A Case Study of Pre-service and Practicing Science Teachers' Awareness of the Nature of Science Foundation for the New British Columbia Grades 8-10 Science Curricula

Peer Teaching Observations of the British Columbia Government's Implementation of the Pan-Canadian Framework for Science 8 to 10.

by

Allana Shillito Pryhitka
Batchelor of Science, University of Victoria, 1989,
Post Degree Certification Education, University of Victoria 1996

A Project Submitted in Partial Fulfillment
of the Requirements for the Degree of

MASTERS IN EDUCATION

in the Department of Curriculum and Instruction

Abstract

British Columbia embraced the Pan-Canadian Science Framework by revising its K-12 Science curriculum between 2005 and 2008 to align with national and international efforts to improve scientific literacy; Grades 8 to 10 were the last and the largest of the changes.

This mixed method project gathered evidence of general scientific literacy in pre-service science teachers; using three surveys, document analyses of how scientific literacy and Nature of Science (NOS) altered common learning outcomes, and an interview of practicing science teachers to assess how the new scientific-literacy-enriched curricula, for Grades 8 to 10, have impacted their teaching.

Pre-service teachers did not recognize science as parsimonious and did not differentiate types of air pollution. The new curricula contained more learning outcomes in the form of Achievement Indicators. Teachers stated that courses were too large to finish, and also that classroom laboratory and research time were cut, in an attempt to finish the new courses.

Supervisor: Dr. Larry Yore

Table of Contents

List of Tables

List of Figures

Acknowledgements

I would like thank Dr. Larry Yore for his unrelenting patience, guidance and understanding. You didn't have to take me on as a grad student but am I ever so thankful you rescued me (again… and again). Wow, what a long haul.

Dr. Kathie Black, thank you for the ideas and support to get going on this long journey, and to Andrew Roome, who acted as my third party go-between during the surveys, and who did a wonderful job of collating all the surveys that were completed.

Todd Milford and Brian Hand, thank you for allowing me to use your science methods classes for my surveys at such short notice.

To Dr. David Blades and Dr. Eileen Van der Flier-Keller, for such a positive experience being a part of the Earth Science and Education research. I needed to apply my hard-earned statistics somewhere, if I could not on my own project.

To my teaching peers who allowed me to interrupt their first week of summer break to talk 'shop' for the interview and to the earlier set of teaching friends: Erin, Andrew, Don, John, Ken, and Greg who helped me with my pilot study wording.

To School District #63, for allowing me the go ahead for my project interview when all seemed lost in the surveys.

To all my teacher friends, sharing your experiences helped. I didn't feel so alone. Your friendship and laughter mean everything to me.

To Mark Roper, thank you for your diligence and keen eye.

Dedication

I would like to dedicate this project to the ladies in my life. My grandmothers and great-grandmothers, who now walk in the spirit world, have been such an inspiration to me with stories of their lives, their hardships and their loves.

For great-grandmother Agnes Helen Jones Kilner, thank you for my mom and your teachings to her.

For grandma Elsie Fairhurst, who, having earned a nursing degree, become a first time mother in her late 30s, and been a working mother for thirty more years afterwards, provided such a strong message of self-reliance and strength to me. Thank you for allowing me to show you in turn what I had learned from you, and to take care of you as you did for me.

To Grams Connie (Cleone) Kilner; from you I learned much about being a woman: to fight when you know you have lost ground, to love when you know it may not be returned, to find beauty, comfort and humor, in small measures, to keep you going, and to let go when all you wanted to do was to hold on.

To my Mom, my hero, who adds richness of learning and love to my life, by sharing hers. Your resilience, courage and amazing sense of humor, none can compare. The big picture never gets blurry in your eyes. Thank you for keeping me focused, always.

To my daughter, Kayla Nicole, who comes from strong women on both sides; these past five years have been a struggle for you, too. This makes part of your story to share with your future; not good or bad, just learning stories. I want to show you, in this dedication, the strength from which you come. If I can do this, if I can succeed, I will have shown you a path your great-grandmothers made for me to give to you. I love you, babe, more than life itself.

Chapter 1
Introduction

The *Common Framework of Science Learning Outcomes* — the framework (Council of Ministers of Education, Canada [CMEC], 1997) is a nationally developed curriculum document, generated from the *Pan-Canadian Protocol for Collaboration on School Curriculum* – the protocol, an initiative growing out of the Victoria Accord (Anderson, Milford, Jagger & Yore, 2009). The intent of this initiative was to facilitate the harmonization of learning goals and science instruction in Canadian schools, to provide the highest quality of education while recognizing provincial jurisdiction for education. CMEC believed that *sharing human and financial resources can increase the quality and efficiency of the curriculum development processes in Canada* (accessed Nov 16, 2010, http://publications. cmec.ca /science/framework/Pages/english/1.html). Learning outcomes for K–12 science education in Canadian schools were developed by Summer Writing Teams, composed of select science teachers from across Canada, under the supervision of two co-directors and a steering committee, composed of members of the CEMC. The Pan-Canadian Science Project (PCSP) was the first joint development project that was undertaken as part of the protocol. The objective of the PCSP was to produce a framework of general and specific science learning outcomes, for Kindergarten through to Grade 12.

The *Framework* (1997, http://204.225.6.243/science/framework/) has a clear focus on the development of science literacy in its foundation statements and learning outcomes, although a specific definition of science literacy is not clearly articulated. The foundations of science education are described as the development of:

understanding of science and technology;

relationships to society and the environment;
skills of inquiry;
knowledge of science concepts;
attitudes to support the acquisition; and,
application of scientific and technological knowledge.

These were derived from the scientific literacy needs of Canadian students and society, as a set of five goals of Canadian science education (CMEC, 1997, p. 3):

1 Encourage students at all Grade levels to develop a critical sense of wonder and curiosity about scientific and technological endeavours.

2 Enable students to use science and technology to acquire new knowledge and solve problems, so that they may improve the quality of their own lives and the lives of others.

3 Prepare students to critically address science-related societal, economic, ethical and environmental issues.

4 Provide students with a foundation in science that creates opportunities for them to pursue progressively higher levels of study, prepares them for science-related occupations, and engages them in science-related hobbies, appropriate to their interests and abilities.

5 Develop in students, of different aptitudes and interests, a knowledge of the wide variety of careers related to science, technology and the environment.

The foundation and goal statements were used to develop learning outcomes, for students from Kindergarten to Grade 12, in biological, physical and earth sciences. Unfortunately, the 1997 release of the framework was too late to influence the last cycle of science curriculum revisions (1996), in British Columbia. This was also true in all other provinces and territories other than Ontario (Anderson, Milford, Jagger & Yore, 2009).

The Ministry of Education in British Columbia (MOE), in 2004, began the process of aligning the provincial science curriculum to the Pan-Canadian Framework. The Framework was a result of the national and international trends towards ‘science literacy for all students’ that focused on educating students about the processes and nature of science (NOS), rather than simply a collection of knowledge-based rote learning. The province of BC had not implemented a wholesale overhaul of science education since 1984. The new Instructional (Integrated) Resources Packages (IRPs) were prescribed for the K-7 grades (2005), Grade 8 (2006), and Grade 9-10 (2007-8), in gradual progression, to allow some degree of implementation in a developmental fashion. These curricular changes in the IRPs require changes for science teachers, both pre-service and in-service, and also for those who are involved in teacher education, in universities and professional development settings, to try to assure the realignment of classroom planning and practices within the Pan-Canadian framework standards.

The central focus of this project is to explore the extent to which, and the mechanisms by which, pre-service and in-service teachers become aware of the nature of science emphasis within the Framework and the new BC IRPs for K-10. University of Victoria Education instructors can access the changes by means of government websites. These e-documents were used in their preservice science education courses, to illustrate the current worldwide science education reforms, which focused on ‘science literacy for all’ (Anderson et al., 2009). Earlier BC IRPs did not reflect the Framework’s philosophy, foundations and learning outcomes, potential connections could been interpreted as tentative. The first indications that the framework and its foundational statements were going to influence BC science curriculum was found in the K-7 Science IRP (draft) for reaction by parents, teachers and administrators. This project concentrated on 2004-2009 which represented the formal recognition and implementation of the new nature of science and science literacy emphasis for science teaching in K-10 in British Columbia. Pre-service teachers engage the new IRPs and framework as part of the science education curriculum and instruction courses. However, classroom teachers are provided little educational support in this orientation and implementation process. They are expected to check the government websites regularly for changes in direction and curriculum. New textbook lists and IRPs are placed on government website (http://www.bced.gov.bc.ca/irp/ program _delivery/science.htm). Hardcopies of IRPs are available at the Queens' Printer for a cost of $16.52 for grade specific science course (accessed Nov 16, 2010, http://www.crownpub.bc.ca/hitlist.aspx). The government placed the onus is on each individual school district to find funding to release teachers for round table discussion and professional development (Pro-D), as well as to purchase new resources prior to 2006 by changing the way school boards were funded to implement new courses. (BCTF website accessed Nov 16, 2010, http://bctf.ca/IssuesInEducation.aspx?id=5646).

Provincial curriculum development and implementation involves a lengthy and co-ordinated process of establishing goals and learning outcomes, identifying and securing appropriate instructional resources, as well as identifying and implementing appropriate instructional practices. This complex process requires an acculturation of the teachers to the philosophy, to the goals and learning outcomes, to the assessment for learning and of learning (teaching and evaluation), and to the acquisition and adaptation of instructional resources and strategies to achieve the new curriculum's prescribed learning outcomes. The success of this process for the K-10 science curricula has yet to be evaluated. The current implementation has narrowly missed certain key opportunities, such as the OECD (Organisation for Economic Co-operation and Development) PISA (Programme for

International Student Assessment) for fifteen and sixteen year olds in 2006 (http://www.pisa.oecd.org/dataoecd/13/33/ 38709385.pdf), and the Pan Canadian Assessment Program's (PCAP) 2007 test on thirteen year olds (http://www.cmec.ca/ Programs/assessment/pancan/Pages/default.aspx). However, Anderson et al. (2009) attempted to document the impact of the Pan-Canadian Framework on science curricula across Canada by surveying ministry of education websites, analysing curriculum documents, as well as interviewing senior administrators for their impressions on levels of implementation and transitions. Twelve years after the release of the framework, British Columbia has incorporated Pan-Canadian Framework goals with respect to science literacy for all and the nature of science into its first major curriculum overhaul in two decades.

The research project here attempts to qualitatively measure the large-scale alterations to the K-10 BC Integrated Resource Plans (IRPs) for science, in three parts. The original focus concentrated on how student teachers are prepared. This group served as focus for the first study, while the curriculum documents served as the focus for the second, and practicing science teachers served as the focus of the third study. Resources employed to gather data include: nature of science (NOS) pre-survey, mid-survey and post-survey of pre-service teachers during their practicum year, analysis of the former and current IRPs, and focus group interviews of practicing classroom teachers during their implementation periods. The project concentrated on the individuals' interpretations of NOS and their concerted efforts to teach NOS purposefully. The knowledge of the pre-service teachers, those who have not taught in a classroom or with the new IRPs, was tested by checking definitions and pedagogical understandings of NOS, as well as by their ability to read and critically determine whether or not the science reported in newspaper articles were valid. Many scholars argue that newspaper and internet articles provide the much of adult population's updated science knowledge (Bardeen, 2000; Einsiedel, 1992, 1994; Jarman & McClune, 2001; Korpan, Bisanz, Bisanz, & Henderson, 1997; Matricardi, Muratori, Porro, & Capozza, 2000; Miller, 1983, 1998; Ryder, 2001). Readers with higher scientific literacy should be able to discern an article's accuracy and validity.

The second focus was the comparison of IRPs. Certain learning objectives are common from the former to the present IRPs, while other learning outcomes are new or have increased explicit emphasis. The results from the IRP document analysis identified the set of interview questions for practicing junior (Grades 9-10) science teachers in the third part of the inquiry. These teachers were asked to discuss certain subject areas, and to evaluate the processes of science in the 2005-2008 IRPs for K-7, 8, 9 and 10th Grades. The results of these three studies serve as evidence for claims made about the success of implementing the NOS and science literacy learning outcomes and for identifying areas of further consideration for science education leaders, teacher educators and Pro-D providers.

The importance of this project is to examine the impact of the new IRPs' explicit theme of NOS in relation to the old IRPs. This change represents a critical and essential component of being a scientifically literate citizen, leading to fuller participation in the public debate about science, technology, society and environment issues that will produce informed decisions and sustainable solutions (Yore, Pimm & Tuan, 2007). Furthermore, this project informs the reader as to what extent the overhaul in the IRPs impacted on the classroom science lessons. To gain insight towards this culmination, this project systematically documents pre-service and in-service teachers' awareness of the explicit and implicit goals, of the learning outcomes and of the emphasis of the new K-10 IRPs being on science literacy. As a result, the project's ultimate focus is to begin to understand the "trickle-down" effect of such a monumental large-scale shift in science education, as it stood for two decades in BC, into the individual science classes.

Chapter 2
Literature Review

The central focus of this project was to document, firstly, reforms in science education, and the associated changes in pre-service teachers' awareness of critical features of these reforms; and, secondly, the changes in recent science curricula K-10, and in-service teachers' views of these features and curricular changes. This chapter provides a brief view of science education, then offers some insights into prior reforms, current reforms, student performance and research methods concerned with science education, as well as the nature of science and science literacy.

Science is defined as a body of knowledge and as the processes of discrete and repeatable steps to finding said knowledge. In operational terms, science is made up of two basic parts: first, the content, knowledge, facts and figures, and then the skills and process, or methods, to constructing knowledge. Skills and knowledge were developed mutually and within a social context. A century ago, traditional education was already being singled out as flawed with respect to an unnatural learning environment. Dewey (1913) recognized the unfavourable direction in which children's education within the classroom was going; children's desks, classrooms and learning material were "all made for listening"; "the attitude of listening means…passivity, absorption"; and schools are "arranged for handling as large a number of children as possible, for dealing with children en masse, as an aggregate of units, involving, again, the children being treated passively" (pp. 48-49). As education enters the twenty-first century, many classrooms still convey the underlying belief that listening is educating. Dewey's vision of a desirable holistic education is one that scientific literacy strives to embody a century later in its science specific education. His emphasis on active hands-on, minds-on learning, with social and practical applications, using student-centred teaching, demonstrates that such approaches are not new.

Other issues associated with the social application of science education continue to be considered. Internationally, the epistemology of rote learning, assessing learning using high-stakes testing, and the quality of teacher preparation and praxis continue to be central issues of concern in education. No one country or institution has been successful in addressing these problems. Yager (2000) repeatedly found that, overall, the personal, societal, economic and intellectual themes are:

Goal 1: Personal Needs
Goal 2: Societal Needs
Goal 3: Career Awareness
Goal 4: Academic Preparation

Project Synthesis (Harms & Yager, 1981; Yager, 2000), as well as a Canadian study (Connelly, Crocker & Kass, 1985), came to the same conclusion: either science education stressed the academic goal almost exclusively, or it prepared students to study more science in post-secondary institutions. The articulation of scientific literacy appears to address these issues that constantly plague science education. For critics and supporters, the idea that science education should be more socially connected is not the debate. What is at issue is how this change is to take place, in the context of politics, accountability, science curriculum and overall education. For some, their curriculum has been adapted to include high degrees of connection to society and technology in the form of STSE (Science, Technology, Society and Environment) courses. True STSE courses delve into historical and philosophical topics. British Columbia’s science curriculum makes mention of STSE values. To add philosophy and history would require the addition new courses.

Politics and high-stakes testing

Post-Sputnik Cold War reality produced comprehensive and thorough science education reforms in the K-12 school system, in order to meet the challenge from Russian science and technology enterprises. Time was of the essence to produce the next generation of scientists, engineers and scientifically-savvy citizens, and to do away with the “techno-peasants” (Prewitt, 1983, p. 53). With such energy and money placed into education, a high degree of accountability followed through the growth of standardized, high-stakes testing systems.

Primarily, these standardized tests were set to measure the level of cognitive scientific knowledge, as well as to understanding the population norms (Miller, 1983). Science educators were enticed and entangled by standardized testing, the tell-text-test approach (Rowe, 1983), and teaching to the test. Teachers and school boards began to be greatly influenced by how well their students fared on these tests. Educational innuendo, to this day, equated a ‘good’ teacher with high student scores, and not with the actual “hands-on, minds-on” science the students were able to demonstrate. Standardized testing rewards abilities to retain facts and dates, not measure levels of imagination and problem solving capabilities. In hindsight, the implications of standardized tests were counterintuitive to the desired results of recruiting random abstract inventors and curious mechanics, the very people that often propel the science and technology.

Political stresses, in addition to the increased accountability, drove up the number and frequency of standardized tests in the 1950s and 1960s (Linn, 2001). British Columbia devised provincial examinations for those who failed to meet adequate Grades on school subjects, and also implemented scholarship examinations for post-secondary entrance between 1966 and 1976. Provincial examinations were reintroduced in the 1983/84 school year (Connelly et al., 1985). The negative connotations of having to write high-stakes, externally imposed examinations may have discouraged many students away from science areas.

Curriculum

The responsibility of producing science curricula, during the politically turbulent post-Sputnik period fell to research scientists in highly specialized fields of science (Solomon, 1994, p. 16). Many scientists had little or no teaching experience in K-12 school settings. The Americans chose private schools to introduce new forms of academic science, while, conversely, the British used the higher achieving streamed public school students. Ironically, both American and British reforms yielded roughly the same result; that of a small percentage of the students leaving secondary school well-educated in sciences. This group was described as “an elite corps of students” (Blades, 1997, p. 15), and demographically pigeon-holed as a “homogeneous group of white males” (Champagne & Hornig, 1986, p. 2).

While these reforms were being carried out, much time and money were used to develop laboratory settings, where students could participate in discovery, or inquiry learning, such as the Nuffield Projects (Solomon, 1994). Unfortunately, the laboratory experience became highly structured recipes or cookbooks which lost their appeal for personalized learning opportunities and things became like a game of chance - the winners of the game being the ones who got “the right answer or result”, or realized “what was supposed to happen” (Driver, 1994, p. 43). The cookbook style laboratory exercises were “intellectual dishonesty” (p. 43) on the part of the curriculum planners; “on one hand, pupils are expected to explore a phenomenon for themselves, collect data and make inferences; on the other hand, this process is intended to lead to the currently accepted scientific law or principle" (p. 43).

Abstract theories in physics, chemistry and mathematics textbooks that read more like dictionaries (Rowe, 1983; Hanrahan, 2002; Tobias, 1990), in addition to the full expectation of high-stakes testing, had established the culture of science education by the late 1970s. "Studying science is perceived as a risk" (Osborne, Simon, & Collins, 2003, p. 1071), where the proliferation of high-stakes testing, incorporated to evaluate the costly programs did not, once again, consider the social and personal needs of the students. The format of standardized testing streamed children into various programs, high schools and post-secondary institutions. Scientific knowledge, or content, out-paced and over-shadowed the scientific skills and processes of the average citizen. Cornerstones of scientific literacy, such as practicality and personal relevance, were absent due to the belief that only the academic content was relevant.

In 1970, a series of several studies explored the state of science, mathematics and social studies education programs which had been implemented in the post-Sputnik era (De Boer, 1991). Positive comments included: the learning material was more updated, and that it contained more pertinent information; it contained more laboratory or discovery activities, and dealt with a smaller number of significant concepts. Criticism revealed that the subject matter was still too difficult for average high school students because of the depth of abstractness and theory. The science was not "help[ing] people in their everyday lives, or allowing them to make a contribution to the well-being of society, and nor was it interesting to the students" (De Boer, 1991, p. 189).

Educators

Dewey recognized the contempt that pre-service and practicing teachers had for science, teaching eighty years ago; "they want very largely to find out *how* to do things with the maximum prospect of success. Put baldly [bluntly], they want recipes" (1929, p. 15). "I suspect that if these teachers are mainly channels of reception and transmission, the conclusions of science will be badly deflected and distorted before they get into the mind of the pupils" (1929, p. 47). Despite reform efforts, this observation ironically remained the norm for government, teachers and students alike in the latter half of the 20^{th} century. The desire of both teachers and students to "get it [information and practices] right" correlated to the heavy curriculum demands for both sides. Time constraints of the school calendar and arbitrary reporting periods incubated impatience for understanding to take place. Problems in implementing such a curriculum were that the body of knowledge grew exponentially, and that technology advanced rapidly (Shamos, 1995; Solomon, 1994).

Porter and Brophy (1988) suggested that much of the education from the 1950s to 1970s was developed under the assumption that students and teachers did not play important roles in education. If fact, teachers were considered to be weak links, or technicians to be programmed. Textbooks and learning resources were produced to leave little human error in the delivery of the subject-specific concepts which were covered, hence the term teacher-proof textbooks (Bybee, 1997a; Porter & Brophy, 1988). Science educators were increasingly entangled between standardized testing (Rowe, 1983) and curricula. The irony of accountability and performance resonated through the twentieth century, where teachers were responsible for students' test scores but had very little influence in the material they taught. Teachers taught students keenly interest in the science but many may have performed poorly on the standardized test. In failing to recognize the humanness in the curriculum, practical everyday science and social implications were omitted, in favour of detached rote facts and memorization. Hodson and Prophet (1994, p. 35) asked two simple questions of science education, "whose view of science is being adopted in the curriculum, and whose interests are being promoted by the particular view of school science that is adopted?"

Current issues in science education

Many academics admit scientific literacy is difficult to define, and there is no shared definition (Aikenhead, 1996; Anderson et al, 2009; Bybee, 1997a; Christensen, 2002; De Boer, 2000; Dillion, 2009; Hodson, 2000; Kemp, 2000, 2002; Laugksch, 2000; McEeaney, 2003; Millar & Osbourne, 1998; Miller, 1998; Osborne et al., 2003; Sadler, 2002; Shamos, 1995; Yager, 2000; Yore, Bisanz & Hand, 2003; Yore et al, 2007). A consensus was formed between some proponents of scientific literacy but some scholars argued that scientific literacy was unattainable. Shen (1975) proposed three logical categories for scientific literacy: practical, civic and cultural literacy. Practical scientific literacy involves science knowledge required for practical or everyday problems and needs, such as obtaining shelter, adequate healthcare and food and water. Civic literacy involves actively participating in the decision-making processes around socio-scientific and political issues. Miller (1983, 1998) references Shen's practical and civil literacies in his work, and Shamos (1995), despite his reservations about aspects of scientific literacy, refers to Shen's practical and civic literacies in a positive light. Cultural scientific literacy would be reserved for those involved in the "intellectual community" (Laugksch, 2000, quoting Shen, p. 77). The goal for mainstream scientific literacy encapsulates the practical and civic aspects.

