start: Writing to learn science. Science Scope, 19(7) 30-32.

Shelley, A.C. (1998). The write approach. Science Scope, 22(1), 36-39.

APPENDIX C

COURSE ASSIGNMENTS

The Unit topic and classroom description must be identified very early in the fall term to provide enough time to plan your unit. The description may include information such as: grade level, the number of science class periods per week and the length of each class; the physical setting of the classroom (i.e. accessibility to sinks, tables, desk arrangement, etc.); student characteristics (i.e. number of boys and girls, learning difficulties/gifted, etc.); the science program used (FOSS, STC, Journeys in Science, Science DiscoveryWorks, etc.); equipment available.

Scoring will be 5 marks.

Due: September 27, 2000

The unit overview will outline the general goals for your unit. Include science content and application outcomes from the Science IRP (K-7), and a series of lesson foci, introductions, activities, and assessment ideas developed for 6 lessons anticipated in your unit. Please reference your activities against specific teacher resources.

Scoring will be 15 marks (3 marks for unit outcomes, 2 marks for each of the six lessons).

Due: October 11, 2000

The first lesson for your science unit will include specific lesson objectives, materials required, pre-experience introduction, experience activity, post-experience questions and formative assessment idea.

Scoring will be 10 marks (2 points for each requirement specific objectives, pre-experience, experience/materials, post-experience and formative assessment).

Due: October 22, 2000

Reflections on your Fall Science Unit is designed to encourage you to become a reflective practitioner. It is important that you assess your effectiveness, analyze your teaching and suggest adjustments to enhance teaching/learning. Some of your suggestions will involve general approaches that can be incorporated into your teaching right away, while other suggestions will be content or topic specific and will not be utilized until you teach the subject or unit again. These suggestions might include decisions to change a planned lesson, to pursue an interesting idea not anticipated, or to take advantage of a teachable moment. An expert teacher makes many of these decisions each day. Reflections will be assessed in terms of the analysis, evidence provided and adjustments suggested. This assignment stresses quality of thinking and not quantity of text.

Scoring will be 5 marks.

Due: January 8, 2001

The reaction papers are designed to develop the habits and strategies related to self-directed professional development utilizing science education journals and science related articles in generalist journals: BC Catalyst, Science Activities, Prime Areas, Science and Children, Instructor, Science Scope, etc. The 1 page (typed, double spaced, 12 point type) assignment consist of 2 parts. First, a concise summary of the article with complete reference information provided in the title. Second, a concise informed personal analysis and evaluation of the proposed ideas in the article. A photocopy of the article should be attached to the reaction paper.

Scoring will be 10 points.

Due: January 22, 2001

The Science Professional Development Portfolio is designed to be only one part of a larger portfolio that you may take to an interview for a potential teaching position. The information must be presented in a concise and easy to read format so that the interviewer will be able to review your portfolio within the time frame of the interview. The science section of the portfolio will include three parts: your own philosophy of science teaching and learning, documentation of your own science teaching experiences (i.e. one lesson taught in practicum that includes the lesson plan used, reflections of the positive and negative aspects of the lesson, possible improvements to the lesson, and associated student work complete with the lesson), and your participation in professional development activities (i.e. another reaction paper, a review of the Tuesday workshops).

Scoring will be 20 marks.

Due: March 2, 2001

APPENDIX D

POOL OF VOLUNTEERS FOR CLASSROOM OBSERVATIONS

<i>INITIAL STAGE</i> (during first survey)	<i>SECOND STAGE</i> (after class description)	<i>FINAL STAGE</i> (after unit overview)
Alan	Len	Susan School B, gr 7 ecosystems
Bob	School A, gr 7, astronomy	
Carol	Susan	
Kelly	School B, gr 7, ecosystems	
Elizabeth	Ned	Mary School E, gr 4/5 light & colour
Fran	School C, gr 6/7, structures	
Gail	Hank	
Hank	School A, gr 5/6, light & colour	
Imogene	Carol	Kara School F, gr 4 skeletal system
Mary	School D, gr 4/5, light & colour	
Kara	Mary	
Len	School E, gr 4/5, light & colour	
Max	Kara	Linda School G gr 3, earth's composition
Ned	School F, gr 4, skeletal system	
Danielle	Emily	
Jackie	School G, gr 4, water	
Emily	Brenda	Julie School J gr 1, Weather
Julie	School H, gr 3, sound	
Christine	Linda	
Tania	School G, gr 3, Earth's Composition	
Debbie	Julie	Kelly School F gr 1, states of matter
Brenda	School J, gr 1/2, Weather	
Pam	Gail	
Susan	School F, gr 1/2, Bears	
Linda	Kelly	
Molly	School F, gr 1, states of matter	
Vera		