Kemp (2002) accepts scientific literacy as worthwhile, but has reservations about its praxis. He prefers a qualitative philosophical approach and regards scientific literacy as a philosophical goal. He takes the stance that, "fifty years of science educational reform goes in cycles, based on popularity, not results" (2000, p. 4). At least the recognition of scientific literacy is present. He questioned whether the methods used to attain scientific literacy are worthwhile. If scientific literacy is truly as important as it is claimed, he argues, then science teachers need to promote scientific literacy and its methodology to the public, as health and humanitarian issues, and not just for reasons of science education. His later work and dissertation focus on the fact that teaching for scientific literacy is difficult, since the term itself has not yet reached any consensus (2002). In this way, Kemp (2005) is reluctant to push scientific literacy as a wholesale curriculum goal, but does endorse meaningful, relevant science education.

The direction and processes needed to attain scientific literacy are contentious. As the educators, educator-researchers and politicians embarked on issues of K-12 science education, a league of scientists and political pundits defined and redefined scientific literacy for the adult population. Miller began revealing US survey results of adult inadequacies in scientific knowledge, in 1983. By publishing such findings, he exposed one of the world's most influential countries as scientifically illiterate galvanizing the American resolve to improve. Miller's initial survey questions are still used today as international standards (NSB, 2006). Different types and forms of scientific literacy were debated (Anderson, Lin, Treagust, Ross, & Yore, 2007; Anderson et al., 2009; Bybee, 1997a, 1997b; De Boer, 1997, 2000; Hodson, 2000; Hurd, 1998; Kemp, 2000; Laugksch, 2000; Millar & Osbourne, 1998; Rubba & Anderson, 1978; Ryder, 2001; Shamos, 1995; Yore et al., 2003, 2007). Regardless of whichever way scientific literacy was defined by scholars, the adult population failed to retain basic facts of science taught during their time in the Grade K-12 system. The connection between school-age science and adults fused, and fuelled the need for alterations in science education.

Scientific literacy encapsulates a number of ideas, methods and tools that humankind requires, in order to gain and make sense of their knowledge, and to address pressing issues. Yore et al.'s (2007) interacting senses of scientific literacy appears to capture the dynamics amongst ideas, methods, tools and issues. According to Yore, scientific literacy includes NOS as a derived sense; a big idea of science involving specific methods, tools, attitudes and processes. NOS, a subset of scientific literacy, is the central theme of this study. One description that aids me in understanding literacy is not what you do know, it is the steps you take when you do not know. Critical thinking skills, inquiry and cognitive and meta-cognitive abilities for science fair projects, research papers, environmental issues, or even purchasing a car or a mortgage can require scientific literacy. The role of a science teacher is to support and guide students; to see how they navigate, retrieve and process information that ultimately leads them to their own knowledge base.

Christensen (2002) uses Latour's (1987) work to differentiate between school-aged children's and adults' scientific literacy. In school, children are presented with ready-made science and facts. As an adult, issues arise where the science is uncertain and controversial. Latour referred to these science problems as science-in-the-making. Sadler (2002) expressed that all science is subject to human bias and emotion. Moral and ethical decision making is the missing link from science education according to Shen's (1975) "civic science literacy". Adult public understanding of science requires connecting many factors, whereas the scientific literacy surveys such as Miller's, Einsiedel's and the Science and Engineering Indicators pertain to school-aged scientific knowledge, not critical thinking skill-sets which the adults use. The Organization for Economic Co-operation and Development's (OECD) Programme for International Student Assessment (PISA) has recognized this, and has assessed students on broad literacy to meet 'real-life' competencies, or knowledge that they use as a result of schooling, rather than a specific school curriculum (accessed online April 24, 2010, http://www.pisa.oecd. org/ dataoecd/51/27/37474503.pdf).

Christensen (2002) puts forward a convincing argument that, perhaps, adult scientific illiteracy is based on false assumptions, and that the scientific facts children learn are the types of science that adults employ. Ungar (2000) refers to this phenomenon as a "knowledge-ignorance paradox" (p. 298), "informational explosions" and the crisis addictions that plague popular culture (p. 298). Science, Ungar writes, is ill equipped to compete in the "attention economy" (p. 298) of today's world. Socially, there is little reward for those who are scientifically literate, unless motivated extrinsically; "there does not appear to be sufficient payoff, in day-to-day events and conversation, to endure the costs of scientific literacy" (p. 308). Thus, only need-to-know events, or circumstances, actually motivate adults to learn discrete pockets of science knowledge, for example, health issues such as heart attacks or asthma, or environmental issues.

A public, or macro-scale knowledge-ignorance paradox describes where the public is sincerely concerned, but the media, crisis jockeys, 'infotainment' specialists, and even the science community itself, provide half-truths and inappropriate information (Tytler, Duggan & Gott, 2001). The public gains knowledge but the source may be questionable or the information is abbreviated excluding relevant items. The reality is that the average public gathers its scientific knowledge in the form of sound-bites, captivating photographs and sensational headlines, and not in structured settings, textbooks and processes, as school-aged children do (Ungar, 2000).

Over the last thirty years, science education has transformed itself from a possible career choice of the highly intelligent, to a source of knowledge required for the average citizen (Ediger, 2002). The introduction of the personal computer in the late seventies and the creation of the Internet have not only redefined technology, but have also indelibly increased access to the body of knowledge of science. Science, technology and human activities had impacted on every society by the end of the twentieth century. Ozone depletion, nuclear energy, waste management, biotechnology, mass food production and pollution forced citizens to recognize the sometimes negative impact of science and technology (Ediger, 2002; McEeaney, 2003). North American efforts recognized the importance of the well-informed citizen, and regulations were implemented to ensure science education became more relevant to all young citizens (AAAS, 1989; NSTA, 1990). In Canada, the comprehensive 1984 Science Council of Canada, Report 36 (Fawcett, 1991), touted scientific literacy and NOS as the impetus for key components of reform.

Current political and assessment tensions

In 1993, The Canadian Ministers of Education Council (CMEC) endorsed the Victoria Declaration, outlining the need for future cohesive science education. The Pan-Canadian Protocol, the blueprint for The Framework, materialized in 1995, and the Pan-Canadian Framework for Science Learning outcomes were introduced two years later. Chapter 3 of the Pan-Canadian Framework details broad attributes of scientific literacy. Specifically, science education aims to help students:

- develop a sense of wonder and curiosity
- acquire new knowledge and solve problems, address science-related societal, economic, ethical, and environmental issues
- create opportunities to pursue progressively higher levels of study and
- develop aptitudes and interests for a wide variety of careers

One decade later, the rationale for the B.C. learning outcomes for Grades 8 to 10 is identical to those of the Pan-Canadian Framework, and the curricula for Grades 8-10 consolidate and integrate these ideas into four critical goals (BCME, 2008):

1. Science, technology, society and the environment (STSE)
2. Skills
3. Knowledge
4. Attitudes

These four goals are identical in interpretation to those promoted by Hurd and Harms in the 1970s (Yager, 2000) and Connelly et al (1985). While the CMEC Framework reflects the Science for All Americans (AAAS, 1989), with a Canadian spin, therefore, Canada and the United States now strive for the same goals for school science education: to graduate generations of scientifically literate citizens.

The International Institute for Educational Planning (IIEP) undertook a five-year study of science education (Caillods, Gottelmann-Duret & Lewin, 1997). The findings provided insight into how science education was progressing, in the light of the social reforms of science. The study found that issues were still persistent in 1997:

- Science was considered a difficult subject to master
- Girls participate less with lower scores

- Inequalities exist between rural and urban schools
- Examinations continue to be mainly recall items and
- High-stakes testing still determines "life chances" for students

These findings support Shamos' (2005) claim that a number of post-mortem studies were done in the 80s, with similar results: if anything, the overall positive effects of the new curricula were marginal: they had no profound effect on student performance. Even with the past three decades of science education reforms, the same problems persist internationally: a shortage of skilled employees; science curriculum concerns focused on recall; and the high-stakes testing determines success to furthering education.

Many science curricula do not make the content personal and relevant to the learners (Driver, 1994). One of the problems is that connections, which are apparent to a scientist, may be far too abstract for students, which means the coherence as perceived by the student has not been achieved. Traditional science teaching materials paid little attention to the ideas that students bring to the learning task, which are significant influences on what students learn in a constructivist classroom and how they apply these ideas to other contexts. PISA asserted that:

> "...students who have acquired some measure of scientific literacy will be able to apply what they have learned in school and non-school situations. A scientific situation is used here to indicate a real-world phenomenon, in which science can be applied." (Accessed online April 24, 2010, http://www.pisa.oecd.org/dataoecd/44/63/33692793.pdf, p. 78)

In the latest OECD PISA results (Bussiere, Knighton, & Pennock, 2007), Canadian youth scored well above many of the fifty-seven countries that participated. Only Finland and Hong-Kong (China) performed better than Canada. All ten provinces took part in the 2006 assessment and formed the national average for Canada. British Columbia finished well within the national average[1].

In light of the 2006 PISA scores, why bother with continuing the discussion about scientific literacy in British Columbia? The last PISA conducted in B.C. was based on the fact that the 15 year olds were educated under the former IRPs during their schooling from Grades K-10, prior to the 2006 assessment. The new IRPs, promoting scientific literacy, were not yet implemented at the middle or secondary schools, and teachers were very comfortable with the older curriculum, as little had changed since 1986. The next national assessment was the Pan-Canadian Assessment Program (PCAP) (Council of Ministers of Education of Canada (CMEC), 2008) for thirteen year olds (Grades 8 and 9), coinciding with the PISA testing for 15 year olds in 2009 (Figure 1). These assessment results will be the first national and international results for B.C. students who were educated under B.C.'s new science curriculum.

[1] PISA assessments are completed every three years. Each session tests reading, mathematics and science, with a specific focus for each round

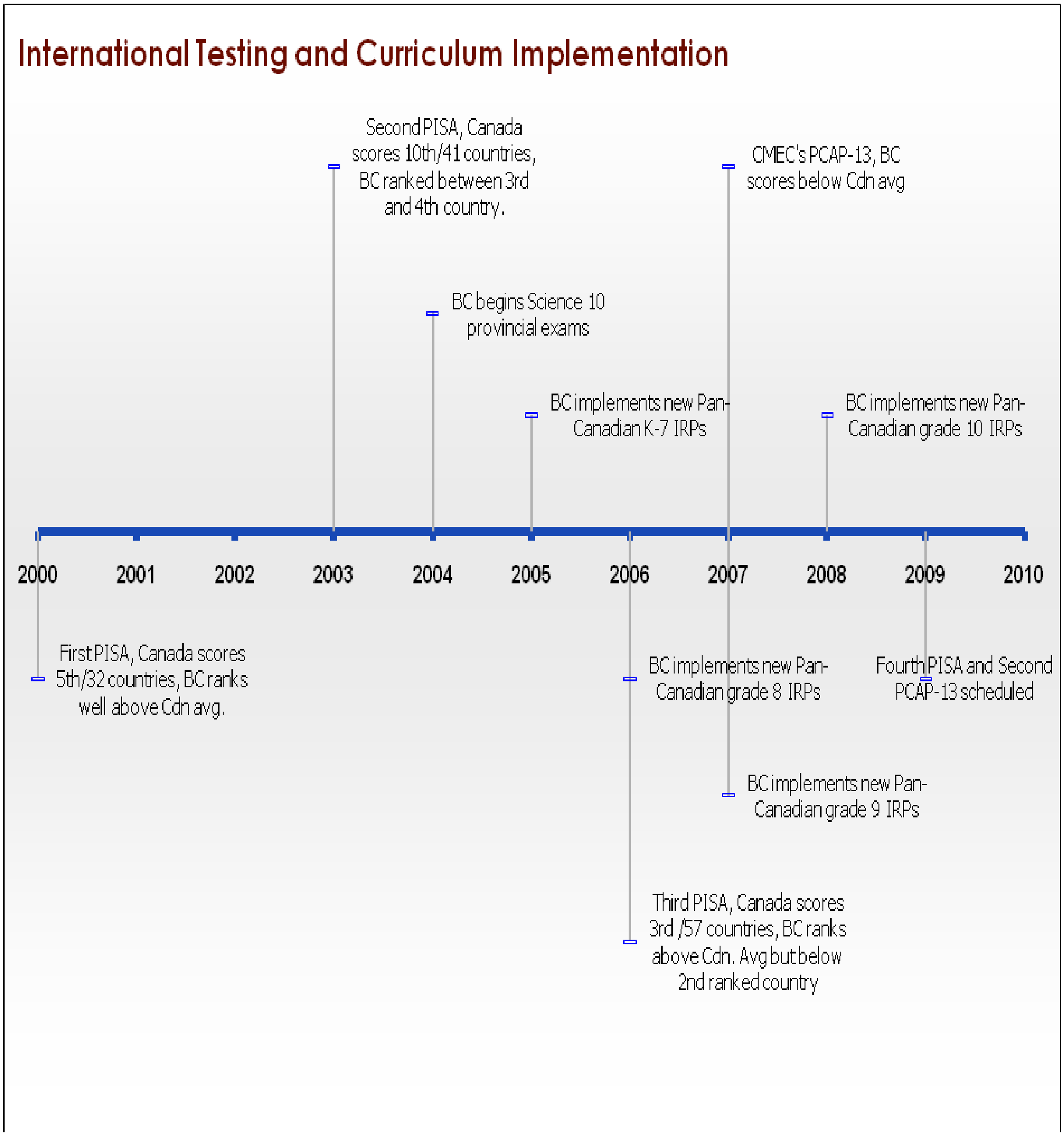

Figure 1. Timeline of international testing (PISA) and national testing (PCAP-13) with respect to BC's IRP implementation.

B.C. curriculum / Integrated Resource Packages (IRP)

The PISA 2009 and PCAP 2008 scores will provide some interesting feedback, as this group of students started the new science curriculum, with a science literacy focus, in 2005 (accessed online April 24, 2010, http://www.bced.gov.bc.ca/irp/irp_sci.htm). Unique to B.C., the science curricula break down into prescribed learning outcomes (PLOs) and Achievement Indicators (AIs). The Ministry of Education states:

> Prescribed Learning Outcomes (PLOs) are the legally required content standards for the provincial education system. They define the required attitudes, skills and knowledge for each subject. The PLOs are statements of what students are expected to know and be able to do by the end of the course.

B.C. has used PLOs since the 1996 revised science curricula. Alberta's equivalents of PLOs are called "General Outcomes", and in Ontario these are referred to as "Overall Expectations" (Alberta Education, 2005; Ontario Ministry of Education, 2008). Nova Scotia's Learning Outcomes Framework is called Specific Curriculum Outcomes (Nova Scotia Department of Education). Each province, although influenced by the Pan-Canadian Framework, has autonomy in their education programs, and refers to their specific learning items differently.

The B.C. Ministry of Education (MOE) has defined AIs as:

> "...statements that describe what students are able to do, in order to demonstrate that they fully meet the expectations set out by the PLOs. Achievement indicators are not mandatory; they are provided to assist teachers in assessing how well their students achieve the PLOs."

AIs are the newest term used by the MOE and have no similar prescriptive tool in Canada with which to compare. British Columbia is the only province or territory that divides their learning outcomes in such detail. These indicators are a completely new concept to B.C. science classroom teachers. As the AIs are the most obvious change in the BC IRP transition, it is my intention to devote time to exploring how AIs are perceived by the government through interpretation of provincial examinations and teachers' perceptions and experience.

Recent pre-service teacher education descriptions

Most student teachers in B.C. are educated in one of nine post-secondary teacher education institutions. The Saanich School District 63 (SD 63) hosts pre-service teachers associated with the University of Victoria (UVic). The UVic program consists of campus-based coursework and various clinical experiences. The coursework addresses general pedagogy, foundations, content specialties and assessment. Historically, a secondary teacher education program had two streams: a year-long practicum, and an internship program or a twelve-week practicum. The internship program had many benefits to the pre-service teacher, since they were involved in a full cycle of the school years, and in course delivery. Start-up and report card routines were quickly established, students accepted the pre-service teacher as teaching staff sooner, and the longer teaching experience was desirable for future employers. UVic supported year-long practica in the Victoria and Kelowna regions, and the twelve-week continuous program allowed students to maintain a September to April school calendar, as well as to observe classroom teachers within a school day and to work part-time.

Due to the changes in the BCCT requirements, this UVic educational option was discontinued in 2007. The shorter practicum was altered, in accordance with the Association of B.C. Deans of Education (ABCDE) and BCCT's *Letter of Understanding (LOU)*, between the nine post-secondary institutions that offered teaching programs (BCCT & ABCDE, 2004). The surveys of pre-service teachers who were involved in this study took place in the 2006-2007 school year prior to any program changes at UVic. Timing of courses, classroom observations and requirements of teachers have since changed.

Research methods for scientific literacy

Science literacy is a credible indicator for looking at teacher education and for on-going development. Scientific literacy is used as an international indicator for quality of education by means of assessment results and is definable and measurable in the classroom (Olsen, 2004; Olsen, Turmo, & Lie, 2001; Orpwood & Garden, 1998). Countries have embraced scientific literacy so it stands to reason that scientific literacy can be utilized to evaluate science teachers. It is logical to expect that teachers should be educated in the very same context as students are.

The work of four scientific literacy researchers: Aikenhead (Canada), Miller (US) and Laugksch and Spargo (South America), has produced three validated surveys of scientific literacy. The most comprehensive and in-depth scientific literacy research instrument was called VOSTS (Views on Science-Technology-Society) (Aikenhead & Ryan, 1992; Aikenhead, Ryan, & Fleming, 1989), and several researchers continue to add to, make adjustments to and improve and adapt VOSTS, to maintain the high standard (Botton & Brown, 1998; Rubba, Bradford, & Harkness, 1996). Miller (1983) created the second scientific literacy questionnaire, used with the American public on a continuous cycle. The results of this instrument precipitated widespread indignation and spurred the American government to take up the issue of scientifically savvy citizenry. Miller continues to collaborate with OECD, and other international organizations, to produce and analyze scientific literacy data (*Jon Miller's Faculty page*, 2006). The third instrument is the *Test of Basic Scientific Literacy* (Laugksch & Spargo, 1996a, 1996b), which utilized the first two surveys in its development, and which is currently used in South Africa, administered to students leaving high school. Other notable research instruments used by Rubba and Anderson (1978) and Lederman (1992, 2000) address only NOS and not practical scientific literacy, as defined by Shen (1975).

The VOSTS (Aikenhead et al., 1989) proved to be unsuitable for the purposes of this study because of administration, complexity of scope, and also because of the time required of participants. Each of the 114 VOSTS questions has paragraph answers and semi-structured interviews. The original survey was 116 pages long, deemed too time consuming for busy preservice teachers to complete three times during their practicum year. The number of possible choices cannot be marked by machine, and there are no correct answers as the survey only records students' ideas (Aikenhead & Ryan, 1992,). Furthermore, the nature of the VOSTS did not lend itself to "test-retest comparisons and hypothesis testing" (Rubba et al., 1996, p. 388), and the instrument itself measures values (Lederman, 1986).

Miller's 1983 surveys delve into the general public's beliefs, formed by high school and personal experience: (1) a vocabulary of basic scientific discourse, sufficient to read, compare and contrast views in a magazine or newspaper; (2) an understanding of NOS; and (3) a level of understanding of the impact of science and technology on individuals and society (Miller, 1998). Most meaningful to this project, Miller focused on a critical indicator of media as sources for his questionnaires. Scientific literacy advocates encourage the use of newspapers and magazines for scientific literacy (Bardeen, 2000; Jarman & McClune, 2001; Korpan, Bisanz, Bisanz, & Henderson, 1997; Matricardi, Muratori, Porro, & Capozza, 2000; Ryder, 2001) as a current, tangible measuring tool for civic and practical science literacy.

The mass media of television, newspaper and the Internet are the largest sources of current scientific issues to the general public (S&E Indicators 2006, Table A7-3). Miller's research instruments use science stories and information collected in the media in order to base his measurements on practical scientific literacy. His results bring to light the dangers of the sound-bites used in "infotainment" (Ungar, 2000) or "infobits" (Shelly, Yore, & Hand, 2009), gleaned by the media consumers. Scientific literacy, linked to mass media, has spurred on some interesting and varied forms of research. Korpan et al (1997) used real and fictitious news clippings in order to understand what types of questions people would ask as they assess the articles, typical of questions asked in school. Ryder (2001) promotes the use of newspaper and mass media to encourage functional scientific literacy in school children and to nurture and cultivate the types of questions individuals should seek to ask when they read the different media.

The instrument most suited to this proposed study was *Test of Basic Scientific Literacy* (TBSL) (Laugksch & Spargo, 1996a, 1996b). Item generation, content expertise, pilot studies, validity and reliability have been addressed extensively. The items can be used with little concern that the prior testing has influenced the results, as participants answer only True (T), False (F) or I don't know (?) for each item. Answers are not specific or unique, so items that reward memorization are eliminated or reduced significantly.

Like the VOSTS, the TBSL was deemed too time-consuming for pre-service volunteers; several aspects of the instrument were employed in attempts to produce the instrument. Desired surveys needed to be reasonable to take, answerable via a web-based venue and have test-retest potential, in order to measure if the year of experiences would have students change their answers. The composite instrument used was a combination of five pieces of work that have been deemed valid and reliable. Einsiedel's *Mental Mapping of Canadians* (1994) and Miller's adult scientific literacy questions (Miller, 1998; NSB, 2006) were used, with reported results and the *Science and Engineering Indicators (NSB, 2006)*. Together, these questions formed the scientific literacy component of each of the three surveys. NOS questions were taken from Rubba and Anderson (1978), which also supported the work of Spargo and Laugksch (1996a; 1996b) and Lederman (1992; 2000). Each sub-scale section tested equal numbers of ideas, with some questions duplicated in order to maintain the same number of items in each test. This melding of instruments reduced time pressures on the preservice teachers but still allowing for preliminary sampling of different topics of scientific literacy and NOS. Pedagogical content knowledge (PCK) questions reveal participants' views, while understanding of scientific protocols in teaching were answered using long answer questions, in a post-survey taken from *Salish I Research* (Richardson & Simmons, 1994; Simmons et al., 1999).

The volunteer in-service teachers are also under time constraints. The focus of this project is to begin to understand the impact, if any, that explicit scientific literacy included in the new IRPs has had on the intended targets, the middle and secondary students. Interview questions for in-service teachers were written with the pressures of classroom in mind: they use the IRPs to direct the content, process and affective focus of instruction.

The in-service teachers will be interviewed using comparisons of the affective domains and common PLOs between former and current IRPs. The *Applications or Procedures of Science*, identical in all three Grade levels, represent the explicit scientific literacy component. Commonly transferred PLOs across the old and new IRPs comprise less than 50% of the new IRP packages. The purpose of the interviews is to gain insight into how the impact of explicit scientific literacy in the new curriculum directly affects the realities of junior high school teachers whose courses they taught had undergone a complete redesign. Anderson et al. (2009) conducted a parallel exploration of the new science curricula across Canada. Each participant in the study added valuable insight into items of the Framework, but some provinces had had it implemented since its inception in 1996, and now the novelty of the change has abated.

B.C. has only recently implemented the Framework (1997) as it missed the last round of curricula revisions (1996). Another purpose of this project is to begin to understand if there is a trickle-down effect, since the B.C. science education mandate was altered to explicitly teach scientific literacy and NOS in individual classrooms. The project’s three areas are: to assay new science teachers’ science literacy with a pilot survey; to analyze common units between old and new IRPs and to gain insight into the realities of the new curriculum in science classrooms. This may serve to describe an overhaul in B.C. education, akin to the instructional changes in the sixties.

The impetus of the CMEC Framework is to return science to an endeavour that all citizens understand and use to better society, be it environmentally, with food technology, with waste management or with alterations in the medical system. This is to be done by the time Haley’s Comet reappears in our skies - 2061. The scientific literacy and NOS push is still in its infancy, and has far to go. However, history can repeat itself, as with the last major reform of the post-Sputnik era. Decades of research, starting in the seventies, continually denounced the changes in science education as ineffective and alienating. For science literacy truly to take hold, teachers, who are, for many, the last link to a formal science education, need to embrace science literacy as a necessity for local and global society, and not just as another top-down government directive or cute slogan. This project attempts to collect qualitative data to support the written government policies that support the teachers, and scientific literacy is a strong impetus in teachers who facilitate it.

Chapter 3
Methodology

The central focus of this project explored the degree of understanding and awareness that teachers have, both pre-service and in-class, concerning the NOS and scientific literacy emphases in the new B.C. IRPs for junior science (Grades 8 -10). The aim was to inform the reader of the impact that the new explicit themes of scientific literacy and NOS have had in working classrooms, and also of the understandings that pre-service science teachers possess, as they enter their practicum year of education. The project is divided into three parts: pre-service teacher volunteers complete three surveys during their final year; document analysis is carried out, of common portions of the old and new IRPs for Grades 8 to 10, including the applications and processes of science; and a peer interview is done, of junior science teachers as a focus group, to add depth to the IRP document analysis, and to provide anecdotal evidence of the changes they observe in their classrooms with the new IRPs.

Pre-service component

The project determined the level of scientific literacy of a volunteer group of pre-service students as they work through their practicum year gaining insight into the level of scientific literacy, especially NOS, and later STSE (Science, Technology, Society and Environment) issues in the news. The pre-service secondary science teachers completed three surveys: prior, during and after stages within their teacher education program. This documented the influences of the methodology courses, as well as the practicum phase. By surveying the students before and after their methodology class, differences can be attributed to this pedagogy course[2]. The third test occurred at the end of the student teachers' appointed practicum, cumulating the academic and first hand experience which documented the

[2] Current preservice education practicum year has changed. The survey results and subsequent evaluation are not any reflections on current model of delivery.

influences of the teacher education program. Only pre-service teachers who completed all three surveys are utilised in this project, which documented changes that occurred as a result of the field experience. Undoubtedly, the student teachers' experiences of learning science, as well as the complex task of teaching, will require the largest amount of self-negotiation and cognitive reorganization. High school students, without the knowledge and specific discourse of the pre-service teacher's science subject area, will force the pre-service teacher to challenge their own forms of learning and assumptions, to better demonstrate basic ideas without the specialized discourse learned in post-secondary schooling. Administering a post-test after the practicum experience should demonstrate the largest changes in scientific literacy.

Survey instrument

The main concern in documenting their science literacy is that of providing an instrument that is criterion-referenced, the construct validity of which has already been established, and that problems therein have been minimized for instances of retesting. Retesting of participants is a critical feature of this study, because an initial, mid-program (post course work but pre-practica) and post practica/program was planned. During the compilation of scientific literacy and NOS surveys, the TBSL (Laugksch & Spargo, 1996a,b) was used as a basic framework because they wrote in depth about the language and grammar strategies that constitute sound valid test items. Although, pedagogically, true and false or multiple-choice answers do not represent an in-depth form of assessing learned knowledge, the rationale behind the true and false questionnaire was sound, especially for test-retest procedures. Due to time restrictions, I was unable to utilize the extensive TBSL for pre-service teachers. The aspect of the survey that was important to me was understanding how the TBSL morphed into an instrument with high reliability and validity.

Rubba and Anderson's NSKS (Nature of Science Knowledge Survey, 1978) was utilized in the TBSL framework, as well as the other successful surveys attempting to encapsulate science literacy and NOS. Over the last thirty years, academics continued to write and reference NSKS, which indicates that the items held equally high reliability and validity (Abd-El-Khalick & Lederman, 2000; Abd-El-Khalick, Lederman, Bell, & Schwartz, 2002; Aikenhead & Ryan, 1992; Aikenhead, Ryan, & Fleming, 1989; Einsiedel, 1994; Laugksch, 2000; Lederman, 1992, 2000; Lederman, Wade, & Bell, 1998; Penick, 1993; Rubba, Bradford, & Harkness, 1996). The scientific literacy items were collected from the media-based instruments of Miller and Einseidel. Miller's survey questions have been used in the International Science and Achievement Indicators (SEI) for many years and continue to form the baseline for the general public's understanding of science. Einseidel interpolated Miller's work to assess Canadian sentiment towards science and technology. In the given time constraints, using well documented instruments had many advantages over constructing an original instrument.

Development of the Scientific Literacy/NOS Instrument

Time limits and functionality were of the essence, in order to assemble a three part instrument. The NSKS were chosen because of the large number of citations, and because the statements were short and concise. The original NSKS had forty eight statements, distributed evenly between six NOS sub-scale categories, giving eight statements per group and, within each grouping, four statements were positive and four were negative. Further paring of the numbers of statements was required due to the ethics committee's concerns the cumulative time required for a three part survey was too much for preservice teachers. Of the six sub-scales, amoral and testable are two of the most familiar themes of science taught in schools. These two categories had only one statement provided for each in each survey. The other four sub-scales are less defined in a school setting, and least often associated with the processes of science. Each of these sub-scales had two statements on each survey for the NMOS portion to allow for more comparisons and understanding of which scale produced more growth during the practicum year. This accounted for ten NOS questions.

The statements had to leave no room for questioning the wording or format. The surveys were double-blinded, which means a third party moderated the notification and collection of completed surveys and produced a confidential coded identification system unavailable to me. Communication between the participants and me did not take place. I had the potential to become a sponsor teacher for one or more of the preservice volunteers so power over issues had to be addressed using complete anonymity. I was unable to clarify or explain anything on the online surveys so the directions and questions had to be concise to leave no room for over-thinking or doubt. NSKS items with compound sentences and/or numerous prepositional phrases were removed, as possible choices for readability reasons. Readability was estimated using the Flesch-Kincaid approach (http://www.online-utility.org/english/readability_test_and_improve.jsp). The pilot trial (Appendix A) verified that the changes improved the survey's readability. Keeping in mind the advice used while developing the VOSTS and TBSL instruments, double negatives were avoided and the word 'not' was used sparsely.

The task remained of which statements to include in the three surveys, given the constraints of 6 sub-scales and the limitations on size of survey. Statements that differed in their wording but which had the same sentiment were considered as being one and the same. For example, in the developmental category, NSKS no. 26, "*Today's scientific laws, theories, and concepts may have to be changed in the face of new evidence*." and NSKS no. 37," *Scientific knowledge is subject to review and change*." NSKS no.37 was used and no. 26 was discarded because of readability and, given size limitations, one idea with one statement was employed. The negative forms of statements were removed. These criterion allowed the eight original statements on each sub-scale to be reduced to five (appendix C). The statements were separated into the six categories, and one item for amoral and testable, and two each for the other four were randomly selected. After each survey, the statements were returned to their respective categories for the next draw of ten stems. Therefore, the three surveys were not identical, but randomly selected representations of the six categories. Individual statements had the chance of being drawn for next survey.

The last change to the NSKS was the choices provided for the participants. Knowing that the scientific literacy section of the surveys would be simply true or false, the Likert 5-point scale of the original NSKS was judged not suitable. The choice of 'don't know' was provided in the British telephone surveys (Durant, Evans & Thomas, 1992). Laugksch and Spargo (1996b) had lamented that their true/false questions could have used an 'I don't know' choice, to discourage students from guessing, and therefore modifying the true/false items with an 'I don't know' choice; it was possible to provide a 3-point Likert-like scale for the scientific literacy scale. The modified answer choices also provided insight into the scientific literacy statements that participants did not know and, at the same time, afforded some choice in the NSKS.

The set of sixteen science-based questions stemmed from studies in the media, portraying science and disseminating scientific stories. Media and science relationships are imperative to understanding how citizens, or the ‘non-attentive public’ (Miller, 1983), acquire practical and civic literacy (Shen 1975). The scientific questions have been extensively used in the Science and Engineering Indicators (S&E) since 1993, and also used in telephone surveys in Britain twenty-two years ago(Durant, et al., 1992). The sixteen questions were drawn randomly, and returned for possible redraw in a later set. These questions are used in Miller’s survey, and also in Einsiedel’s, and the International Science and Engineering Indicators are completed on a regular basis, with high validity and reliability statistics.

The complete survey was piloted with six practicing teachers. Each teacher had classroom experience in junior science, one had written junior science textbooks for Alberta and B.C., and two were practicing Learning Assistance teachers. The advice provided indicated that the Rubba items were too vague and left many interpretations for the teachers (Appendix A: Pilot of Scientific Literacy and Nature of Science Modifications). Using the online analysis, the original statement was entered and compared to the suggested modified version. Each correction increased the readability and Grade level of the statements. The science knowledge questions were less controversial, but small punctuation and syntactic changes were recommended to clarify two of the eleven statements. The teacher suggested that the participants will likely be looking for more “hidden” meaning in the statements, rather than accepting them at face value. Statements should be fairly restrictive, leave little room for “over thinking” and be self-explanatory. Appendix A provides the original statements, with the refined statements used in the three surveys.

Changing the format of the instrument in any way requires verification of the modified version. Given the wide use of the surveys in a large and long-standing public domain, permission from the original authors was not requested. Validity and reliability of each item were assumed to be reasonable in the modifying survey, however, a Cronbach α was run on the 18 items of each survey, in attempts to establish the internal consistency, which will be reported later (Chapter 4).

Data collection

The initial focus of this project involved collecting three surveys and completing a quantitative data analysis to document NOS understanding during a practicum year. Ethical approval required that the results of the three surveys were only to be released after the practicum year was completed, at the end of April 2006. The surveys were submitted to a third party. Electronic correspondence at the end of the science methods course and pre-practica, and also at the closing of the practica term, was relayed through the third party. Unforeseen complications just prior to the first sitting effected a lower than expected participation rate of the web-based survey. Only a portion of participants (N= 6) completed all three surveys, and were compared for growth. Therefore, descriptive analyses were used because of the small survey size. Acceptable α values <0.70 were not expected, given the disappointing sample size.

Document Analysis: Integrated Resource Plans (IRPs) / Prescribed Learning Outcomes (PLOs)

The IRPs for the document analysis were obtained from the MOE website. The older 1996 curricula are no longer available online but an Internet search found copies of the older IRPs at http://nature.ca/genome/05/051/0514/0514_ref_e.cfm#070. Due to the length of documents for each Grade, only the common portions of the IRPs were examined. Comparison of the parallel portions of the older (1996) and newer versions (2006 - 2008) concentrated the effort on familiar material for focus groups, which would allow teacher participants to speak with some expertise and practical experience.

Each junior science IRP was broken down into the content areas of traditional study: physical science (chemistry and physics), earth and space, and biology. Although the subject disciplines remained, the diverse content of each area could have produced an entirely different set of learning outcomes with identical topic headings. The starting point of the analyses was the common learning outcomes. The rationale and goals of each IRP version carried the same doctrines: that science was to enhance the quality of life, encourage life-long learning and tolerance, increase employment opportunities and problem-solve real life issues. Each new junior science curriculum carried over different sections of the former IRP. The learning outcomes that were common to both the 1996 and 2006 Grade 8 courses were light waves and kinetic molecular theory. Grade 9 had chemistry and astronomy in common between the 1996 and 2006, and Grade 10 earth science (plate tectonics) and most portions of chemistry were similar.

Much of the analysis was focused directly on the impact of the new Achievement Indicators (AIs), introduced in 2006 – 2008. Achievement indicators (AIs) are unique to the new curricula. PLOs cannot be compared directly to AIs as part of the teaching directives because both versions of the IRPs contain PLOs already. Overall changes in learning outcomes and topic areas were noted in tables, which examined common learning outcomes between the 1996 and 2006-2008 junior science curricula (Appendix G, Tables9-11).

Teacher focus group

The focus group was composed of practicing teachers, who have experienced teaching the current IRPs, who could provide insights into the changing praxis of the new IRPs compared to the 1996 versions. This focus group provided insights to compliment the pre-service teachers as they entered the new educational mandate, and the IRP documents illuminated the new features effected by the Pan-Canadian Framework. The in-class teachers represent the classroom realities where broad bureaucratic policy intersects with the intimate needs of student learning.

The stipulations to receiving an invitation to participate were that the teachers must have had experience teaching both older and current versions of the same grade of science. This constraint removed many teachers from possible participation because Grade 8 is taught in a middle school (Grades 6 to 8) and teachers may have multiple assignments, and the science 9 and 10 are taught together in the secondary schools in the Saanich School District. Middle school teachers teach Grade 6 and 7 as well. Some teachers felt that the time lapse since teaching old and new Grade 8 science was not helpful for the interview, while other middle school teachers were taking on the new curriculum for the first time and had not yet put the course into any kind of perspective. Grade 9 and 10 teachers have the opportunity to teach both Grades at the same time in a semester system, and often do. There was a considerable population of teachers that taught only senior Grades of science, or were finishing teaching junior science for the first time.

Recruiting teachers with experience in both old and new curricula for Grades 9 and 10 was a difficult process because many teachers had not taught these assignments. Five teachers, teaching Grades 8 to 10 science, volunteered to be interviewed about the changes in the junior science curricula. The resulting group of teachers was two Grade 8 teachers (one from an 8-12 school, the other from a 6-8 middle school), and three teachers who have taught Grades 9 and 10 science from both the 1996 and current IRPs. One teacher, Barbara, has a BEd, as in the elementary program with an MEd. One high school teacher, Leon, has a BEd with interests and previous studies in a variety of science areas. The high school Grade 8 teacher, Frank, and the remaining three high school teachers have science major degrees, with a post-professional certificate in education.

The focus of the interview was: to have the participants agree, by their grade speciality, that the parallel PLOs, from old to new, were correctly identified as common during the data analysis; to discuss personal changes in praxis after implementation of the current PLOs; and, to relate how the PLOs of science literacy and NOS are woven into classroom instruction. Prior to the interview, the participants received a package of all the PLOs for their Grade(s), old matching with new. Textbooks and complete copies of the IRPs were also available for reference and reflection. Teachers for each grade were interviewed separately. Grade 9 and 10 teachers were encouraged to discuss both grades, as teachers in the high school have normally had teaching assignments of both Grades 9 and 10 simultaneously, or within the given school year. The whole group was then reconvened to address the scientific literacy and NOS PLOs, because Grades 8 through 10 share the identical processes or applications of science PLOs. Teachers prompting one another resulted in a much more lively discussion; the set interview questions for this final section of the interview transformed into probing and clarification, rather than solicited answers. The questions for the semi-structured protocols for Grades 8, 9 and 10 are provided in Appendix F.

Chapter 4
Results

The report of the results will reflect the order of the study: pre-service teachers, document analyses, and focus groups. The psychometrics of any instruments used will be reported as part of the results.

Pre-service Survey Results of Scientific Literacy

Pre-service students' definitions of science literacy and NOS were in keeping with commonly held understandings of these ideas. The term 'literacy' projected a general reference to the ability to read and write. Peeling away layers of this generalization, one can elaborate and add that literacy also entails reading a wide variety of written materials with reasonable understanding. When 'science', used as a noun-adjective or as metonymy (Yore et al., 2007), is added to literacy, one can naturally assume that science literacy is the ability to read, write and communicate things procedurally scientific. Only one pre-service participant applied the traditional literacy part of science to refer to solving human and social problems aligned with the OECD interpretation (2001). The pre-service teachers' responses to scientific literacy produced more detailed answers than did NOS, which appears to indicate a lack of awareness of NOS. Lederman (2000) and Abd-El-Khalick's (2000) works extol the benefits of specifically teaching NOS separately from the body of knowledge known as science. History and philosophy of science (HPS) courses have been shown to increase awareness of the human endeavour of science.

The responses to Survey 1 from the participants were in keeping with my expectations, based on personal experience. As a science graduate, science teacher and former researcher, I admit to having next to no context for NOS. This ignorance was the impetus for my embarking on this project, in order to understand scientific literacy and NOS, and to incorporate them into my teaching, in preparation for the new curriculum.

Unfortunately, the definitions of scientific literacy and NOS were not directly asked about in surveys 2 or 3. The terms were measured indirectly by the evaluation and critique of the science-related newspaper articles. Recognizing this error, the ideal evaluation would have been to include room for explicit scientific literacy and NOS definitions in survey 3, to gain insight into how many of the pre-service teachers developed understanding of these ideas, from their science methods courses, and whether they could apply such knowledge to evaluate and critique the articles. The manner in which the participants applied their scientific literacy and NOS will be discussed shortly.

True/False Portion of Survey

As previously noted the sample size of this project was disappointingly small and did not allow for any meaningful statistical analyses. Reliability of the surveys was explored using the Cronbach α coefficients for internal consistency. Cronbach α's were low, as would be expected with such a small sample, and in the case of survey 2, negative: Survey 1 $\alpha = 0.157$, Survey 2 $\alpha = -0.733$ and Survey 3 $\alpha = 0.340$. The negative α is due to the sum of the individual item variances being greater than the scale variance (Nichols, 1999). This may have occurred in the initial scoring of the items when the statements were reworded to express the opposite or negative sentiment of NOS. The scoring was not reversed to preserve the initial intent. The changes in responses across the three surveys were examined using paired, two-tailed, T-Tests. There were no significant ($p > .05$) gains apparent for the participants' scientific or NOS related knowledge across the courses and experience of the practicum year.

Another difficulty in producing such a survey was the coverage of knowledge that was attempted. Science disciplines covered in the first eight questions were taken from Astronomy, Biology, Chemistry, Physics, Earth Science and Environmental Science. The NSKS statements encompassed 6 categories of thinking scientifically. The original NSKS asked seemingly repetitive questions and used the negative forms of the statements to describe the six subcategories of NOS. This was done to increase the reliability of the science related sub-scale, by increasing the number of items, and to document the 'guessing' effect for similar reflected pairs of items. However, time constraints in the survey process did not allow for much repetitiveness between statements. Therefore, much lower reliability measures were expected for this exploratory study.

The scientific items presented in the surveys could be interpreted as unrelated to a general population. An astrophysicist need not be knowledgeable in genetics to be a successful scientist, or possess a high degree of cultural scientific literacy (Shen, 1975). Reliability measures the relationship amongst items and indicates the consistency of the measure. These science items were intended to show science teachers' understanding of concept statements pertaining to the Grade 8 -10 science curricula. As the pre-service teachers became more familiar with the curricula in their methods course and practicum year, the α's would likely increase for repeated measures of these ideas. The items selected were justified as they matched curricula and media articles. Therefore, the validity of the survey was judged to be reasonable for this study. However, the sample size was too small to detect any changes in correlation over the time working with curricula and teaching experience.

Two themes were evident in all three surveys; firstly, the idea that science is parsimonious, or frugal, was the least recognized statement, and secondly, the causes of environmental conditions, such as ozone depletion and acid rain, rated the lowest number of correct responses, in terms of scientific facts. Parsimony and pollution are entwined in an interesting way. Parsimony is about simplicity, which runs contrary to the complex, inter-disciplinary nature of most STSE issues. Each complex issue has public perception problems and is fraught with misconceptions.

A parsimonious, or ‘less is better’, view of science has a paradoxical connotation. Within a small area of science, or even a single experiment, the knowledge and discoveries are detailed, but kept concise and brief. For example, in biology, phylogeny (taxonomy) and genetics have maximum parsimony built into the very essence of the work. Mathematics, computer science and philosophy (Occam’s razor) are all composed of the same approach of frugality. However, in daily life, people seek many facts and details, while in laboratory work, and in reports, parsimony is accepted and striven for as a goal. Ironically, when science is regarded as a large amorphous body of knowledge, a technological overload of areas, topics and facts, the general perception of science, or NOS, is far from being meagre. Einsiedel (1992, p.90) wrote that “the media perpetuates the mystique of the science enterprise with their presentations of science as an arcane and extraordinarily complex activity.” The technological and communication advances of the last century has enabled the body of science knowledge to grow exponentially, generate new areas of science, and alter the forums where the sciences’ validity is argued. Access to the World Wide Web has distorted people’s sense that science and misrepresented its simplicity and elegance.