APPENDIX E

NATURE OF SCIENCE KNOWLEDGE SURVEY**

1. Scientific laws, theories, and concepts do not express creativity.
Strongly Agree Agree Neutral Disagree Strongly Disagree
2. Scientific knowledge is stated as simply as possible.
Strongly Agree Agree Neutral Disagree Strongly Disagree
3. The laws, theories, and concepts of biology, chemistry, and physics are related.
Strongly Agree Agree Neutral Disagree Strongly Disagree
4. The applications of scientific knowledge can be judged good or bad; but the knowledge itself cannot.
Strongly Agree Agree Neutral Disagree Strongly Disagree
5. It is incorrect to judge a piece of scientific knowledge as being good or bad.
Strongly Agree Agree Neutral Disagree Strongly Disagree
6. If two scientific theories explain a scientist's observations equally well, the simpler theory is chosen.
Strongly Agree Agree Neutral Disagree Strongly Disagree
7. Certain pieces of scientific knowledge are good and others are bad.
Strongly Agree Agree Neutral Disagree Strongly Disagree
8. Even if the applications of a scientific theory are judged to be good, we should not judge the theory itself.
Strongly Agree Agree Neutral Disagree Strongly Disagree
9. Scientific knowledge need not be capable of experimental test.
Strongly Agree Agree Neutral Disagree Strongly Disagree
10. The laws, theories, and concepts of biology, chemistry, and physics are not linked.
Strongly Agree Agree Neutral Disagree Strongly Disagree

** Rubba, P.A. & Andersen, H.O. , 1978.

11. Consistency among test results is not a requirement for the acceptance of scientific knowledge.
Strongly Agree Agree Neutral Disagree Strongly Disagree
12. A piece of scientific knowledge will be accepted if the evidence can be obtained by other investigators working under similar conditions.
Strongly Agree Agree Neutral Disagree Strongly Disagree
13. The evidence for scientific knowledge need not be open to public examination.
Strongly Agree Agree Neutral Disagree Strongly Disagree
14. Scientific laws, theories, and concepts are not stated as simply as possible.
Strongly Agree Agree Neutral Disagree Strongly Disagree
15. There is an effort in science to build as great a number of laws, theories, and concepts as possible.
Strongly Agree Agree Neutral Disagree Strongly Disagree
16. We accept scientific knowledge even though it may contain error.
Strongly Agree Agree Neutral Disagree Strongly Disagree
17. Scientific knowledge expresses the creativity of scientists.
Strongly Agree Agree Neutral Disagree Strongly Disagree
18. Moral judgment can be passed on scientific knowledge.
Strongly Agree Agree Neutral Disagree Strongly Disagree
19. The laws, theories, and concepts of biology, chemistry, and physics are not related.
Strongly Agree Agree Neutral Disagree Strongly Disagree
20. Scientific laws, theories, and concepts express creativity.
Strongly Agree Agree Neutral Disagree Strongly Disagree
21. It is meaningful to pass moral judgement on both the applications of scientific knowledge and the knowledge itself.
Strongly Agree Agree Neutral Disagree Strongly Disagree
22. The evidence for scientific knowledge must be repeatable.
Strongly Agree Agree Neutral Disagree Strongly Disagree