The second survey statement, indicating that the participants were weak on pollution issues, ties in with the problem of parsimony and misconceptions in education and media. The knowledge-based questions brought to light important issues: the causes of acid rain, ozone depletion and greenhouse gas warming. These debates have certainly had open forum in the media for decades. Within the realm of air pollution lie three major categories: acid rain, ozone depletion and greenhouse gases. Acid rain is caused by industrial by-products and combustion engines producing sulphur oxides and nitrogen oxides. Refrigerants and propellants, the chloro-fluorocarbons, produce radicals high in the atmosphere and interfere with the Earth's natural ability to make ozone, O_3. The greenhouse effect is accumulations of carbon dioxide, (CO_2), methane, (CH_4), and water, (H_2O), preventing the infra-red energy from dissipating back into space. Each aspect of air pollution is the result of distinctly different chemical groups. All participants, despite their background, incorrectly answered this statement in survey 1. In survey 3, four out of the six participants answered incorrectly. Survey 2's environmental question, of whether air pollution caused the greenhouse effect, was answered correctly in each case. This suggests that the concept of greenhouse gases is understood, but ozone and acid rain issues, more specific areas of air pollution that concern specific chemicals, are misunderstood.

The media portion of the surveys requested participants to critique the stories, and they were also asked what questions they would raise with their students. Each article contained three pieces of numerical data. The participants wrote more critiques and concerns based on the Mayo Clinic article, which linked Parkinson's disease and pesticides (Survey 3, Appendix D), than the article connecting the severity and number of hurricanes with global warming (Survey 2, Appendix C). In survey 3, some of the medical information was omitted, in order to observe if any of the participants, using scientific literacy skills, would question the credibility of the claim and the remaining data about Parkinson's disease. A question about whether Parkinson's disease had a genetic component was raised by one participant, who asked about family history. However, the most obvious question, about 'Who did the research?', was addressed by only one participant, who wrote that the authors' names and actual research should be made available. The most common critique that showed up in five out of the six responses was, 'What types of questions were asked?' One respondent asked about the reliability of participants' memory recall as a measure of Parkinson's disease. One respondent misread the numerical result of 2.4 times as 2.4%.

Although the answers to the media article detailing Parkinson's and men were meaningful, the critiques of the respondents did not address the pieces of information removed from the article. Socio-economic factors or gender concerns did not play into any answers from the participants. The purposeful deletion of gender and other socio-economic groupings was to assess whether socio-economic factors are included in the affective domain awareness of the pre-service teachers' pedagogy and NOS. A major part of the deleted material compared the statistics on how well the females of the same socio-economic background fared (Appendix E). The farming (rural and employment) aspect was left out to determine if anyone would question where the pesticide exposure took place. Granted the survey was not designed to take a lot of the participants' time, but generally the first responses are what media consumers tend to base decisions and conclusions upon.

This small exercise of leaving selected purposeful pieces of information out of the article supports the Lederman and Abd-El-Khalick suggestion that NOS requires explicit teaching, in order to challenge unconscious biases in science. Abd-El-Khalick and Lederman found the level of NOS to significantly improve when undergraduate students were prompted and taught questions and information to ask of science teachings (2000). By articulating what students needed to ask of science, the depth of understanding the human-ness of the science students encountered.

The complete uncensored weather article reviews (Table G.4, Appendix G), which attempted to have the reader connect hurricane numbers and intensity with global warming, received less and softer criticism. Four out of the six participants believed the article was ‘a good starting point’ for research, and that the article was unbiased. One participant wholeheartedly believed the story was just there ‘to sell papers’. This same participant (#1007) also reported that the medical article was ‘heavily biased’. Respondent #1007 did not identify any type of media from which (s)he could obtain information. The one remaining participant identified that the story was biased, and that the other side of the argument (no connection between hurricanes and global warming) was not represented. This participant (#1010) presented a very neutral view of both articles. Participant #1010’s study major was in Asian and Pacific studies.

Integrated Resource Packages (IRPs): General Trends

When the draft IRP was presented in 2005, the number of topics remained at four basic units, plus applications of science. However, the number of PLOs in Grade 8 decreased from 31, in 1996, to the current 24 (Table 1). Teachers were able to keep and carry over 32% of the former Grade 8 curriculum material into the new Grade 8 curriculum. The physical science unit of optics, Kinetic Molecular Theory and some water erosion resources were able to be reused from the former IRPs. This left two thirds of the PLOs new to Grade 8, along with the presence of achievement indicators for the 2006 implementation.

Table 1. *Numerical aspects of Grade 8 1996 and 2006 IRPs with respect to totals and percentages of PLOs.*

Topic	1996		2006			
	No. PLOs	% Total	No. PLOs	% Total	No. AIs	% total
Applications of Science	9	29.0	8	33.3	34	37.0
Biology	8	25.8	4	16.7	16	17.4
Chemistry	5	16.1	4	16.7	-	-
Physics	6	19.4	5	20.8	30	32.6
Earth Science	3	9.7	3	12.5	12	13.0
Total PLOs	*31*	*100.0*	*24*	*100.0*	*92*	*100.0*

Grade 9 also maintained the same four basic units and the applications of science unit. The total number of PLOs in Grade 9 decreased from 34 to 23, (Table 2). However, twelve former PLOs do not correspond exactly to the newer topics. Some of the older PLOs are seen in the new IRPs as achievement indicators only (Appendix F). This is significant to the classroom teacher because (s)he is then able to determine the amount of material one can reuse and how much will need to be started from scratch. Although the number of PLOs had dropped on first glance, some of the older PLOs were simply moved to AI status. This move makes the much hyped ‘smaller IRPs’ look impressive but the same material is contained in both versions. There are a number of new PLOs in the 2007 versions of Grade 9 science, and each with AIs that do not have any previous material from the prior version. Teachers initially found comfort in the fact that there was common material they could use from their prior resources. What caught them unawares was that the older material was covered more quickly than previously because some material was listed as AIs, and new PLOs needed to be taught as well.

Table 2. *Numerical aspects of the Grade 9 1996 and 2006 IRPs with respect to totals and percentages of PLOs.*

Topic	**1996**		**2006**			
	No. PLOs	% Total	No. PLOs	% Total	No. AIs	% total
Processes of Science	9	26.5	7	30.4	41	39.4
Biology	8	23.5	3	13.0	12	11.5
Chemistry	6	17.6	4	17.4	15	14.4
Physics	5	14.7	4	17.4	19	18.3
Earth/Space Science	6	17.6	5	26.1	17	16.3
Total PLOs	34	100.0	23	100.0	104	100.0

The number of PLOs in Grade 10 saw the largest decrease, from 31 to 24 (Table 3), still keeping the four main units. Approximately one-third of old curriculum PLOs was similar enough to be reused in the new Science 10 course, implemented in September 2008. This included the topic of radioactivity, some chemistry and the plate tectonics portion of the earth science (Appendix F). No former Biology 10 could be used, as this material was transferred to the new Grade 9 curriculum. The amount of common teaching material able to be reused constituted less than 25% of the new course material, based on PLOs, because the biology and physics units were completely changed and portions of the other two units were also new. The present Grade 10 science course has had more material compressed into it.

Table 3. *Numerical aspects of the Grade 10 1996 and 2008 IRPs with respect to totals and percentages of PLOs.*

Topic	1996		2008			
	No. PLOs	% Total	No. PLOs	% Total	No. AIs	% total
Processes of Science	8	20.5	7	30.4	41	25.6
Biology	7	17.9	3	13.6	35	21.9
Chemistry/ Radioactivity	6 5	15.4 14.7	4 1	18.2 4.5	31 10	19.4 6.3
Physics	7	17.9	2	9.1	10	6.3
Earth/ Space Science	6	15.4	5	22.7	33	20.6
Total PLOs	39	100.0	22	100.0	160	100.1

Some general trends in the three Grade levels were noted. As the Grade increased the proportion of common transferable material decreased (Table 4). Grade 10 science, with an accompanying provincial examination, had only 23% common material transferred. All three Grades still maintained the four units, or topics, with the incorporation of applications of science to weave into the learning. The Applications of Science (AOS)/ Processes of Science (POS) unit had an interesting opposite trend. The number of PLOs for this unit remained the same, but on a percentage basis this means the proportion or weighting of POS actually increased in the new IRPs because the total number of PLOs was reduced. Not only did the POS unit remain intact during the transition, each PLO has, added to it, a list of AIs to further describe what students should be able to demonstrate in order to fully understand each outcome. Implications of this trend are discussed later in Table 6 of this chapter, regarding provincial examination analysis.

Table 4. *Summary of common learning outcomes across curricula and junior science Grades.*

Grade	No. common new IRPs bolded (*1996 IRPs common, italicized*)	Percentage of commonality (%) Common IRPs /total IRPs	No. AIs associated with present IRPs (% of IRP)
8	Biology **3** (*5*) Phys. Science **8** (*5*)	**11/24 (46%)** *[10/31 (32%)]*	**27/92 (29%)**
9	Chemistry **4** (*6*) Astronomy **3** (*6*)	**7/23 (30%)** *[12/34 (32%)]*	**25/ 104 (24%)**
10	Chemistry **3** (*6*) Earth Science **2** (*6*)	**5/22 (23%)** *[12/39 (31%)]*	**57/160 (36%)**
8-10	Application/Processes of Science **7** (*8*)	**Grade 8 7/24 (29%)** *[8/31(26%)]* **Grade 9 7/23 (30%)** *[8/34 (24%])* **Grade 10 7/22 (32%)** *[8/39 (21%])*	**40/92 (43%)** **40/104 (38%)** **40/160 (25%)**

The revision of the junior science IRPs promised to contain fewer learning outcomes, which would allow for a deeper consideration of the core material. The *Science Curriculum Review Report* (2001) echoed the AAAS call for less material with deeper learning, 'to take a more "depth" rather than "breadth" approach.' (Accessed January 27, 2010 from http://www.bced.gov.bc.ca/irp/reports/scireview.pdf p.3 bullet 1). Teachers welcomed, with cautious optimism, this idea that more time could be spent on fewer PLOs, to allow some deeper learning and reflection through conducting experiments, and doing more hands-on activities. Grade 10 saw the largest drop in PLOs of all three Grades. Based on this fact, the BC government appeared to hold true that the number of PLOs would be decreased, in order to enrich the learning in each unit. Due to the length of each science IRP, only PLOs that were common to both the 1996 and the present curricula are examined in-depth.

Achievement Indicators (AIs)

The implementation of the new BC science IRPs heralded the four goals of the Pan-Canadian Framework, alignment with Alberta, Ontario, Manitoba and the Atlantic Provinces science curricula and Aboriginal TEKW (Traditional Ecological Knowledge and Wisdom). The second part of the document analysis was to gain insight into how the creation of Achievement Indicators (AIs) would aide BC students to attain higher levels of science literacy. The MOE introduced the AIs into all its K to 12 PLOs. The MOE included the identical description of AIs in each IRP:

- *statements that describe what students are able to do in order to demonstrate that they fully meet the expectations set out by the Prescribed Learning Outcomes*
- *not mandatory*
- *provided to assist teachers in assessing how well their students achieve the Prescribed Learning Outcomes. (p. 7, Grade 10 document)*

This description is reworded slightly from the 1995 curricula. In the former IRPs, the prescribed learning outcomes (PLOs) were:

- *statements of what students are expected to know and be able to do*
- *content standards*
- *set out the knowledge, enduring ideas, issues, concepts, skills, and attitudes for each subject*
- *benchmarks that will permit the use of criterion-referenced performance standards. It is expected that actual student performance will vary*
- *depend[ent] on the professional judgment of teachers, guided by provincial policy*
- *to enable teachers to use their experience and professional judgment when planning and evaluating (Science 8-10, MOE, 1995, p. iii)*

From a teacher's point of view, the two descriptions overlap in meaning. This would not be a problem, except that the term PLO was retained by the MOE, and the AIs appear as a subset of PLOs, intended to help less experienced teachers define the actions or performance associated with the PLOs.

Looking nationwide, AIs are unique only to BC and difficult to compare operationally. Other Canadian provinces do segment their curricula like BC, but the bullets and/or subsets are used differently to BC's AIs. Alberta's educational system divides up units into concepts (the big pictures), or outcomes, which are supported by bullets, to demonstrate learning (Accessed January 27, 2010, http://education.alberta.ca /media/654829/sci7to9.pdf). Prince Edward Island's current science curricula look very much the same as the former BC IRPs. The outcomes are written with suggestions as to how the teacher may assess for learning, or as prompts to engage students further, as well as including a suggested resource list. Ontario's most recent 2008 science revisions have 'Big Ideas' (BC's equivalent to units like Biology and Chemistry), 'Overall Expectations' (BC's PLOs), and 'Specific Expectations' are described as questions that students would be expected to answer (Accessed January 27, 2010, http://www.edu.gov.on.ca/eng/ curriculum/secondary/science910_2008.txt). Curricula from other provinces appear to have large broad PLOs with subsets of minor learning outcomes. A more concise idea of AIs was not found in other current provincial education documents.

The impact of the addition of AIs was a major focal point in the data analysis and focus group interviews. Tables 1, 2 and 3 compare the PLO and AI data for all three Grades for the former and present science IRPs. The numbers of PLOs were reduced significantly, as promised, with Grade 10 science enjoying the largest decrease, percentage wise. The addition of AIs, however, was the largest in Grade 10, with 160. Science 10 was altered the most during the IRP implementation and ended up with only 23% common material from the 1996

IRP. Grade 8 Science had the largest amount of common material as a result of the transition, with the fewest number of AIs added in the new IRP. Grade 9 floated in the middle, with regard to the carrying over of the same PLOs and the addition of AIs. However, the time allotments provided for each course appears to be insufficient to cover the specific AIs (Table 5).

Table 5. *MOE suggested instructional time frames for Grades 8 to 10 Science IRPs based on 100 hour course.*

Grade	Processes of Science	Biology	Physical Science*	Earth/Space Science
8	Integrated with other organizers. None given.	20-25 hours	40-48 hours	20-22 hours
9	Integrated with other organizers. None given.	20-25 hours	40-45 hours	20-25 hours
10	Integrated with other organizers. None given.	20-25 hours	40-45 hours	20-25 hours

* Physical science incorporates both chemistry and physics topics.

Table 5 illustrates that the MOE expects each of the three Grades to complete the science courses in the same amount of time. From a numerical count of PLOs, AIs and commonality of subject material, the relationship between AIs and increasing scientific literacy goals was not apparent. One would expect to see some directives from the MOE such as:

- to relate time commitments in each unit to the number of AIs, so teachers are able to budget their classroom time for science literacy
- to spend more classroom time dedicated to the POS unit, or
- to prescribe that each science subject area is to have a POS time commitment allotted

This would provide a framework for teachers to incorporate explicit science literacy activities into each unit.

Science 10 Provincial Examination 2008-2010

BC's current graduation program requires that a provincial examination in Grade 10 Science, Mathematics and English be written to satisfy graduation requirements under its 2004 Graduation Program. With no clear working classroom definition of what AIs' roles are in the present IRPs, copies of the Science 10 provincial examination, released after the implementation of the new IRP, were analyzed to form an understanding of how the MOE treated AIs for examination purposes, and for the increased importance of scientific literacy. Three released examination keys on the Ministry of Education website (retrieved Dec 7, 2009: http://www.bced.gov.bc.ca/exams/search/searchResults.php) were scrutinized. Table 6 delineates Science 10 components into percentages and suggested instructional timelines. The data presented in Table 6 did not suggest any relationship between the increased emphasis on processes of science (POS), (NOS and scientific literacy), and the provincial examination breakdown. Answer keys to the Science 10 provincial examinations do not indicate which questions were designated to address the POS. If growth and improvement in scientific literacy is to be measured, analysis of the Grade 10 IRP and the provincial examination gave no indication that either the POS or the purpose of the science curriculum change was assessed. As these POS are to be integrated throughout the provincial examination, there is no relevant way of demonstrating whether the students developed the knowledge or science literacy. It was unclear at this juncture, using the provincial examinations for evidence based conclusions, how the MOE measures the increased emphasis on science literacy and the roles AIs have in enhancing the POS.

Table 6. *Breakdown of the available science 10 provincial examinations available on the government website compared to the topic weightings of the IRP.*

Topics (Unit)	Suggested instructional time	Weighting of provincial exam	Weighting: percent of PLOs	Weighting: percentage of AIs
Processes of Science (A)	None designated	Not specified	30%	26%
Life Science (B)	20-25 hours	26%	14%	22%
Physical Sciences (C)	40-45 hours	48%	32%	32%
Earth/ Space Science (D)	20-25 hours	26%	23%	21%

Bloom's Taxonomy

As a final attempt to understand the AIs as a classroom teacher, Bloom's taxonomy was employed, as it involves cognitive, affective and psychomotor learning domains, which were part of scientific literacy (Yore et al., 2007). Science 10 was used in this analysis because it listed the smallest number of PLOs, with the largest number of AIs of the three Grades for the current IRPs. Under the old version, science 10 contained the largest number of PLOs, and the provincial examinations also categorize the level of difficulty of their posted examination questions. These conditions provided a listing of verbs that under Bloom's taxonomy could be used to interpret possible relationships between PLOs and AIs.

Three classifications of question difficulty are used in provincial examinations: 'K' for knowledge, 'U' for understanding and 'H' for higher order thinking. If the categorization was translated into Bloom's Taxonomy, the knowledge level correlates to a 'K' type examination question, or learning outcome. A 'U' classification could be correlated to comprehension and application levels. Higher order thinking, an 'H' question, encompasses analysis, synthesis and evaluation levels. Itemized PLO and AI verbs of both the old and present curricula of science 10 and common PLOs and AIs learning verbs are categorized according to Bloom's Taxonomy (Appendix G, table 13). Figure 2 below summarizes the results of these classifications.

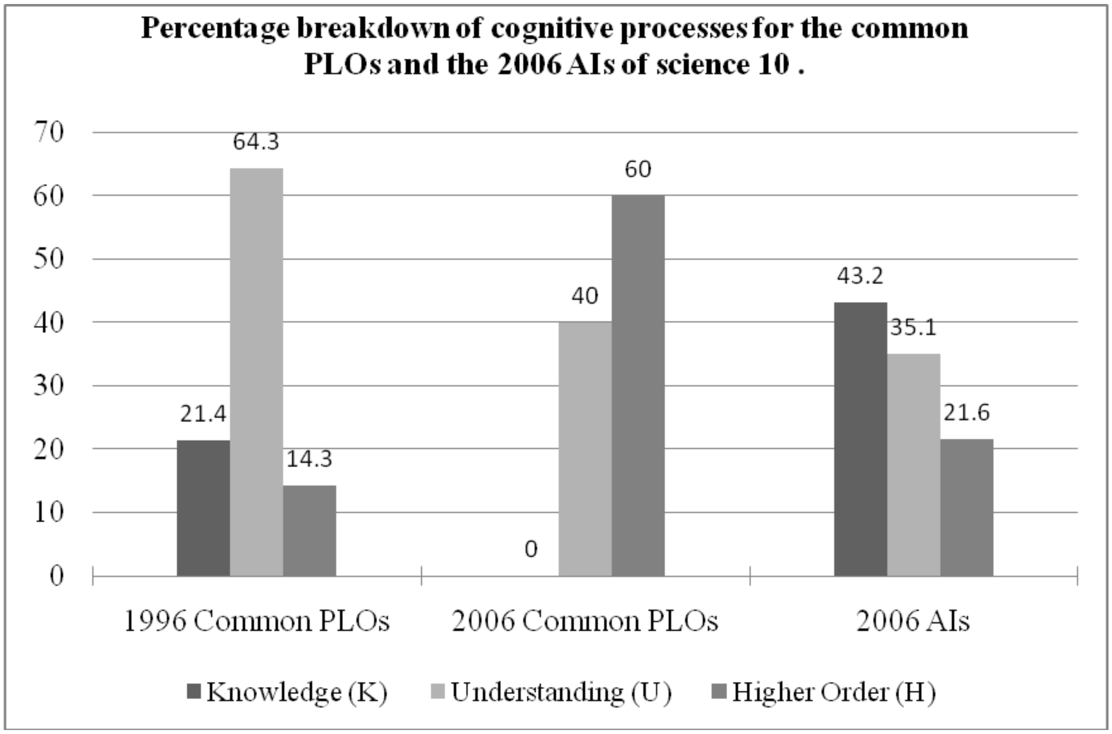

Figure 2. Results of grouping PLO and AI cognitive verbs into low (Knowledge), mid (Understanding) and high (Higher order) categories based on MOE classification.

Bloom's taxonomy allowed for clarification of the subtle differences between a 2006 learning outcome and an AI. Older 1996 PLOs contained a mixture of cognitive levels, whereas the common sections of the current course use higher cognitive levels to describe the PLO, and a more rudimentary wording to describe the AIs. If this arrangement is true, the relationship is that the AIs are subsets, or minor learning outcomes, that are used to describe the given PLO, considered as the major learning outcome. This is commonly seen in curricula in other provinces. If the MOE had intended the AIs to serve as pillars of each PLO, then the descriptions and directions to the educators should be more concise. AIs in this assumed integral format are mandatory, and are important to student learning in other provinces. The MOE has written that the AIs are optional, and does not communicate why the numbers of AIs vary across PLOs.

To test this idea that AIs, with their lower cognitive thinking verbs, are used to back-fill the higher thinking order of the new PLOs, biology examination questions from 'sample Examination A', 'sample Examination B' and 'Released Examination' in the 2008/2009 school year, were used. Biology 10 is now rewritten to address Ecology only, and has three assumed equally weighted PLOs: B1, B2 and B3. Figure 3 illustrates that the biology PLO with the largest number of AIs received the largest number of examination questions. It was evident that B1 was weighted more heavily than B3, and that B3 was more heavily weighted than B2, yet there is no disclaimer in the PLO list in the 2006 IRP (p. 30) that any PLO is more important to demonstrate than others.

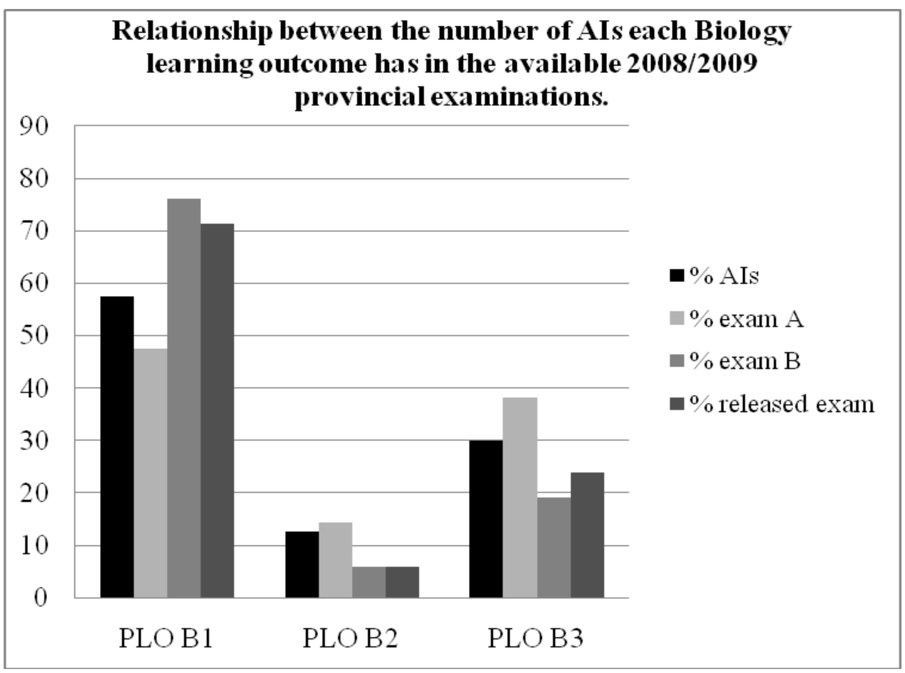

Figure 3. Relationship between the numbers of AIs of each Biology 10 learning outcome and the number of questions attributed to each PLO in available provincial examinations for 2008/2009.

The higher number of questions referring to a specific PLO may be simply that the learning outcome was a complicated idea, or system, and used higher thinking skills and more processes of science. Prior to the 2006 curriculum, learning outcomes were employed to break down complicated ideas, to allow students to demonstrate smaller ‘pieces of the curriculum’, to gain success, and guide teachers in their preparation of lessons and for setting instructional pace. If the reason that one learning outcome garners more attention in the provincial examination than other PLOs is because of its complexity, then this should be explicitly stated to the teachers and instructors of pre-service teachers. Since individual AIs are stated as being optional, it may be too subtle for inexperienced and generalist teachers, and test designers, to detect the implied importance and complexity of the PLOs. The disproportionate ratio of the test questions asked per PLO, leads back to the full IRP document for further evaluation. An interesting observation was compiled that connects key elements, a checklist of vocabulary and knowledge and AIs. Test questions were based on the vocabulary words from the AIs, not PLOs, which implied that the optional AIs were the subject of test questions, not PLOs. For science 10 and learning assistance teachers, the focus of test preparedness and study skills lies in the so-called optional AIs, and not in studying each PLO as though it is weighted equally for demonstrating understanding of the whole unit. Furthermore, only the traditional science subject areas of Biology, Chemistry, Physics and Earth Science are addressed. There is no final assessment of POS, either for Grade 10 topics or generally from students’ first 10 years of science education.

In concluding this analysis, the number of prescribed learning outcomes did decrease as a result of the latest curriculum revision. In the place of lower numbers of PLOs, a multitude of achievement indicators appeared. The document analysis focused much effort on the BC Science 10 course, as it provided the only means to determine how the MOE construes AIs to advance scientific literacy in BC. Studying the final examination exemplars, the IRP document and the AIs, there is clear evidence that the MOE does interpret AIs to be actual learning outcomes that students are obliged to demonstrate, conflicting with the statement that, “Achievement indicators are not mandatory.” (Science 10 IRP, 2008, p.7). No data were obtained to indicate how the MOE is to monitor the gains in scientific literacy made by students receiving instruction from the new IRPs, as the provincial examinations do not indicate which questions pertain to Processes of Science. The absence of such questions does not allow for scientific literacy improvement, or for depth of understanding to be measured.

In-Service Teacher Interview

The teacher interview revealed aspects of the curriculum change that I had not contemplated. These unanticipated concerns included a Grade 8 placement in a middle school, the extent of how vocabulary-laden the grades 8-10 science courses had become, and the suggestion that the courses are lending themselves to making the science curriculum an area that generalist teachers could facilitate. Not having taught Grade 8 or dealt with any middle school system, the complexities of implementing a new science curriculum in a middle school, without a science specialist, were viewed as significant.

The two Grade 8 teachers that participated in the interview, Frank and Barbara, had taught in different school districts in the province. Frank worked in a district that did not have a middle school. The Grade 8 students were part of the high school system. The contrast between resources, peer support and equipment was to the detriment of the middle school teacher, Barbara. Empathy was abundant for Barbara’s efforts to bring in a new curriculum, on a limited budget, with no support from the high schools. There exists a certain frustration in delivering such a course within a younger school setting, where assemblies, field trips, sports and fun days occur frequently and, as a result, the number of teaching hours dwindles quickly.

Although Frank's Grade 8 classes were supported well, with equipment and facilities to enable hands-on learning, he commented on how little time was allocated for teaching such a long and varied course. Neither Grade 8 teacher had successfully finished the entire list of topics nor PLOs since the current IRP was introduced. Frank did have a colleague who had finished most of the Grade 8 course, using power point lessons and less than five laboratory activities. The very thought of sacrificing experiments and activities to complete a 'science' course was completely counterintuitive to Frank. He pinpointed the concern, shared by all of the teachers, that in order to be able to finish the course, one had to forego a number of hands-on activities and laboratory sessions. Ironically, it is the MOE's new PLOs that direct the schools to supply Grade 8 classes with microscopes, biological supplies and learning materials for fluid dynamics, and, at the same time, deliver a curriculum which two Grade 8 teachers could not complete without the costly materials needed to facilitate learning. In both districts there was little collaboration time, and professional development with district colleagues was minimal. Suggested unit and lesson planning, therefore, were not co-ordinated in order that supplies could be shared.

The Grade 9 and 10 teachers, with established laboratory settings, had problems with the limited instructional time for the course content. Research assignments and activities were set aside for teacher-directed learning and individual seat-work. The Grade 9 teachers took particular issue with the new topics selected for Grade 9: genetics, mutations, electrical circuitry and related algebra. Ben made the observation that his involvement with the literacy committee at his school did more for supporting student learning than the few seminars he attended for the new Grade 9 course.

Indeed, the vocabulary has become more of a focal point of science instruction than the process development. The Science curriculum returned to an unpopular form of education and the high-stakes testing of thirty years ago, with respect to an overwhelming vocabulary list of rote learning (Rowe, 1983; Caillods et al, 1997; Hanrahan, 2002; Hodson & Prophet, 1994; Shamos, 1995). In Leon and Ben’s school there is a concerted effort to improve the literacy of their students. Many students arrive at high school reading well below their Grade level. The cumbersome vocabulary and heavy reliance on the new textbook is an additional strain on the lower level reader. The Ohm’s Law, power and energy components require algebra and graphing, two skills that students are expected to acquire during their Grade 9 and 10 Mathematics. Mathematical abilities and the scheduling of mathematics, with respect to science, presents issues with teaching material which is not formally recognized as learning outcomes, but is critical to demonstrating scientific knowledge. Children who are not equipped to learn at the Grade appropriate level complicate time constraints considerably for the teacher. Personally, I have taught Science 9 honours classes, who are very proficient for their Grade, and found I could not sustain an appropriate learning pace, with varied activities and discussions, and finish the PLOs in the given 100 hours of instructional time. In order to complete all that was necessary, seat-work and copying bolded vocabulary word definitions were assigned and scored frequently.

The Grade 10 teachers nodded to reaffirm the other teachers’ issues with the implementation of the new curriculum. The MOE introduced a new graduation program in

2004. The 2004 program also enforced the policy that provincial examinations take place at the Grade 10 level in English, Science and Mathematics. The Science 10 provincial examination has been set since January 2005, when the first school semester finished. Science 10 teachers are under a tremendous amount of pressure to prepare their students for these examinations. Naturally, when the PLOs changed and a new format of IRP arrived, the teachers were apprehensive. The new curriculum brought changes in Physics (and accompanying mathematics regarding vectors, scalar measurements and movement), and Biology as Ecology and Earth Science (with a Geography component). Two of the three teachers had some upper level course content from which to borrow, which required much modification, and relied heavily on the textbook and the referenced websites to obtain information. The Grade 10 teachers complained bitterly that this left next to no time for laboratory activities, or any extra time, which is needed to research the new units and develop personal teaching materials.

The Grade 10 course grew significantly larger in content, as well as in terms of the sheer number of pages of paper. Ben, Leon and Ivy believed that the course required more ‘chalk talk’ and teacher-centred instruction. They believed there was not enough time for students to gather into groups, complete activities and then debrief, in order to complete a laboratory write-up. Leon stated that he was able to convey the same material in fifteen minutes of a lecture as he could in two classes in the laboratory. The main criticism of such a vocabulary-laden agenda was that it was off-putting for the students. The teachers I interviewed were unhappy about teaching vocabulary at the expense of teaching the process of science. Science had become an exercise in memorization. Leon echoed the critics of two decades earlier, who acknowledged that studying Science 9 and 10 was like reading a dictionary. He also stated repeatedly that the course was moving away from best practices, such as spending time on laboratory activities, to more highly scripted textbook work. He was concerned that the courses would become so prescriptive that a science specialist would no longer be needed to teach high school science, because any teacher could pick up the textbook, IRPs, and visit a publisher's website and complete the course. Leon's sentiment was eerily like that of the teacher-proof educational materials described by Rowe (1983), Bybee (1997a) and Porter and Brophy (1988).

The concluding discussion did not address the AIs and their interpretation with respect to the listed PLOs as planned. The teachers talked around the topic of AIs and the POS indirectly, choosing instead to treat the whole IRP as 'the course', and did not differentiate the AIs from the PLOs. When it was explained that each current IRP had fewer PLOs than the 1996 curriculum, the teachers suggested that the new PLOs were packed with more details and higher order processes. There are two chapters within each science Grade IRP, one describes only the PLOs for the course, and the other has the PLOs and the AIs together. Each teacher referred only to the chapter with the AIs in preparation for their lesson plans, and skipped the chapter with only the PLOs entirely. Barbara and Ivy understood that the AIs were suggestions, while teachers with more classroom experience recognized that former PLOs were converted into AIs. This translated into treating all AIs that were examined on the provincial examination as discrete PLOs. The sample provincial examinations in Biology have indeed been correlated to specific AIs, believed to be optional, not the general PLOs, which teachers are led to believe are the fundamental mandates.

The final interview question set was to look at the POS to determine how these PLOs are covered in the individual classrooms. The POS, in Grade 10, for example (Table 9), comprise one-third of the course, according to the PLOs. The scientific literacy component is one PLO with four AIs. The majority of the teachers understood that the POS are recognized as part of the curriculum. Fewer realized that Grades 8 to 10 shared the same POS, and none developed separate purposeful lesson plans and activities to address the POS section. All present agreed that, although the PLOs are important to scientific enterprise, little or no time in their lesson plans is allocated specifically for scientific literacy and NOS.

POS require a tremendous amount of time and resources, most notably a library and computer stations, and they are most often dropped to make up for time shortages. To teach and guide schoolchildren through the debating or experimentation processes requires much effort on the part of the teacher, already taxed with modifying and adapting class materials for students with learning and behaviourial issues. Community initiatives and field trips are also very difficult to arrange, and present financial limitations, as students are no longer expected to pay for expenses related to the basic school program. The paperwork to organize field trips in the Saanich school district is laborious, often requiring a second adult to facilitate. Connecting students with industry, educational opportunities and nature, outside the time allotted for science in a school is very difficult in today's educational realities. No teacher interviewed in the secondary schools takes their students on field trips, and Barbara offered that her middle school Grade 8 class went on only one field trip the previous year because it had been free, and parents were able to drive. All teachers agreed that POS are the essential part of science that needs to be taught, and the PLOs 'get in the way' of teaching science well.

The MOE advocates that each of its science courses is 'lab/activity oriented' in the 2004-2005 CMEC transfer guide (Accessed January 27, 2010, http://www.cmec.ca/

Publications/Lists/Publications/Attachments/184/transfer-guide-2004-05.pdf, pp. 30-31), and in the 2008 Grade 10 IRP introduction, which stated “Science education is an activity based process.” (p. 20). The MOE adds:

> *Although the instructional approach for Science 8 to 10 is intended to be experiential in nature, the Grade 10 course has a set Graduation Program examination, worth 20% of the final course mark.* (p. 11, Science 10 IRP 2008)

However, the ‘flexibility’ in the science program rests solely with the school:

> *Schools have the responsibility to ensure that all Prescribed Learning Outcomes in this curriculum are met; however, schools have flexibility in determining how delivery of the curriculum can best take place.* (p. 27, Science 10 IRP)

The Pan-Canadian Framework and scientific literacy promote constructivist approaches to learning and teaching. The science 10 IRPs suggest:

> *There is some flexibility in the Science 8 to 10 curriculum, providing opportunities for individual teacher and student choice in the selection of topics to meet Prescribed Learning Outcomes. This flexibility enables educators to plan their programs by using topics and examples that are relevant to their local context and to the particular interests of their students. (p. 19, Science 10 IRP, 2008)*

In March 2009 the BC Science Teachers Association (BCScTA) released a report of Science 10 teachers, providing feedback on the provincial examination and the new Science 10 IRP (accessed January 27, 2010 from http://www.bcscta.ca/Sci10%20Report.pdf). In this report, a number of teachers indicated that they understood scientific literacy and NOS, by commenting on how the new IRPs and provincial examination impact on their classrooms.

- Less or no labs, videos, projects, field trips – the backbone of an interesting science program
- Teachers have limited or no flexibility
- Teachers cannot deviate from PLOs – no current events or local topics
- Students struggle with the very high vocabulary demands
- Lower student interest in senior science courses; Students do not like science any more
- Miss out on science literacy work (a focus of the Pan-Canadian Science Curriculum)

- A wide range of material is covered with insufficient time to absorb any of it, which results a lower likelihood of students retaining the information
- Students must memorize lots of trivial facts
- Science has become a reading and textbook course, instead of being hands-on
- The examination narrows discussion, curtails exploration and forces unrealistic expectations upon many students
- Students spend more time … trying to remember information rather than learning skills

Of the two hundred and two teachers taking this survey, many may not have fully developed definitions of NOS or scientific literacy, but there is a sense that they understand that science is more than simply knowing a collection of facts and vocabulary. Science is a process, a human endeavour that requires collaboration, co-operation and discussion. Many points raised in the interview are echoed in the summary of the March 2009 BCScTA report:

> *The vast majority of respondents indicated that the Science 10 Provincial Final Examination has caused a significant decrease or entire deletion of lab activities…, coupled with a preponderance of direct instruction through lectures. Additionally, Science 10 students now rarely have the opportunity to do group work, research projects and classroom presentations, take field trips to Science facilities or explore local topics or current events, due to the stringency of the approximately 100 Prescribed Learning Outcomes and hundreds of scientific terms that students have to memorize for this examination. Respondents repeatedly stated that the science teachers in their schools no longer wish to teach Science 10.*

These concerns are supported by other reviews in the past (Connelly et al, 1985; IIEP, 1997; Linn, 2001; Yager, 2000), suggesting that concerns about science education are on-going.

Although teachers did not articulate scientific literacy and NOS through the interviews, they definitely had a clear expectation of themselves, and the curriculum, to facilitate an appropriate, scientifically literate, learning environment. They understood that students moving about in a classroom, working with friends or groups, and conducting experiments, separated Science classes from Social Studies or English. Teachers appreciate that facilitating learning requires as little as possible teacher-centred activity. Science requires compromise, multiple attempts at experimentation and social interaction. Currently, their frustrations lie with the knowledge that, with the implementation of the new curricula, they have been unable to teach in the fashion they believe supports scientific literacy.

Classroom teachers find less time to complete laboratory and research projects. Grade 10 Science teachers are bound by covering the new science IRPs, so that the students can be successful in their multiple-choice provincial examinations. Grade 9 science teachers feel the need to take middle-school minded children and get them prepared for the Grade 10 examinations. The two Grade 8 teachers provided a wealth of information about the complexities of the physical setting of their science classes and coursework. Senior science classes are, traditionally, preparing students for post-secondary education by fulfilling credits required for graduation and provincial examinations. The general feeling of science classroom teachers is that the new curriculum is more information-filled, and is written in such a way that meaningful hands-on work is removed, to allow for larger classes and smaller science budgets. The pre-service teachers admit that their science methods courses, although helpful to understanding how to facilitate learning, fall short in terms of preparing them for the realities of the classroom.

High-stakes testing (i.e. the Grade 10 BC provincial examination) has been shown to have detrimental effects on students and teachers alike. "Teaching to the test, narrowing of curricula, cheating, crowding out student-enriching activities and test preparation…[are] corruptions caused by high-stakes testing (HST) (Ryan & Weinstein, 2009, p**.** 230)… teachers and students alike have "a fear of failing." With the fear of failing, teachers' instructional behaviours become more controlling and impact teachers' experiences negatively, leading to more job stress and burn-out." (Ryan & Weinstein, 2009, p**.** 228)**.**

Ryan and Weinstein touch upon a valuable point in suggesting that secondary school teachers have a heightened fear of failing because of high-stakes tests, as noted with the last sentence of the March 2009 BCScTA summary, "Respondents repeatedly stated that the science teachers in their schools no longer wish to teach Science 10." A twenty percent standardized final exam may not seem high stakes but with at-risk students socially promoted without grade level reading and numeracy abilities, twenty percent makes all the difference to being successful in Grade 10 science. Much of the meagre educational support students receive in class are not allowed when they enter into the computer lab or examination room to write the final examination.

With efforts to engage students in scientific literacy and learning, the top-down decision-makers of education fail to realize that people, regardless of age or context, learn through inquiry in group settings. These decision-makers assumed implicitly that the teachers will make the necessary connections to scientific literacy and NOS. This requires rethinking. The decision-makers and curriculum developers need explicitly to discuss the "how-to" of science education (Lederman, 2000; Schwartz & Lederman, 2002; Shappiro, 1996). The drawback with implementing a new curriculum, based on scientific literacy, is that there is the false presumption that teachers already have shared definitions of this idea, and they have the tools to impart this to their students. Meaningful discourse in a conducive inquiry environment, like an appropriate topic-specific Pro-D, enriches pedagogy and connects teachers' emotions as a united group (Grimmett, Dagenais, D'Amico, Jacquet, & Ilieva, 2008), with positive impacts on their own teaching. Regardless of the country, academics have found a strong correlation between teachers' common repertoire of teaching skills and student learning.

Summary

The impetus for this project was to delve into my personal lack of scientific literacy and NOS by reading academic articles, connecting with the pre-service teaching program, performing document analysis, and polling other practicing teachers in order to solidify understanding of the problems and suggest potential solutions. The pre-service teacher surveys did not produce negative results in terms of scientific literacy or NOS. If anything, the fact that the university students were able to articulate these concepts was much better than I could have done in a similar situation. The document analysis required the most impartial effort and likely provided the most valid insights in curriculum changes and potential implementation problems. The teacher interviews crystallized the disconnect between traditionally defined PLOs from 1996 and the new format of the present IRPs. Teacher interviews indicated confusion and misrepresentation in portions of the IRPs. The mandate of the PLOs and AIs are not explicit and thereby may produce conflicts among teacher autonomy, interests and pedagogy. It is noted that one-quarter of each of the Grade-level PLOs is dedicated to increasing scientific literacy, and NOS, through POS. However, analyses of the released examinations indicate no POS-focused test questions.

The negative feedback consistently emphasized: that there was not enough time to cover all of the topics in a single course; that science education had become more vocabulary driven and less hands-on; and that there was little room to accommodate students of various abilities. Test writing has become the main focus to getting marginal kids passed, not understanding science related issues. Teachers rely on the IRP directives to provide pacing and preparation for all students to finish the complete course. PLOs, traditionally, were treated with equal weighting of importance, and formed the backbone to lesson planning with appropriate pacing. If the AIs have become the focal point of the MOE and test writers, teachers should be advised to consider the number of AIs in each unit, rather than the PLOs, and that the new curricula have become too overloaded, violating the 'less is more' axiom of current science education reforms. This is in opposition of their promise to implement science courses that are enriched in science literacy, where students have time to delve into scientific issues and explore them experimentally. With no MOE feedback, the science courses, especially science 10, seemed to have returned to, the situation of the post-Sputnik science education reforms (Shamos, 1995) and tell-text-test approach (Rowe, 1983).

Chapter 5
Conclusion

Overview

The central focus of this study was to document the understanding, awareness and curriculum implications of scientific literacy in the new science IRPs, as well as the surveying of pre-service and practicing teachers of science. Scientific literacy has been advocated for over 50 years, but there appear to be several interpretations of the idea, ranging from knowledge of science (Vision I) to applications of science in everyday contexts (Vision II), in addition to interacting fundamental and derived senses, leading to fuller participation in the public debate of socio-scientific issues (Roberts, 2007; Yore, et al., 2007). This project was to consist of a three-part inquiry: a survey measuring the scientific literacy and NOS gains of pre-service teachers during their practicum year; an analysis of the science IRPs; and a focus group of practicing science teachers. Conditions for the sourcing and implementation of the full sets of electronic surveys, as well as the sudden departure of the science methods instructor for the 2005/2006 practicum year, posed serious concerns as to whether the project would be feasible. Only six pre-service teachers completed all three surveys within the given time frame, and the project transformed from being a quantitative analysis to a triangulation mixed method design (Creswell, 2005). Data from the true/false/I don't know statements and local newspaper clippings were used to "quantify qualitative data" (Creswell, p. 520), and analysis of the surveys connected the themes of the qualitative document analysis of the former and present junior science IRPs with peer interviews with science teachers.