23. Scientific knowledge is not a product of human imagination.
Strongly Agree Agree Neutral Disagree Strongly Disagree
24. Relationships among the laws, theories, and concepts of science do not contribute to the explanatory and predictive power of science.
Strongly Agree Agree Neutral Disagree Strongly Disagree
25. The truth of scientific knowledge is beyond doubt.
Strongly Agree Agree Neutral Disagree Strongly Disagree
26. Today's scientific laws, theories, and concepts may have to be changed in the face of new evidence.
Strongly Agree Agree Neutral Disagree Strongly Disagree
27. We do not accept a piece of scientific knowledge unless it is free of error.
Strongly Agree Agree Neutral Disagree Strongly Disagree
28. A scientific theory is similar to a work of art in that they both express creativity.
Strongly Agree Agree Neutral Disagree Strongly Disagree
29. There is an effort in science to keep the number of laws, theories, and concepts at a minimum.
Strongly Agree Agree Neutral Disagree Strongly Disagree
30. The various sciences contribute to a single organized body of knowledge.
Strongly Agree Agree Neutral Disagree Strongly Disagree
31. Scientific beliefs do not change over time.
Strongly Agree Agree Neutral Disagree Strongly Disagree
32. Scientific knowledge is a product of human imagination.
Strongly Agree Agree Neutral Disagree Strongly Disagree
33. The evidence for a piece of scientific knowledge does not have to be repeatable.
Strongly Agree Agree Neutral Disagree Strongly Disagree
34. Scientific knowledge does not express the creativity of scientists.
Strongly Agree Agree Neutral Disagree Strongly Disagree

35. Biology, chemistry, and physics are similar kinds of knowledge.
Strongly Agree Agree Neutral Disagree Strongly Disagree
36. If the applications of a piece of scientific knowledge are generally considered bad, then the piece of knowledge is also considered to be bad.
Strongly Agree Agree Neutral Disagree Strongly Disagree
37. Scientific knowledge is subject to review and change.
Strongly Agree Agree Neutral Disagree Strongly Disagree
38. Scientific laws, theories, and concepts are tested against reliable observations.
Strongly Agree Agree Neutral Disagree Strongly Disagree
39. If two scientific theories explain a scientist's observations equally well, the more complex theory is chosen.
Strongly Agree Agree Neutral Disagree Strongly Disagree
40. Scientific knowledge is specific as opposed to comprehensive.
Strongly Agree Agree Neutral Disagree Strongly Disagree
41. Scientific theories are discovered, not created by man.
Strongly Agree Agree Neutral Disagree Strongly Disagree
42. Those scientific beliefs which were accepted in the past and since have been discarded, should be judged in their historical context.
Strongly Agree Agree Neutral Disagree Strongly Disagree
43. Scientific knowledge is unchanging.
Strongly Agree Agree Neutral Disagree Strongly Disagree
44. Biology, chemistry, and physics are different kinds of knowledge.
Strongly Agree Agree Neutral Disagree Strongly Disagree
45. Consistency among test results is a requirement for the acceptance of scientific knowledge.
Strongly Agree Agree Neutral Disagree Strongly Disagree
46. Scientific knowledge is comprehensive as opposed to specific.
Strongly Agree Agree Neutral Disagree Strongly Disagree

47. The laws, theories, and concepts of biology, chemistry, and physics are interwoven.
Strongly Agree Agree Neutral Disagree Strongly Disagree
48. A piece of scientific knowledge should not be judged good or bad.
Strongly Agree Agree Neutral Disagree Strongly Disagree