The analysis of the year-long surveys of scientific literacy, operationally defined as knowledge of science content, nature of science and science processes, produced three themes: limited recognition of scientific literacy centered on Vision I or Vision II, misconceptions concerning air pollution and the disconnect of science as being a parsimonious activity. Document analysis of the IRPs wove an interesting tapestry between these three themes (or, the new IRPs indicated that new curricula address more environmental and climate concerns than the former IRPs). The new PLOs concerning climate were largely responsible for the lack of common materials between the old (1996) and new (2005) IRPs, as there are currently more PLOs dealing with climatology and its multidisciplinary impacts on all aspects of science. Incorporating PLOs which address air pollution, climate change and weather, indicated that the policy makers were aware of emerging needs and current socio-scientific issues. Analysis of the IRPs also confirmed the disconnect that science is parsimonious. More emphasis was placed on vocabulary (scientific terminology) and achievement indicators, instead of a holistic approach, which reinforces to students that science is a collection of facts to be memorized, not interconnected processes with repeatable arrangements. Vision III of scientific literacy includes interacting senses, leading to the deliberation of socio-scientific issues. The fundamental sense of scientific literacy is the ability to read, write and speak about scientific matters, science processes and emotional positions (affective domain), and the derived sense of scientific literacy is the understanding of the big ideas of science, NOS, and scientific inquiry, with each playing an equally valuable role (Yore et al., 2007). That pre-service teachers did not recognize science as a parsimonious enterprise was reinforced in the IRP analysis findings, which encourage long lists of vocabulary words and AIs with no overlapping topics.

The science teacher interviews took place after the pre-service teachers had completed their practicum and after the document analysis was finished. The interviews initially served to confirm the IRP analyses on common instructional material between the

1996 and the 2006-2008 junior sciences but, unintentionally, led to a demonstration of their personal intrinsic scientific literacy and their understanding of NOS. The teachers interviewed gave approximately the same definitions of scientific literacy and NOS as the pre-service teachers, but unique to the practicing teachers was their collective fundamental and derived senses of scientific literacy. Scientific literacy was described and defined more clearly while discussing their issues and struggles with the new IRPs, than in their interview definitions of science literacy and the NOS. Teachers, agreeing with the document analysis, told of the conflicts the new IRPs had on their teaching practices and lesson planning. The new IRPs, in their opinion, are creating more of a chasm in science education by emphasizing more material to cover, represented in the AIs, and more rote memorization to address the time efficiency required to cover the AIs. Although a standardized final provincial examination in Grade 10 does, admittedly, keep all teachers covering the whole course, the focus is on helping the student to pass the examination. However, the Grade 10 examination does not explicitly access the science processes and Vision II or Vision III of scientific literacy. This, therefore, does not allow students to demonstrate either personal learning or an appreciation of an area of science beyond understanding of science knowledge, similar to the consequences of science educational reforms of the post-Sputnik educational crises.

Speculations

The trio of surveys produced no significant gains in science or NOS knowledge for the pre-service teachers as they moved through their practicum year. As mentioned, the sample size was too small to permit any statistically meaningful data, but one can still interpret the data descriptively, as these people were already more scientifically literate than the general public, due to their educational background, choice of reading materials and personal areas of interest. The southwestern coast of BC is rich in environmental issues, outdoor activities and climate change impacts. Although there was room for individual gains in the surveys, pre-service teachers averaged 75% on their science facts and 70% in their NSKS sections. No individual had a decrease in their score. A positive finding was the participants seem to already have a high acuity for science issues. Victoria and Vancouver have the head offices for the Suzuki Foundation, Islands' Trust, Western Wilderness Committee, Sierra Club and The Land Conservation group, as well as several universities and government research stations. These groups, and the natural geography and geology of this area, tend to influence local media to cover such scientific topics and socio-scientific issues. This is what also makes lower Vancouver Island a rich context in which to teach science and promote authentic participation in public debates about socio-scientific issues.

Another view of the results would be that the pre-service teachers' scientific literacy was not challenged in surveys 2 and 3, or in the practicum year. Their misunderstanding of science as being parsimonious can be explained, at least in part, by knowing that the advancement of technology produces so much information without connections. The incorrect air pollution answers in all three surveys were noteworthy. Each pre-service teacher should have approached some aspect of air pollution, such as ozone, greenhouse gases or acid rain, as a topic in one of their university science units. An arising concern is how these teachers will be able to facilitate learning of climatic topics correctly. Further pre-service projects in the area of climatological knowledge would seem to be recommended and worthwhile.

As for the new curricula, an increased effort in the areas of natural resource conservation, ecology and climate studies were welcome changes to the junior high school science courses. The problem was that the curricula had remained largely unchanged since the mid 1980s (small adjustments were made in 1996) and BC not only had to make large-scale changes to keep up with the science, but also with national and international science education programs. Whereas other Canadian provinces had mandated curriculum upgrade dates, BC was one of the last provinces to use the Pan-Canadian Framework as a foundation for provincial curricula, and has no mandated time period within which to review the curriculum. With all the supporting information, of current methods of science teaching and revised curricula, the arrival of the new IRPs was eagerly anticipated by BC science teachers, looking for new topics and up to date issues to cover.

Document analysis of scientific literacy and NOS at each Grade, and at provincial examinations at the Grade 10 level, has produced learning directives that are counterintuitive to scientific literacy, and resemble the 1960s post-Sputnik frenzy of cramming in more facts, teacher-proofing the curriculum, testing more students and relying on single test scores, rather than individual growth of learning. The MOE has no curriculum branch listed in its directory and includes curriculum concerns with the Education Standards Unit. Its email contact (EDUC.Achievement@gov.bc.ca) appears to demonstrate its emphasis: Achievement refers to test scores and statistical measurement, not curriculum.

As stated earlier, the document analysis of the IRPs was difficult, but insightful, as these documents drive my lesson planning, direct my classroom instruction and reorganize my personal pedagogy each semester. As a teacher, I am bound by the IRPs, some days hopelessly so. The changes in the IRPs most certainly needed to take place, although change is difficult to implement and to make take hold. The cash-strapped, downsized MOE has discontinued responsibility for curriculum implementation and has provided very few opportunities for teachers to prepare for these changes on district and personal levels. Leadership for professional development days, according to the teachers, was assumed by the publishing companies selling their educational materials, and not the MOE. The MOE did not lead the implementation of the new IRPs, but still holds control in overseeing the highly contentious provincial examinations. This disconnect, the lack of ownership or a representative at the ministry level to respond to questions or concerns of school districts, the BC Science Teachers' Association and schools, has exacerbated the implementation of the changes in IRPs.

Since the IRPs were published and authorized, the MOE has not provided any further direction on the explanation of AIs, or how AIs were designed to improve science literacy, or how to align learning outcomes with the Pan-Canadian Framework. The AIs are said to be suggestions which indicate that the student has fully grasped the PLO, but, in the provincial examinations, the AIs are directly tested and the actual weighting of each PLO is not indicated. The higher number of AIs listed for a PLO is a strong indication that the PLO will be weighted higher in test questions. Teacher suspicions appear to be confirmed when the new IRPs have increased content coverage, and the AIs appear to be prioritized as the 'actual' PLOs. Fewer PLOs should allow for more NOS connections, and a deeper, richer understanding of these connections. However, the large number of AIs associated with each PLO has increased the quantity of facts and vocabulary that students are expected to learn. The document analysis of the IRPs did seem to support claims that teachers are unable to finish the whole IRP for their Grade, within the allotted instruction time limits, as the amount of material for just the common units and topics, between the 1996 and present IRP, did increase.

Scientific literacy goals, represented by the science applications for Grades 8 to 10, are listed at twenty-five percent of each course. These goals are to be integrated throughout the course as the other topics are taught. In the teacher interviews, the teachers saw this as a weak attempt to incorporate explicit scientific literacy teachings. Indeed, with no communication between the MOE and science teachers, I looked to dissecting provincial examinations in order to understand how twenty-five percent of a course composed of science applications was distributed within the other seventy-five percent of the content areas. No science literacy or NOS statements were identified on the three examinations available and, therefore, an accumulation of three years of new IRPs focused on science literacy is not included or tested on provincial examinations. The teachers interviewed have a cynical understanding that science applications are not valued by the MOE. I noted the following statements: "If the government didn't make room for it [POS], neither can I." ; and "If I didn't have to teach so much other stuff [in my science class], I could teach some real science (laughter)."

Implications

This project may suggest a number of research topics concerning pre-service teacher education. The year-long survey was exploratory in an attempt to measure scientific literacy growth, based on a compilation of older surveys. In preparing the surveys for the pre-service teachers, it was discovered that the Science Methods' course outline did not provide prescribed learning outcomes related to scientific literacy, nature of science and science processes. Development of the surveys, alongside the science methods courses' PLOs, would allow for more retention of learning, and more meaningful measurement of the effects on the pedagogy of the new teachers. Furthermore, I am concerned about pre-service teachers' understanding of environmental science. Tytler et al (2001) described an excellent learning opportunity for scientific literacy, regarding environmental concerns, catching the so-called experts exhibiting poor scientific processes. McCaffrey and Buhr (2008), in a meta-analysis of misconceptions in anthropogenic climate change, call for a stand-alone set of courses dealing with the interdisciplinary topics required for understanding the complexities of climate change, especially for teacher education. During the surveys, the pre-service teachers consistently erred on ozone depletion and acid rain causes. This is a grave indication that these teachers may continually teach their own misconceptions to their students. Should science methods courses allow time for the learning of science material, not just science teaching, or should a **co**-requisite climatology course be offered for all science teachers? A BSc degree does not guarantee knowledge in all fields, or current understanding in the case of mature pre-service teachers. One suggestion gleaned from these surveys is that pre-service teachers, working in the most contentious global climate change era, require a better understanding of the global and environmental processes. A scientifically literate citizen is imperative to understanding differences between natural and anthropogenic factors affecting climate conditions and change.

The impetus for doing this project was my wanting to delve into my own scientific literacy and NOS understandings, in order to improve my pedagogy and my understanding of current issues in science education. Involvement in professional development sessions with other science teachers is my vehicle for continuing with personal learning and growth, and also for supporting other science teachers. It is clear that the long anticipated IRPs fell short of teacher expectations, which were that the IRPs would support all students and make meaningful changes to the topics which students were to learn. Since 1996, the last edition of the IRPs, the gestalt of the classroom has changed significantly. Inclusion practices and class size issues have had a great impact on how science is taught in BC. There is a need, within the professional development community, to gather science teachers and create opportunities to vent, share and explore alternatives for the classroom, which encompass scientific literacy, and thereby return learning to a student-centred event, and allow teachers to forego the 'checklist of AIs'. Educating science teachers about NOS and scientific literacy would be a start.

Professional development that focused on clustering PLOs and AIs, which allows more classroom time for group and project work, would be most welcome for the Grades 8 and 9 sciences. However, Grade 10 teachers appear more cynical, and reluctant to engage in professional development as the provincial examinations loom over their classrooms. Furthermore, those teachers who do not have continuing contracts and seniority are less likely to try new techniques or invest the time needed to implement these ideas. They would rather focus on students earning acceptable test marks, and avoiding conflict, than espousing a greater understanding of scientific literacy and NOS, which are not part of the current examinations. There was a general feeling that Science 10 has become more of a bureaucratic process than a learning environment. Two teachers felt that their teaching autonomy has diminished significantly, as the rigid teacher-proofing of available learning resources seldom draws on their own expertise and areas of interest. Lack of communication with the MOE regarding the new science IRPs, in the last two years, has dampened optimism. Perhaps professional development which addresses the concerns expressed in the focus group, and which provides support for teaching the NOS and POS, can resuscitate scientific literacy and the esprit de corps among the teachers. This project of scientific literacy in the new BC junior science curricula will hopefully encourage meaningful dialogue among teachers, including those in pre-service, to increase explicit scientific literacy learning, reinforce sound environmental science, and regain some of the magic of observing students learning to make connections, and experiencing the ‘ah-ha’ moments, the most defining and intoxicating times in science education.

Bibliography

Abd-El-Khalick, F., & Lederman, N. G. (2000). The influence of history of science courses on students' views of nature of science. *Journal of Research in Science Teaching, 37*, 1057-1095.

Abd-El-Khalick, F., Lederman, N. G., Bell, R. L., & Schwartz, R. S. (2002). Views of nature of science questionnaire (VNOS): Toward a valid and meaningful assessment of learners' conceptions of nature of science. *Journal of Research in Science Teaching, 39*, 497-521.

Aikenhead, G. S., Ryan, A. G., & Fleming, R. W. (1989). *Views on Science-Technology Society (VOSTS)*. Retrieved May 16, 2006

Aikenhead, G. S., & Ryan, A. G. (1992). The Development of a New Instrument: "Views on Science-Technology-Society" (VOSTS). *Science Education, 76*, 477-491.

Aikenhead, G. S. (1996). Science Education: Border Crossing into the Subculture of Science. *Studies in Science Education, 27*, 1-52.

Alberta Education. (2005). *Programs of Study: Science 10*. Retrieved August 31, 2009, from http://education.alberta.ca/media/654833/science10.pdf

American Association for the Advancement of Science. (1989). *Science for all Americans-Project 2061*. Washington, DC: Oxford University Press.

American Association for the Advancement of Science. (1993). *Benchmarks for scientific literacy*. New York, New York: Oxford University Press.

American Association for the Advancement of Science. (2007). *Global climate-change resources*. Retrieved January 14, 2010, from http://www.aaas.org/news/press_room/climate_change

Anderson, J. O., Lin, H.-S., Treagust, D. F., Ross, S. P., & Yore, L. D. (2007). Using large-scale assessment datasets for research in science and mathematics education: Programme for international student assessment (PISA). *International Journal of Science and Mathematics Education, 5*(4), 591-614.

Bardeen, K. (2000). *Improving student science literacy through an inquiry-based, integrated science curriculum and review of science media.* Unpublished Action research project for Master of Arts, Saint Xavier University and Skylight Field-Based Master's Program, Berwyn, IL.

Black, K. (2004) *Science Methods Student Survey for EDUC 403 and EDCI 767 classes*, University of Victoria, British Columbia, Canada

Blades, D. (1997). *Procedures of Power & Curriculum Change: Foucalt and the Quest for Possibilities in Science Education.* (Vol. 35). New York, New York: Peter Lang Publishing Inc.

Botton, C., & Brown, C. (1998). The Reliability of Some VOSTS Items When Used with Preservice Teachers in England. *Journal of Research in Science Teaching, 35*, 53-71.

British Columbia College of Teachers and the Association of BC Deans of Education. (2004). *Letter of Understanding*. Retrieved September 4, 2009, from http://www.bcct.ca/documents/AboutUs/Committees/agrmt_bcct_abcde.pdf

British Columbia Ministry of Education. (2005, June). *Draft of science 8-10 integrated resource package*. Retrieved November, 2005, from http://www.bced.gov.bc.ca/irp/drafts/sci810_draft.pdf

British Columbia Ministry of Education, M. (2005, July 28, 2005). *Curriculum implementation update*. Retrieved May 5, 2006, from http://www.bced.gov.bc.ca/irp/program_delivery/scik10_implement_sched.pdf

British Columbia Science Teachers' Association (2009). *Science 10 provincial final exam: Provincial survey results*. Retrieved March 9, 2010 from http://www.bcscta.ca/Sci10%20Report.pdf

Bussiere, P., Knighton, T., & Pennock, D. (2007). *Measuring up: Canadian results of the OECD PISA study. The performance of Canada's youth in science, reading and mathematics 2006: First results for Canadians aged 15*. Ottawa, Ontario: Statistics Canada.

Bybee, R. W. (1997). *Achieving scientific literacy: From purposes to practices*. Portsmouth, NH: Heinemann.

Bybee, R. W. (1997, October 4). *The Sputnik Era: Why is this educational reform different from all other reforms.* Paper presented at the Reflecting on Sputnik: Linking the Past, Present and Future of Educational Reform, Washington, DC.

Caillods, F., Gottelmann-Duret, G., & Lewin, K. (1997). *Science education and development: Planning and policy issues at secondary level*. Paris, France: Pergamon.

Canadian Ministers of Education Council. (1997). Common framework of science learning outcomes: Pan-Canadian protocol for collaboration on school curriculum. Retrieved Dec 13, 2010 from http://publications.cmec.ca/science/framework/Pages/english/CMEC%20Eng.html

Canadian Ministers of Education Council. (2008). *PCAP-13 2007: Report on the assessment of 13-year-olds in reading, mathematics, and science*. Retrieved March 9, 2010, from http://www.cmec.ca/Programs/assessment/pancan/pcap2007/Documents/PCAP2007-

Report.en.pdf

Canadian Ministers of Education of Canada, C. (2008, 2008-12-05). *PISA 2006*. Retrieved August 30, 2009, from http://www.pisa.gc.ca/home-eng.shtml

Champagne, A., & Hornig, L. E. (1986). Critical questions and tentative answers for the school science curriculum. In A. Champagne & L. E. Hornig (Eds.), *This year in science education: The science curriculum* (pp. 1-12). Washington, DC: American Association for the Advancement of Science.

Christensen, C. (2009). Risk and school science education. *Studies in Science Education, 45*, 205-223.

Connelly, M. F., Crocker, R. K., & Kass, H. (1985). *Science education in Canada, Volume I: Policies, practices and perceptions.* Ontario Institute for Studies in Education.

Creswell, J. W. (2005). Mixed Methods Designs. In *Educational research: Planning, conducting and evaluating quantitative and qualitative research* (2nd ed., pp. 509-547), Upper Saddle River, New Jersey: Pearson Education, Inc.

De Boer, G. E. (1991). *A history of ideas in science education: Implications for practice*. New York, NY: Teachers College Press.

De Boer, G. E. (1997, October 4). *What we have learned and where we are headed: Lessons from the Sputnik era*. Paper presented at the Reflecting on Sputnik: Linking Past, Present and Future of Educational Reform, Washington, DC.

De Boer, G. E. (2000). Scientific literacy: Another look at its historical and contemporary meanings and its relationship to science education reform. *International Journal of Research in Science Teaching, 37*, 582-601.

Dewey, J. (1913). *The school and society* (11th ed.). Chicago, Illinois: The University of Chicago Press.

Dewey, J. (1929). *The sources of a science of education*. New York, NY: Liveright.

Dillion, J. (2009). On scientific literacy and curricular reform. *International Journal of Environmental and Science Education, 4*, 201-213.

Driver, R. (1994). The fallacy of induction in science teaching. In R. Levinson (Ed.), *Teaching Science*. New York, NY: Routledge.

Durant, J., Evans, G., & Thomas, G. (1992). Public understanding of science in Britain: The role of medicine in the popular representation of science. *Public Understanding of Science, 1*, 161-182.

Ediger, M. (2002). *Societal trends and the curriculum (Report No. CS-511-631)* (Opinion paper). East Lansing, MI: National Centre for Research on Teacher Learning.

Einsiedel, E. F. (1992). Framing science and technology in the Canadian press. *Public Understanding of Science, 1*, 89-101.

Einsiedel, E. F. (1994). Mental maps of science: Knowledge and attitudes among Canadian adults. *International Journal of Public Opinion Research, 6*, 35-44.

Hanrahan, M. (2002, July 11-14). *Learning Science: Sociocultural dimensions of intellectual engagement.* Paper presented at the ASERA, Townsville, Queensland, Australia.

Harms, N. C., & Yager, R. E. (Eds.). (1981). *What research says to the science teacher* (Vol. 3). Washington, DC: National Science Teachers Association.

Hodson, D., & Prophet, R. B. (1994). Why the science curriculum changes: Evolution or social control? In R. Levinson (Ed.), *Teaching Science*. New York, NY: Routledge.

Hodson, D. (2000). Toward universal scientific literacy. *Orbit, 3*1, 13.

Hurd, P. D. (1998). Scientific literacy: New minds for a changing world. *Science Education, 82*, 407-416.

Jarman, R., & McClune, B. (2001). Use the news: A study of secondary science teachers' use of newspaper in the science classroom. *Journal of Biological Education, 35*, 69-74.

Kemp, A. C. (2000, April 24-28). *Scientific literacy for all: Rationales and realities.* Paper presented at the Paper presented at American Education Research Association, New Orleans, LA.

Kemp, A. C. (2002, January 10-13). *Implications of diverse meanings for 'scientific literacy'.* Paper presented at the Annual International Conference of the Association for the Education of Teachers in Science, Charlotte, NC.

Khalid, T. (2001). Pre-service teachers' misconceptions regarding three environmental issues. *Canadian Journal of Environmental Education, 6*, 102-120.

Korpan, C. A., Bisanz, G. L., Bisanz, J., & Henderson, J. M. (1997). Assessing literacy in science: Evaluation of scientific news briefs. *Science Education, 81*, 515-532.

Laugksch, R. C., & Spargo, P. E. (1996). Development of a pool of scientific literacy test-items based on selected AAAS literacy goals. *Science Education, 80*, 121-143.

Laugksch, R. C., & Spargo, P. E. (1996). Construction of a paper-and-pencil *Test of Basic Scientific Literacy* based on selected literacy goals recommended by the American Association for the Advancement of Science. *Public Understanding of Science, 5*, 331-

359.

Laugksch, R. C. (2000). Scientific literacy: A conceptual overview. *Science Education, 84*, 71-94.

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

Lederman, N. G. (1992). Students' and teachers' conceptions of the nature of science: A review of the research. *Journal of Research in Science Teaching, 29*, 331-359.

Lederman, N. G., Wade, P. D., & Bell, R. L. (1998). Assessing the nature of science: What is the nature of our assessments? *Science and Education, 7*, 595-615.

Lederman, N. G. (2000). Improving science teachers' conceptions of nature of science: a critical review of the literature. *International Journal of Research in Science Teaching, 22*, 665-701.

Linn, R. L. (2001). A century of standardized testing: Controversies and pendulum swings. *Educational Assessment, 7*, 29-38.

Matricardi, G., Muratori, R., Porro, E., & Capozza, A. (2000, April 8-10). *Science education and controversial issues: A case study (ERIC report No. ED447305).* Paper presented at the Cross-Roads of the New Millenia Conference, Abu Dhabi, United Arab Emirates.

McEeaney, E. H. (2003). The worldwide cachet of scientific literacy. *Comparative Education Review, 47*, 217-237.

Millar, R., & Osbourne, J. (Eds.) (1998). *Beyond 2000: Science education for the future.* London, England: Nuffield Foundation.

Miller, J. D. (1983). Scientific literacy: A conceptual and empirical overview. *Daedalus, 112*, 29-48.

Miller, J. D. (1998). The measurement of civic scientific literacy. *Public Understanding of Science, 7*, 203-223.

National Research Council. (2001). *Educating teachers of science, mathematics and technology; New practices for the new millennium*. Washington, DC: National Academy Press.

National Science Board. (2006). *Science and Engineering Indicators* (No. NSB 06-01). Arlington, VA: National Science Foundation.

Nichols, D. P. (1999). *My Coefficient a is Negative!* Retrieved August 16, 2010 from http://www.ats.ucla.edu/stat/spss/library/negalpha.htm

Olsen, R. V., Turmo, A., & Lie, S. (2001). Learning about students' knowledge and thinking in science through large-scale quantitative studies. *European Journal of Psychology of Education, 16*, 401-418.

Olsen, R. V. (2004, April 1-4). *The OECD PISA assessment of scientific literacy: how can it contribute to science education research?* Paper presented at the NARST, Vancouver, Canada.

Ontario Ministry of Education. (2008). *The Ontario Curriculum, Grades 9 and 10: Science*. Retrieved August 31, 2009 from http://www.edu.gov.on.ca/eng/curriculum/secondary/science910_2008.pdf

Organisation for Economic Co-Operation and Development, & OECD. (2001). *Knowledge and skills for life: First results from the OECD programme for international student assessment (PISA)*. Retrieved January 7, 2010 from http://www.pisa.oecd.org/dataoecd/44/53/33691596.pdf

Organization for Economic Co-operation and Development, O. (2005, Jan 14, 2005). *OECD PISA home page*. Retrieved May 1, 2006 from http://www.pisa.oecd.org/pages/0,2966,en_32252351_32235731_1_1_1_1_1,00.html

Orpwood, G., & Garden, R. A. (1998). *TIMSS monograph no. 4: Assessing mathematics and science literacy*. Vancouver, Canada: Pacific Educational Press.

Osborne, J., Simon, S., & Collins, S. (2003). Attitudes towards science: A review of the literature and its implications. *International Journal of Science Education, 25*, 1049-1079.

Penick, J. E. (1993). *Scientific Literacy: An Annotated Bibliography.* Paper presented at the ICASE/UNESCO Conference: Project 2000+: Scientific Literacy for All, Paris, France.

PISA, OECD. (2001). *Measuring up: The performance of Canada's youth in reading, mathematics and science*. Retrieved March 9, 2010 from http://www.pisa.gc.ca/pisa/81-590-xpe.pdf

PISA, OECD. (2004). *Measuring up: Canadian results of the OECD PISA study. The performance of Canada's youth in mathematics, reading, science and problem solving.* Retrieved March 9, 2010 from http://www.cmec.ca/Programs/assessment/ interstudent/pisa2003/Documents/pisa2003.en.pdf

PISA, OECD. (2007). *Measuring up: Canadian results of the OECD PISA study. The performance of Canada's youth in science, reading and mathematics.* Retrieved March 9, 2010 from http://www.pisa.gc.ca/81-590-E.pdf

Porter, A. C., & Brophy, J. (1988). Synthesis of research on good teaching: Insights from the work of the Institute for Research on Teaching. *Educational Leadership, 45*, 74-85.

Prewitt, K. (1983). Scientific illiteracy and democratic theory. *Daedalus, 112*, 49-64.

Richardson, L., & Simmons, P. E. (1994). *Self Q research methods and analyses. Teacher pedagogical philosophy interview: Theoretical background and data.* Athens, GA: University of Georgia.

Rowe, M. (1983). Science education: a framework for decision-makers. *Daedalus, 112*, 123-142.

Rubba, P. A., & Anderson, H. O. (1978). Development of and instrument to assess secondary school students' understanding of the nature of scientific knowledge. *Science Education, 62*, 449-458.

Rubba, P. A., Bradford, C. S., & Harkness, W. J. (1996). A new scoring procedure for the views on science-technology-society instrument. *International Journal of Science Education, 18,* 387-400.

Ryan, R. M., & Weinstein, N. (2009). Undermining Quality Teaching and Learning: A Self-Determination Theory Perspective on High-Stakes Testing. *Theory and Research in Education, 7*, 224-233.

Ryder, J. (2001). Identifying science understanding for functional scientific literacy. *Studies in Science Education, 36*, 1-44.

Sadler, T. D. (2002, October). *Sociospecific issues and the affective domain: Scientific literacy's missing link.* Paper presented at the Annual Meeting of the Southeastern Association for the Education of Teachers in Science, Kennesaw, GA. (ERIC Document Reproduction Service ED 472 041)

Shamos, M. H. (1995). *The myth of scientific literacy*. New Brunswick, New Jersey: Rutgers University Press.

Simmons, P. E., Emory, A., Carter, T., Coker, T., Finnegan, B., Crockett, D., et al. (1999). Beginning teachers: Beliefs and classroom actions. *Journal of Research in Science Teaching, 36*, 930-954.

Solomon, J. (1994). The laboratory comes of age. In R. Levinson (Ed.), *Teaching Science*. 7-38, London, England: Routledge.

Tobias, S. (1990). *They're not dumb, they're different: Stalking the second tier.* Tucson, Arizona: Research Corporation.

Tytler, R., Duggan, S., & Gott, R. (2001). Dimensions of evidence, the public understanding of science and science education. *International Journal of Science Education, 23*, 815-

832.

Ungar, S. (2000). Knowledge, ignorance and the popular culture: climate change versus the ozone hole. *Public Understanding of Science, 9*, 297-312.

Yager, R. E. (2000). History and future of reform. *The Clearing House, 74*, 51-54.

Yore, L. D., Bisanz, G. L., & Hand, B. M. (2003). Examining the literacy component of science literacy: 25 years of language arts and science research. *International Journal of Science Education, 25*, 689-725.

Yore, L., & Treagust, D. (2006). Current realities and future possibilities: Language and science literacy—empowering research and informing instruction. *International Journal of Science Education*, *28*, 291-314.

Yore, L. D., Pimm, D., & Tuan, H.-L. (2007). The literacy component of mathematical and scientific literacy. *International Journal of Science and Mathematics Education, 5*, 559-589.

Appendix A
Building of surveys

Table A1. *Pilot of Scientific Literacy and Nature of Science Modifications.*

Please download (word document), type an X in the box of your choice. Please don't feel bad to mark "?" I didn't even know some of the answers when I started my research. Thanks for taking time to help, Allana.

I. Scientific Literacy (T=true, F=false and ?=Don't know) (5 minutes) Please type an "x" beside the letter of your choice.

Scientific Knowledge

	Pilot Survey Questions	**Final Survey 1 Questions**
1	The centre of the Earth is very hot.	The centre of the Earth is very hot.
2	The continents have been moving their location for millions of years and are starting to slow down.	The continents, known to have moved and collided for millennia, have all stopped all movement.
3	Electrons are smaller than atoms.	Electrons are smaller than atoms.
4	All radioactivity is man-made.	All radioactivity is man-made.
5	A father's gene determines whether the baby is a boy or girl.	A father's genes determines whether the baby is a boy or girl.
6	Antibiotics kill viruses as well as bacteria.	Antibiotics kill viruses as well as bacteria.
7	Radioactive milk can be made safe by boiling it.	Radioactive milk can be made safe by boiling it.
8	Aerosol sprays with chlorofluorocarbons (CFC's) cause acid rain.	Aerosol sprays with chlorofluorocarbons (CFC's) cause acid rain.

Table A.2. *Rubba and Anderson's NSKS*

	Pilot Survey Questions	Final Survey 1 Questions
1.	The applications of scientific knowledge can be judged good or bad; but the knowledge itself cannot.	I believe the knowledge, by itself, cannot be judged good or bad although *how* science is used can be judged this way.
2.	Scientific laws, theories, and concepts do not express creativity.	I believe scientific laws, theories, and concepts do not show creativity.
3.	Scientific knowledge is a product of human imagination.	I believe imagination and creativity helped produce scientific knowledge.
4.	Scientific beliefs do not change over time.	I believe scientific beliefs do not change over time.
5.	We accept scientific knowledge even though it may contain error.	I believe we accept scientific knowledge even though it may have errors.
6.	If two scientific theories explain a scientist's observations equally well, the simpler theory is chosen.	If two scientific theories explain a scientist's observations ***equally well***, the simpler theory is chosen.
7.	Scientific knowledge is comprehensive as opposed to specific.	I believe scientific knowledge tries to be more comprehensive (universal or general) rather than specific (detailed and narrow).
8.	The evidence for scientific knowledge must be repeatable.	I believe that the evidence for scientific knowledge must be repeatable.
9.	The laws, theories, and concepts of biology, chemistry, and physics are not related.	I believe that the laws, theories, and concepts of biology, chemistry, and physics are not related.
10.	The various sciences contribute to a single organized body of knowledge.	I believe that the various sciences contribute to a single organized body of knowledge.

Comments/concerns about any question's language, vagueness, worth, difficulty would be greatly appreciated, Allana ☺.

Table A.3. *Building the Survey Instruments using Science in the media (Miller (1983) and Einsiedel (1994))*.

Please circle your best answer. If you are unsure of an answer, circle question mark (?)

Area of Science	Statement	Pre	Mid	Post
Astronomy	The universe began with a huge explosion.		2	
Astronomy	The Sun travels around the Earth.		2	3*[1a]
Astronomy	The Earth takes 30 days to travel around the sun.		2	3*[2a]
Biology	Human beings are developed from earlier species of animals.		2	
Biology	A father's gene determines whether the baby is a boy or girl.	1		3
Biology	Antibiotics kill viruses as well as bacteria.	1		3
Earth Science	The centre of the Earth is very hot.	1		3
Earth Science	The continents have been moving their location for millions of years and are starting to slow down.	1		
Earth Science	Dinosaurs and humans lived at the same time		2	
Physical Science	Electrons are smaller than atoms.	1		
Physical Science	All radioactivity is man-made.	1		
Physical Science	Lasers work by focusing sound waves.		2	3
Physical Science	Light travels faster than sound.		2	3
Physical Science	Radioactive milk can be made safe by boiling it.	1		
Phys. Science	ir pollution can cause a green house effect.		2	3*[1b]
Physical Science	Aerosol sprays with chlorofluorocarbons (CFC's) cause acid rain.	1		

* = Objects in question were exchanged to prevent test-retest reward.

1a. The Earth travels around the Sun.

2a. The moon takes about 30 days to travel around the Earth.

1b. Air pollution by burning fossil fuels causes ozone depletion.

Table A.4. *Division of NSKS into the Pre, Mid, and Post Surveys.*

Category	Q#	Stem	**Pre**	**Mid**	**Post**
Amoral	4	The applications of scientific knowledge can be judged good or bad; but the knowledge itself cannot.	**1**		
	5	It is incorrect to judge a piece of scientific knowledge as being good or bad.			**3**
	7	Certain pieces of scientific knowledge are good and others are bad.			
	8	Even if the applications of a scientific theory are judged to be good, we should not judge the theory itself.			
	18	Moral judgement can be passed on scientific knowledge.			
	21	It is meaningful to pass moral judgement on both the applications of scientific knowledge and the knowledge itself.			
	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.			
	48	A piece of scientific knowledge should not be judged good or bad.		**2**	

Creative	1	Scientific laws, theories, and concepts do not express creativity.	**1**		**3**
	17	Scientific knowledge expresses the creativity of scientists.			
	20	Scientific laws, theories, and concepts express creativity.			
	23	Scientific knowledge is not a product of human imagination.			**3**
	28	A scientific theory is similar to a work of art in that they both express creativity.		**2**	
	32	Scientific knowledge is a product of human imagination.	**1**		
	34	Scientific knowledge does not express the creativity of scientists.			
	41	Scientific theories are discovered, not created by man.		**2**	
Developmental	25	The truth of scientific knowledge is beyond doubt.			**3**
	26	Today's scientific laws, theories, and concepts may have to be changed in the face of new evidence.			
	31	Scientific beliefs do not changeover time.	**1**		
	37	Scientific knowledge is subject to review and change		**2**	
	42	Those scientific beliefs which were accepted in the past and since have, been discarded, should be judged in their historical context.			
	43	Scientific knowledge is unchanging.			
	16	We accept scientific knowledge even though it may contain error.	**1**		**3**
	27	We do not accept a piece of scientific knowledge unless it is free of error.		**2**	
Parsimonious	2	Scientific knowledge is stated as simply as possible.			**3**
	6	If two scientific theories explain a scientist's observations equally well, the simpler theory is chosen.	**1**		
	14	Scientific laws, theories, and concepts are not stated as simply as possible.			
	15	There is an effort in science to build as great a number of laws, theories, and concepts as possible.			
	29	There is an effort in science to keep the number of laws, theories, and concepts at a minimum.		**2**	
	39	If two scientific theories explain a scientist's observations equally well, the more complex theory is chosen.	**1**		
	40	Scientific knowledge is specific as opposed to comprehensive.			
	46	Scientific knowledge is comprehensive as opposed to specific.		**2**	**3**
Testable	9	Scientific knowledge need not be capable of experimental test.			
	11	Consistency among test results is not a requirement for the acceptance of scientific knowledge.		**2**	
	12	A piece of scientific knowledge will be accepted if the evidence can be obtained by other investigators working under similar conditions.			**3**
	13	The evidence for scientific knowledge need not be open to public examination.			
	22	The evidence for scientific knowledge must be repeatable.	**1**		
	33	The evidence for a piece of scientific knowledge does not have to be repeatable.			
	38	Scientific laws, theories, and concepts are tested against reliable observations.			
	45	Consistency among test results is a requirement for the acceptance of scientific knowledge.			
Unified	3	The laws, theories, and concepts of biology, chemistry, and physics are related.			**3**
	10	The laws, theories, and concepts of biology, chemistry, and physics are not linked.			
	19	The laws, theories, and concepts of biology, chemistry, and physics are not related.	**1**		
	24	Relationships among the laws, theories, and concepts of science do not **contribute to** the explanatory and predictive power of science.		**2**	
	30	The various sciences contribute to a single organized body of knowledge.	**1**		

35	Biology, chemistry, and physics are similar kinds or knowledge.		
44	Biology, chemistry, and physics are different kinds of knowledge.		**3**
47	The laws, theories, and concepts of biology, chemistry, and physics are interwoven.	**2**	

Table A.5. Breakdown of Topical statements within each survey instrument.

Area of Science	**Pre**	**Mid**	**Post**
Astronomy	0	3	2
Biology	2	1	2
Earth Science	2	1	1
Physical Science (Chemistry and Physics)	4	3	3

Table A.5b. *Breakdown of NSKS subscales within each survey instrument.*

	Pre	Mid	Post
Amoral	1	1	1
Creative	2	2	2
Developmental	2	2	2
Parsimonious	2	2	2
Testable	1	1	1
Unified	2	2	2

Appendix B
Survey 1

EDUC 403/ EDCI 767 Science Methods Student Survey (Dr. Kathie Black)

This survey of four pages contains questions about you, your learning style, previous science courses and general information. All answers are confidential. A third party will code both these pages to ensure anonymity. Please do not write in the space below, as this is necessary for assignment of anonymous code number. Thank you for participating.

STUDENT NUMBER: ____

	If employed, how many hours do you work per week? Please select and underline. i) part time (under 20 hours) ii) full time (more than 20 hours) iii) not employed
	What are your hobbies or interests?
	What science questions are you curious about?
	What concerns do you have regarding teaching science?
	What are your goals in this class and as a teacher?

Secondary Science Preservice Student Teacher Survey

This survey contains questions about you, your learning style, previous science courses and general information. Please TYPE an "X" that best fits your situation and fill in the blanks for other questions. Please choose ONE answer unless instructed to circle all that apply. If you do not understand a question, please ask for assistance. All answers are confidential. Thank you for participating.

What is your age? a) 20-24 b) 25-29 c) 30-34 d) 35-39 e) 40-44 f) 45-49 g) other

Gender: ☐ Male ☐ Female

What preservice program are you enrolled in?

PPDP	B. Ed	
☐ Elementary	☐ Elementary	☐ Intern
☐ Secondary	☐ Secondary	

Have you had teaching or instructional experience in any of the following: (please type an X in front of each letter)	a) Substitute teaching b) Volunteering/working in Schools c) Volunteering/working in informal settings i.e camps, sports, museums, tutoring, coaching etc d) Other:______________________________ e) None

	Course	Number of semester courses taken					
Type an X beside number of Post secondary science courses you have taken throughout your undergraduate degree. (Circle only those that apply)	Biology	1	2	3	4	5	ε 6
	Biochemistry	1	2	3	4	5	ε 6
	Chemistry	1	2	3	4	5	ε 6
	Geology	1	2	3	4	5	ε 6
	Microbiology	1	2	3	4	5	ε 6
	Environ Sci.	1	2	3	4	5	ε 6
	Physics	1	2	3	4	5	ε 6
	Other:	1	2	3	4	5	ε 6

What year and University did/will you receive your degree?
Year:_____ University:________________

Declared Major(s) 15 units of 3rd & 4th year	Single Major:________________________________ Double Major:_______________________________
Minor(s) 6 units of 3rd & 4th year	Single Minor: _______________________________ □ Double Minor: ______________________________

CIRCLE the science courses you have taken in Grade 11 and 12. (Circle all that apply)	Bi 11	Chem 11	Phys 11	Earth Sc 11	Sci&Tech11
	Bi 12	Chem 12	Phys 12	Geog. 12	Other:

Please type lettered choice(s) in blanks, from choices on the right, that best describes you:

I mainly use _____________ as my source of science and social issues about my *local* community.	a) television b) internet c) newspapers d) magazines e) radio f) other people g) educational background h) libraries j) journals
I mainly rely on ___________ and _______ to understand science, social and technological issues I am curious about.	
_____________ , I believe, has the best reliability of all the sources. I can trust this to have the most accurate information.	

Survey 1 [aka pre-test]

This survey is to assess your initial knowledge of scientific literacy, pedagogical content knowledge and curricula. This survey will be scored but not added to any Grade to any course. If you are unsure of an answer, please mark the "?" for section I and please answer every question regardless of whether you know the correct answer.

Keep in mind you haven't been taught any science methods.

I. Scientific Literacy (T= true, F= false and ?= Don't know) (5 minutes)
Please type an "x" beside the letter of your choice.

The centre of the Earth is very hot.	T	F	?
The continents, known to have moved and collided for millennia, have all stopped all movement.	T	F	?
Electrons are smaller than atoms.	T	F	?
All radioactivity is man-made.	T	F	?
A father's genes determines whether the baby is a boy or girl.	T	F	?
Antibiotics kill viruses as well as bacteria.	T	F	?
Radioactive milk can be made safe by boiling it.	T	F	?
Aerosol sprays with chlorofluorocarbons (CFC's) cause acid rain.	T	F	?
I believe the knowledge, by itself, cannot be judged good or bad although *how* science is used can be judged this way.	T	F	?
I believe scientific laws, theories, and concepts do not show creativity.	T	F	?
I believe imagination and creativity helped produce scientific knowledge.	T	F	?
I believe scientific beliefs do not change over time.	T	F	?
I believe we accept scientific knowledge even though it may have errors.	T	F	?
If two scientific theories explain a scientist's observations ***equally well***, the simpler theory is chosen.	T	F	?
I believe scientific knowledge tries to be more comprehensive (universal or general) rather than specific (detailed and narrow).	T	F	?
I believe that the evidence for scientific knowledge must be repeatable.	T	F	?
I believe that the laws, theories, and concepts of biology, chemistry, and physics are not related.	T	F	?
I believe that the various sciences contribute to a single organized body of knowledge.	T	F	?

II. Pedagogical Content Knowledge (PCK) and NOS (8 minutes)

1. Speculation is an important procedure in science. **Inferring**, **predicting** and **hypothesizing** are different forms of speculation. Outline, in point form, how these processes are a) *similar* and b) *different*.

2. Define the difference between a ***pre***conception and ***mis***conception **AND** use an example to illustrate your answer.

Bold the correct word and/or delete the incorrect choice(s) to complete the two statements.

3. To make (INFERENCES / OBSERVATIONS) about an experiment, one must first make (INFERENCES / OBSERVATIONS).

4. For a (FACT/ LAW/ THEORY) to become widely accepted, a consensus of assumptions from many are needed. A (FACT/ LAW/ THEORY) must be supported by observable (FACT/ LAW/ THEORY).

III. Curricula.

In point form or TWO sentences, answer the following in the given spaces. (7 minutes)

1. How would you explain the "Nature of Science"?

2. What does term "Scientific Literacy" mean to you?

3. Explain how a prescribed learning outcome (PLO) is not necessarily the same as chapter review in a textbook?

4. Two students are working on the same topic, one student is reading a science text and the other is performing a lab. Give an example of an alternative method to learning the science topic.

Appendix C
Survey 2

Survey 2 (aka mid-test) Research ID Code: ________

This survey is to assess your developing knowledge of scientific literacy, pedagogical content knowledge and curricula. This survey will be scored but not added to any Grade to any course. If you are unsure of an answer, please mark the "?" for section I and please answer every question regardless of whether you know the correct answer. Keep in mind you haven't begun your formal student teaching yet.

I. Scientific literacy (5 minutes)

The universe began with a huge explosion.	T	F	?
The Sun travels around the Earth.	T	F	?
Lasers work by focusing sound waves.	T	F	?
Human beings are developed from earlier species of animals.	T	F	?
Dinosaurs and humans lived at the same time	T	F	?
Light travels faster than sound.	T	F	?
The Earth takes 30 days to travel around the sun.	T	F	?
Air pollution can cause a green house effect.	T	F	?
A piece of scientific knowledge should not be judged good or bad.	T	F	?
Scientific theories are discovered, not created by man.	T	F	?
A scientific theory is similar to a work of art in that they both express creativity.	T	F	?
Scientific knowledge is subject to review and change.	T	F	?
We do not accept a piece of scientific knowledge unless it is free of error.	T	F	?
There is an effort in science to keep the number of laws, theories, and concepts at a minimum.	T	F	?
Scientific knowledge is comprehensive as opposed to specific.	T	F	?
Consistency among test results is a requirement for the acceptance of scientific knowledge.	T	F	?
Relationships among the laws, theories, and concepts of science do not contribute to the explanatory and predictive power of science.	T	F	?
The laws, theories, and concepts of biology, chemistry, and physics are interwoven.	T	F	?