APPENDIX F

FACTOR ANALYSIS INFORMATION

Pre-Test Component Loadings

	Subscales	F1	F2	F3	F4	F5	F6
Q7	A-	0.269	0.198	0.325	0.506	0.227	0.053
Q18	A-	0.143	-0.306	0.643	-0.107	0.057	0.087
Q21	A-	0.347	-0.217	0.496	-0.053	-0.412	0.051
Q36	A-	0.070	0.263	0.692	-0.077	0.138	-0.181
Q4	A+	0.075	0.067	0.616	0.058	-0.055	-0.275
Q5	A+	0.238	0.188	0.566	-0.059	0.245	0.100
Q8	A+	-0.064	0.056	0.365	-0.028	0.347	-0.104
Q48	A+	0.102	0.195	0.694	0.062	0.033	0.125
Q1	C-	-0.005	0.664	0.159	0.260	-0.047	-0.166
Q23	C-	-0.031	0.633	0.158	0.036	0.376	0.290
Q34	C-	0.188	0.779	0.111	0.138	0.095	-0.085
Q41	C-	-0.104	0.352	0.015	0.398	-0.121	0.002
Q17	C+	0.213	0.809	-0.098	-0.008	0.095	-0.139
Q20	C+	0.132	0.745	0.176	-0.014	-0.075	0.006
Q28	C+	0.062	0.805	-0.023	-0.031	-0.087	0.121
Q32	C+	-0.076	0.579	0.131	-0.134	0.368	0.052
Q25	D-	-0.181	0.230	-0.102	0.668	0.068	0.132
Q27	D-	-0.315	-0.040	0.030	0.376	0.153	0.338
Q31	D-	0.636	0.214	0.278	0.227	0.331	-0.003
Q43	D-	0.521	-0.180	0.109	0.402	0.245	-0.166
Q16	D+	-0.200	-0.028	-0.278	0.088	0.055	0.016
Q26	D+	0.536	0.075	0.211	-0.029	0.280	0.046
Q37	D+	0.230	0.195	0.105	0.476	0.378	-0.412
Q42	D+	0.162	0.161	0.256	0.175	0.435	0.214
Q14	P-	0.378	0.190	0.344	-0.119	0.212	0.390
Q15	P-	-0.391	0.014	0.431	0.172	-0.009	-0.377
Q39	P-	0.267	0.143	0.356	-0.258	-0.143	-0.157
Q40	P-	0.250	0.088	-0.251	0.563	-0.229	0.020
Q2	P+	0.156	0.207	-0.074	-0.481	0.082	0.258
Q6	P+	-0.352	-0.135	0.504	0.061	0.039	0.076
Q29	P+	-0.394	0.160	0.507	0.250	0.008	-0.111
Q46	P+	0.075	-0.057	-0.077	0.666	-0.139	0.148
Q9	T-	0.318	-0.170	-0.046	-0.130	0.223	0.077
Q11	T-	0.142	0.006	0.004	-0.039	0.605	0.193
Q13	T-	0.131	0.236	0.065	-0.038	0.277	0.384
Q33	T-	-0.005	0.101	-0.162	-0.171	0.507	-0.080
Q12	T+	0.111	0.062	0.240	0.006	0.627	0.056
Q22	T+	0.278	-0.067	-0.034	-0.156	0.581	0.053
Q38	T+	0.157	0.263	0.516	0.008	0.267	-0.366
Q45	T+	0.177	-0.077	-0.026	0.097	0.588	-0.262
Q19	U-	0.703	0.055	-0.008	-0.114	-0.027	0.157
Q10	U-	0.758	0.153	0.066	0.017	0.244	-0.149
Q24	U-	0.286	0.210	0.257	-0.110	0.533	-0.176
Q44	U-	0.088	0.002	0.246	-0.132	0.060	-0.617
Q3	U+	0.778	0.133	0.154	0.063	0.179	0.009
Q30	U+	0.045	-0.049	0.016	0.135	0.432	-0.186
Q35	U+	-0.016	0.126	0.015	-0.129	0.255	-0.710
Q47	U+	0.576	0.176	0.087	0.228	0.127	-0.301

Variance Explained by Components (unrotated solution - pretest)

1	2	3	4	5	6
8.264	3.918	3.615	2.847	2.681	2.381

Percent of Total Variance Explained (unrotated solution - pretest)

1	2	3	4	5	6
17.217	8.162	7.530	5.931	5.585	4.960

Total: 49.39%

Variance Explained by Components (rotated solution - pre-test)

1	2	3	4	5	6
4.751	4.768	4.516	3.005	4.055	2.610

Percent of Total Variance Explained (rotated solution - pre-test)

1	2	3	4	5	6
9.898	9.933	9.407	6.261	8.448	5.437

Total: 49.38%

Post-test Component Loadings

	Sub-scale	F1	F2	F3	F4	F5	F6
Q7	A-	0.026	0.743	-0.023	-0.066	0.147	0.018
Q18	A-	0.316	0.419	0.321	0.357	-0.012	0.065
Q21	A-	0.307	0.290	-0.090	0.477	0.113	0.253
Q36	A-	0.063	0.665	0.093	0.298	0.178	-0.227
Q4	A+	-0.269	0.620	0.054	0.015	0.222	0.188
Q5	A+	0.005	0.603	-0.082	-0.079	0.367	0.075
Q8	A+	-0.235	0.280	-0.089	0.271	0.161	0.401
Q48	A+	-0.119	0.735	0.004	0.190	-0.054	0.029
Q1	C-	0.394	-0.039	0.038	0.597	0.230	0.096
Q23	C-	0.577	-0.114	-0.048	-0.337	0.160	0.017
Q34	C-	0.792	0.076	0.029	0.135	0.024	0.234
Q41	C-	0.019	0.154	-0.042	-0.268	0.355	-0.003
Q17	C+	0.657	0.021	0.091	0.096	0.062	-0.024
Q20	C+	0.751	-0.079	0.008	0.190	0.327	0.051
Q28	C+	0.554	0.047	0.137	0.095	0.257	0.096
Q32	C+	0.542	0.018	0.061	-0.438	0.227	0.122
Q25	D-	0.374	0.158	0.017	0.007	0.361	0.271
Q27	D-	0.459	-0.172	-0.355	-0.295	-0.045	0.098
Q31	D-	0.502	0.406	0.405	0.087	-0.011	-0.345
Q43	D-	0.369	0.143	0.247	-0.183	0.112	-0.095
Q16	D+	-0.019	-0.089	-0.032	-0.313	-0.007	0.200
Q26	D+	0.274	0.170	0.255	-0.374	0.176	-0.130
Q37	D+	0.346	0.393	0.367	-0.230	-0.034	-0.341
Q42	D+	0.083	0.578	0.137	-0.413	0.081	0.015
Q14	P-	0.149	0.019	-0.120	0.098	0.017	0.618
Q15	P-	0.002	0.307	0.034	0.485	-0.027	0.307
Q39	P-	0.256	0.411	-0.036	0.058	0.121	0.084
Q40	P-	0.040	-0.302	0.281	-0.105	-0.233	0.609
Q2	P+	0.149	0.106	-0.169	-0.048	0.101	0.528
Q6	P+	0.017	0.250	-0.373	-0.190	0.377	0.330
Q29	P+	-0.124	0.427	0.034	0.178	0.079	0.537
Q46	P+	-0.072	-0.164	0.320	0.032	-0.373	0.576
Q9	T-	-0.022	-0.239	0.376	-0.139	0.276	-0.242
Q11	T-	0.245	-0.178	0.526	0.124	0.457	-0.057
Q13	T-	0.268	0.379	0.268	-0.038	0.351	-0.098
Q33	T-	0.058	0.156	0.680	0.048	0.077	0.071
Q12	T+	-0.017	-0.058	0.457	-0.200	-0.072	0.060
Q22	T+	-0.001	0.114	0.749	0.034	0.032	-0.105
Q38	T+	-0.400	0.136	0.282	0.049	0.273	0.119
Q45	T+	0.123	-0.050	0.666	0.074	0.354	0.131
Q19	U-	0.128	0.221	0.250	0.188	0.797	-0.021
Q10	U-	0.112	0.224	0.145	0.212	0.801	-0.062
Q24	U-	0.268	0.042	0.251	-0.108	0.145	0.413
Q44	U-	-0.093	0.030	0.046	0.544	0.338	0.129
Q3	U+	0.130	0.215	-0.020	0.032	0.754	0.126
Q30	U+	0.050	0.130	0.145	-0.397	0.310	0.202
Q35	U+	0.157	-0.085	0.048	-0.001	0.692	-0.067
Q47	U+	0.188	0.189	0.095	-0.072	0.728	0.027

Variance Explained by Components (Unrotated solution - post-test)

1	2	3	4	5	6
8.110	4.216	3.376	2.896	2.646	2.434

Percent of Total Variance Explained (Unrotated solution - post-test)

1	2	3	4	5	6
16.897	8.783	7.034	6.033	5.513	5.071

Total: 49.33%

Variance Explained by Components (Rotated solution - post-test)

1	2	3	4	5	6
4.624	4.579	3.540	2.931	4.968	3.037

Percent of Total Variance Explained (Rotated solution - post-test)

1	2	3	4	5	6
9.634	9.539	7.374	6.105	10.351	6.327

Total: 49.33%

VITA

Surname: Bright

Given Names: Patricia Gayle

Place of Birth: Winnipeg, Manitoba, Canada

Educational Institutions Attended:

University of Victoria	1997 to 2001
University of Victoria	1980 to 1985

Degrees Awarded:

B.Ed. (with distinction)	University of Victoria	1985
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Author



Patricia Gayle Bright

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