II. Curriculum: (10 minutes)

A group of students are concerned about this newspaper article and would like to do a report. They come to you as their teacher and ask for your help. Read the article and answer the following questions:

Experts call for windy summer
By Mike De SOUZA Can West News Service

OTTAWA. Canadians should brace for another "busy" season of hurricanes and storms, Environment Canada predicted Monday.
Following last year's record breaking summer of 28 storms, three times above normal, meteorologists said the warm waters of the Atlantic ocean will continue to fuel a period of "heightened hurricane activity".
But the Canadian Hurricane Centre in Halifax says the jury is still out on whether the changes are related to global warming. 'There's a lot of debate still going on about that.", said Environment Canada meteorologist Chris Fogerty. Certainly, warmer water does fuel the energy of the storms, but we're not totally conclusive about how the storm intensity or numbers will change in the future."
Fogerty said the level of hurricanes has generally risen and dropped oil in 20- year cycles over the past century. "We've been in an active period of intensity since the 1990's," he said. "So, perhaps in 20 years, we may see a drop in the number of storms, if the past is any indication."
Environmental groups argue that global warming is making low-level hurricanes into much more powerful storms such as 2005's hurricane Katrina. (Times Colonist, June 7, 2006)

1. Is the information, in your mind, unbiased and legitimate for a student report? Why?
2. Suppose that you must determine whether if the information is valid and authentic. What additional pieces of information, if any, would you like to have about the researchers' reports to decide whether the author's reporting is correct? Use point form within space below only.
3. List possible teaching and organizational skills and techniques you would use to help these students, in point form only.
4. One student isn't as "productive" as the others. The others come to you to voice their concern about the Grade they will receive if the "reluctant" member of the group does not meet group expectations? Briefly described, in point form, the step(s) you would take.

Appendix D
Survey 3

Please submit completed survey in one of the following ways:
Fax survey to: 250-655-2701 in care of Andrew Roome
Scan and email survey to: Andrew_Roome@sd63.bc.ca
Place in self addressed envelope and mail: 10640 MacDonald Park Rd, Sidney BC, V8L 5S7

Survey 3 (aka post-test)

This survey is to assess your scientific literacy, pedagogical and course content knowledge. This survey will be scored but not added to any Grade to any course. If you are unsure of an answer, please mark the "?" for section I and please answer every question regardless of whether you know the correct answer. Thank you for participating.

I. Scientific Literacy (T=true, F=false and ? = Don't know) (5 minutes)

The Earth travels around the Sun.	T	F	?
The centre of the Earth is very hot.	T	F	?
Lasers work by focusing light waves.	T	F	?
A father's gene determines whether the baby is a boy or girl.	T	F	?
Antibiotics no only kill bacteria but viruses too.	T	F	?
Light travels faster than sound.	T	F	?
The Moon takes about 30 days to travel around the Earth.	T	F	?
Air pollution by burning fossil fuels cause Ozone depletion.	T	F	?
	T	F	?
It is incorrect to judge a piece of scientific knowledge as being good or bad.			
Scientific laws, theories, and concepts do not express creativity.	T	F	?
Scientific knowledge is a product of human imagination.	T	F	?
The truth of scientific knowledge is beyond doubt.	T	F	?
We accept scientific knowledge even though it may contain error.	T	F	?
Scientific knowledge is stated as simply as possible.	T	F	?
Scientific knowledge is comprehensive as opposed to specific.	T	F	?
A piece of scientific knowledge will be accepted if the evidence can be obtained by other investigators working under similar conditions.	T	F	?
The laws, theories, and concepts of biology, chemistry, and physics are related.	T	F	?
Biology, chemistry, and physics are different kinds of knowledge.	T	F	?

II. Pedagogical Content Knowledge (PCK)

Please read the following news article and answer the questions below.

"Study Concludes That Pesticide Use Increases Risk Of Parkinson's In Men"

Researchers have found that using pesticides increases the risk of developing Parkinson's disease for men. "This confirms what has been found in previous studies: that occupational or other exposure to herbicides, insecticides and other pesticides increases risk for Parkinson's," says Jim Maraganore, M.D.. "What we think may be happening is that pesticide use combines with other factors, causing men to cross over the threshold into developing the disease. The investigators identified all those in Olmsted County, Minn., who had developed Parkinson's disease between 1976 and 1995. The researchers conducted telephone interviews with 149 of those with Parkinson's and 129 of those who did not have the disease to assess exposure to chemical products. Overall, the study found that the men with Parkinson's were 2.4 times more likely to have had exposure to pesticides than those who did not have Parkinson's. This study was undertaken due to conflicting results from previous studies of pesticides and other chemical products and risk for Parkinson's. (June 15, 2006)

Funding for the study is from two grants from the National Institutes of Health. The medical-records linkage system of the Rochester Epidemiology Project also made this study possible.

Is the research legitimate? What further requests of information would you need from the researchers to fully endorse the research, deem it authentic and valid and present to your students? **Present statements in point form. (10 minutes)**

Answer: Extra points will be given if these terms are included and used correctly: misconception, preconception, theory, fact, inference, observation, Nature of Science, Scientific Literacy, control, variable, reliability.

III Personal Educational Experiences (20 minutes).

Were your education/pedagogy courses beneficial to you when you began teaching? Explain.

Were your undergraduate science/mathematics courses beneficial to you when you began teaching? Explain.

If you could:

What changes would you make in education courses to make the experience more meaningful?

What changes would you make in undergrad science/math courses to make the experience more meaningful?

In reference to the teaching model/package that you have undertaken, if you had to divide that up into a pie chart, how much of the chart would come from undergraduate subject training, graduate training, education courses, your on-the-job experience, or anything else that you can think of?

Anything you'd like to add about the **surveys** you took part in this past year? Where there any questions or items that you thought were unfair or inappropriate for a student teacher in your position? Any suggestions to improving the research to better the post professional degree programs at UVic?

Appendix E
Original Parkinson's disease article

Authentic news article as written, the underlined portions of the article are those pieces of information left out to measure whether or not participants would ask questions of the missing data.

Study Concludes That Pesticide Use Increases Risk Of Parkinson's In Men

19 Jun 2006

Mayo Clinic researchers have found that using pesticides for farming or other purposes increases the risk of developing Parkinson's disease for men. Pesticide exposure did not increase the risk of Parkinson's in women, and no other household or industrial chemicals were significantly linked to the disease in either men or women.

Findings will be published in the June issue of the journal Movement Disorders.

"This confirms what has been found in previous studies: that occupational or other exposure to herbicides, insecticides and other pesticides increases risk for Parkinson's," says Jim Maraganore, M.D., Mayo Clinic neurologist and study investigator. "What we think may be happening is that pesticide use combines with other risk factors in men's environment or genetic makeup, causing them to cross over the threshold into developing the disease. By contrast, estrogen may protect women from the toxic effects of pesticides."

The investigators identified all those in Olmsted County, Minn., home of Mayo Clinic, who had developed Parkinson's disease between 1976 and 1995. Each person with Parkinson's disease was matched for comparison to someone similar in age and gender who did not have the disease. The researchers conducted telephone interviews with 149 of those with Parkinson's and 129 of those who did not have the disease, or a proxy for these people, to assess exposure to chemical products via farming occupation, non-farming occupation or hobbies. The investigators were unable to determine through these interviews the exact exposure levels of these individuals or the cumulative lifetime exposure to pesticides.

Overall, the study found that the men with Parkinson's were 2.4 times more likely to have had exposure to pesticides than those who did not have Parkinson's. Women who had Parkinson's, on the other hand, had a far lower frequency of exposure to pesticides than men with the disease.

This study was undertaken due to conflicting results from previous studies of pesticides and other chemical products and risk for Parkinson's.

Article adapted by Medical News Today from original press release.

Funding for the study is from two grants from the National Institutes of Health. The medical-records linkage system of the Rochester Epidemiology Project, http://mayoresearch.mayo.edu/mayo/research/rep also made this study possible.

To obtain the latest news releases from Mayo Clinic, go to http://www.mayoclinic.org/newsMayoClinic.com http://www.mayoclinic.org/news is available as a resource for your health stories.

Contact: Lisa Lucier
Mayo Clinic

Appendix F
Common PLO lists

Grade 8

Common Prescribed Learning Outcomes 1996

Life Science (Social Issues) *It is expected that students will:* assess different impacts of using renewable and non-renewable natural resources compare and contrast the practical, ethical, and economic dimensions of population growth and polluted environments relate extraction & harvest of earth's resources to sustainability & reduction of waste evaluate how major natural events &human activity can affect local & global environments & climate change critique the hypothesis that the earth is like a living organism
Physical Science (Matter, Properties & the Periodic Table) • use kinetic particle model to describe structure & properties of various states of matter **Physical Science (Energy)** ***It is expected that students will:*** • demonstrate and explain how basic concepts relating to heat and light are used in common applications • distinguish among reflection, absorption, radiation, and transmission • compare and contrast reflection and refraction • demonstrate and explain how colour is perceived in different environments

Common Prescribed Learning Outcomes 2006

Earth and Space Science

KEY ELEMENTS: EARTH AND SPACE SCIENCE

Estimated Time: 20-22 hours

By the end of this grade, students will have understood the properties of water and its effect on the biosphere and surface of the Earth.

Vocabulary

arêtes, climate, convection, crevasse, density, deposition, erosion, erratics, eskers, fiord, freezing point, glaciers, gravity, ground water, hanging valley, horns, hydrologist, iceberg, landslide, melting, moraines, ocean current, outwash, salinity, striations, tectonic processes, tsunami, turbidity currents, weathering (chemical, biological, physical)

Knowledge

- sources of fresh water
- properties of salt water and fresh water
- effect of ocean currents and winds on regional climates
- effect of water and ice on surface features
- weathering and erosion
- evidence and effects of glaciation
- impact of waves, tides, and water flow on surface features
- productivity and species distribution in aquatic environments
- diversity of aquatic life forms

Skills and Attitudes

- use the Internet for research
- use given criteria for evaluating evidence and sources of information (e.g., identify supporting or refuting information and bias)
- relate cause to effect
- assess human impact
- show respect and sensitivity for the environment

Achievement Indicators

GRADE 8 EARTH AND SPACE SCIENCE: WATER SYSTEMS ON EARTH

PRESCRIBED LEARNING OUTCOMES	SUGGESTED ACHIEVEMENT INDICATORS
It is expected that students will:	*The following set of indicators may be used to assess student achievement for each corresponding prescribed learning outcome.* *Students who have fully met the prescribed learning outcome are able to:*
D1 explain the significance of salinity and temperature in the world's oceans	❑ describe the world distribution of water (97.2% ocean, 2.8% fresh, 2.15% ice, 0.61% groundwater, 0.01 lakes and rivers, 0.001% atmosphere) ❑ identify similarities and differences between salt water and fresh water (e.g., freezing point, density) ❑ define *ocean currents* ❑ describe how winds and ocean currents influence regional climates (e.g., moderating effects)
D2 describe how water and ice shape the landscape	❑ define weathering and erosion ❑ describe how gravity directs the movement of water and ice and transports weathered materials through slow processes (rivers and glaciers) and fast processes (landslides) ❑ identify and illustrate various alpine and continental glacial features (e.g., cirques, arêtes, horns, hanging valleys, crevasses, moraines, eskers, outwash, fiords, icebergs, striations, erratics) ❑ describe how waves and tides are generated (e.g., waves: wind action; tsunamis: tectonic processes; tides: gravitational pull) ❑ describe the impact of water movement (e.g., waves, tides, river flow) on surface features (e.g., weathering, erosion, deposition)
D3 describe factors that affect productivity and species distribution in aquatic environments	❑ identify various factors that affect productivity and species distribution in aquatic environments (e.g., temperature, nutrients in the water, turbidity, currents, sunlight, salinity, pollutants, water depth, resource extraction, dams) ❑ describe how changes in aquatic environments are monitored (e.g., through the use of satellite imagery) ❑ relate human activities to the distribution of aquatic species, with specific reference to First Nations peoples in BC (e.g., harvesting technologies, preservation techniques, use of resource)

Physical Sciences:
Fluid and Dynamics

PRESCRIBED LEARNING OUTCOMES	SUGGESTED ACHIEVEMENT INDICATORS
C6 describe the relationship between solids, liquids, and gases, using the kinetic molecular theory	❑ outline the kinetic molecular theory ❑ distinguish between solids, liquids, and gases based on particle arrangement and motion ❑ define terms related to changes of state (e.g., temperature, heat, evaporation, condensation, solidification, melting, sublimation)

Optics

KEY ELEMENTS: PHYSICAL SCIENCE

Estimated Time: 40-48 hours

By the end of the grade, students will have a basic understanding of forces and the properties of waves, light, and fluids.

Optics (estimated time: 20-24 hours)

Vocabulary

amplitude, angle of incidence, angle of reflection, angle of refraction, blind spot, concave, converging, convex, cornea, crest, diverging, electromagnetic radiation, energy, focal point, frequency, gamma rays, infrared, iris, lens, microwaves, normal, opaque, optic nerve, pupil, radio waves, refraction, retina, sclera, spectrum, translucent, transparent, trough, visible light, ultraviolet, wave, wavelength, X-rays

Knowledge

- waves: reflection, refraction, and energy transfer
- light: properties, transmission, reflection, absorption, refraction
- electromagnetic spectrum
- types and applications of electromagnetic radiation
- parts of the eye
- cornea-lens-retina system
- human vision and optical systems

Skills and Attitudes

- use dissection equipment safely
- use a ray box
- use a microscope
- use mirrors and lenses
- show respect for living things

GRADE 8 PHYSICAL SCIENCE: OPTICS

PRESCRIBED LEARNING OUTCOMES	SUGGESTED ACHIEVEMENT INDICATORS
It is expected that students will:	*The following set of indicators may be used to assess student achievement for each corresponding prescribed learning outcome.* *Students who have fully met the prescribed learning outcome are able to:*
C1 demonstrate knowledge of the behaviour of waves	❑ define *waves* and describe their characteristics, using examples and sketches ❑ demonstrate wavelength, frequency, and amplitude, with corresponding explanations ❑ describe how waves are reflected off a barrier and refracted when passing from one medium to another
C2 explain the properties of visible light	❑ connect the behaviour of waves to visible light (e.g., both waves and light reflect and refract) ❑ identify and describe properties of visible light (e.g., prism to demonstrate spectrum of colour, pinhole camera to demonstrate how light travels in a straight line) ❑ show how light is transmitted and absorbed by different materials (e.g., opaque, translucent, transparent; creation of shadows) ❑ demonstrate how visible light is reflected (e.g., relate angle of incidence and angle of reflection for curved and plane mirrors) ❑ demonstrate how visible light is refracted (e.g., bending of rays, changes of speed, diverging and converging lenses)
C3 compare visible light to other types of electromagnetic radiation	❑ differentiate radio waves, microwaves, infrared, visible light, ultraviolet, X-rays, and gamma rays in terms of wavelength, frequency, and energy transferred ❑ relate different types of electromagnetic radiation to their daily lives
C4 explain how human vision works	❑ illustrate the parts of the eye, including sclera, cornea, retina, lens, optic nerve and blind spot, iris, and pupil ❑ describe the cornea-lens-retina system ❑ describe common defects in human vision (e.g., near-sighted, far-sighted) ❑ describe several ways of correcting or extending human vision (e.g., contact lenses, laser surgery, binoculars) ❑ identify similarities and differences between the eye and another optical system (e.g., microscopes, telescopes)

Grade 9

Common Prescribed Learning Outcomes 1996

Physical Science **Elements, Compounds, and Reactions** *It is expected that students will:* • describe how elements are characterized by the nature of their particles • predict the properties of elements based on their position in the periodic table • write formulae and names for simple compounds • compare and contrast physical and chemical changes • infer the Law of Conservation of Mass through experimentation • identify the effects of various factors on the rate of chemical reactions
Earth and Space Science ***The Solar System and the Universe*** *It is expected that students will:* • describe the organization of the solar system • describe a variety of remote sensing techniques for assessing conditions beyond Earth • compare distances of objects in space • describe the characteristics by which stars are classified • compare the life cycles of stars of different sizes • explain, with examples, the relationship between astronomical discoveries and current understanding of the universe

Common Prescribed Learning Outcomes 2006
Physical Science: Atoms, Elements and Compounds

KEY ELEMENTS: PHYSICAL SCIENCE

Estimated Time: 40-45 hours

By the end of this grade, students will have demonstrated understanding of how the nature of the atom relates to chemistry and electricity.

Atoms, Elements, and Compounds (18-20 hours)

Vocabulary

alkali metal, alkaline earth metal, atom, atomic mass, atomic number, Bohr model, conductivity, covalent compounds, density, electron, element, halogens, ionic compounds, mass, melting/boiling point, molecule, multiple ion charge, metal, metalloid, neutron, noble gases, non-metal, polyatomic ions, proton, state, subatomic particles, volume

Knowledge

- properties and states of matter
- physical and chemical change
- subatomic particles, properties, and location
- Bohr model
- atomic theory
- the structure and components of atoms and molecules
- metals, non-metals, and metalloids
- periodic table
- chemical symbols for elements
- chemical formulae for simple ionic compounds

Skills and Attitudes

- create models of atoms and ions
- draw Bohr models
- use the periodic table and common ion chart
- write chemical formulae and symbols
- name chemical compounds

Achievement Indicators

PRESCRIBED LEARNING OUTCOMES	**SUGGESTED ACHIEVEMENT INDICATORS**
It is expected that students will:	*The following set of indicators may be used to assess student achievement for each corresponding prescribed learning outcome.* *Students who have fully met the prescribed learning outcome are able to:*
C1 use modern atomic theory to describe the structure and components of atoms and molecules	❑ describe the development of atomic theory, including reference to Dalton, Rutherford, and Bohr ❑ distinguish between atoms and molecules ❑ identify the three subatomic particles, their properties, and their location within the atom
C2 use the periodic table to compare the characteristics and atomic structure of elements	❑ explain the organization of the periodic table of elements (e.g., atomic number, atomic mass, properties, families) ❑ distinguish between metals, non-metals, and metalloids ❑ use the periodic table to predict the properties of a family of elements (e.g., alkali, alkaline earth, halogens, and noble gases) ❑ draw a Bohr model of each atom up to atomic number 20 (including only protons and electrons)
C3 write and interpret chemical symbols of elements and formulae of ionic compounds	❑ differentiate between elements and compounds ❑ write chemical symbols for atoms and ions of elements ❑ differentiate between atoms and ions in terms of structure, using Bohr models ❑ write chemical formulae for ionic compounds, including those involving metals with non-metals, multivalent metals, and polyatomic ions ❑ name ionic compounds, given the chemical formula
C4 describe changes in the properties of matter	❑ identify physical properties of matter, including mass, volume, density, state at room temperature, colour, melting/boiling point, and conductivity ❑ differentiate between physical and chemical changes, citing observable evidence ❑ name the changes of state of matter, and describe how the kinetic molecular theory explains those changes

Earth and Space Science

KEY ELEMENTS: EARTH AND SPACE SCIENCE

Estimated Time: 20-25 hours

By the end of the grade, students will have examined the formation, composition, and characteristics of the solar system, stars, and universe.

Vocabulary

asteroids, axis tilt, Big Bang, colonization, comets, constellations, Copernicus, galaxies, Kepler, moons, nebulae, planets, probes, Ptolemy, revolution, rotation, satellites, solar and lunar eclipses, spectroscopes, star clusters/types, Sun, telescopes, terraforming

Knowledge

- technologies advance understanding of the solar system, stars, and universe
- components of the universe and solar system
- significance of Earth's rotation, revolution, and axis tilt
- celestial sphere in relation to constellations and their location
- motion of constellations, planets, moons, sun, asteroids, and comets
- solar and lunar eclipses
- implications of space travel

Skills and Attitudes

- illustrate astronomical phenomena
- show respect for Aboriginal perspectives
- identify ethical considerations associated with space travel

Achievement Indicators

PRESCRIBED LEARNING OUTCOMES		SUGGESTED ACHIEVEMENT INDICATORS
It is expected that students will:		*The following set of indicators may be used to assess student achievement for each corresponding prescribed learning outcome.* *Students who have fully met the prescribed learning outcome are able to:*
D1	explain how a variety of technologies have advanced understanding of the universe and solar system	❑ identify and describe a range of instruments that are used in astronomy (e.g., telescopes, spectroscopes, satellites, probes, robotic devices) ❑ give examples of how astronomers use astronomical and space exploration technologies to advance understanding of the universe and solar system (e.g., using red shift to support the idea of an expanding universe, using parallax to measure distance)
D2	describe the major components and characteristics of the universe and solar system	❑ identify galaxies, star clusters/types, planets, constellations, nebulae according to their distinguishing characteristics ❑ relate mass to different stages in the life cycle of stars ❑ describe theories on the nature of the solar system (e.g., Ptolemy, Copernicus, Kepler) ❑ describe the formation of the solar system (e.g., condensing nebula) and its components (e.g., planets, moons, comets, asteroids, the Sun) and the formation of the universe (e.g., Big Bang) ❑ describe the processes that generate and events that distribute the energy of the Sun and other stars (e.g., nuclear fusion, solar flares and prominences, sun spots, solar wind)
D3	describe traditional perspectives of a range of Aboriginal peoples in BC on the relationship between the Earth and celestial bodies	❑ identify passages related to the relationship between the Earth and various celestial bodies within specific traditional stories of BC Aboriginal peoples ❑ respond to BC Aboriginal stories and presentations focusing on the nature of stars, the moon, planets, comets, or eclipses (e.g., by creating illustrations; by identifying similarities among stories or between stories and contemporary scientific understanding)
D4	explain astronomical phenomena with reference to the Earth/moon system	❑ describe the formation of the Earth's moon, with reference to supporting evidence ❑ describe the significance of Earth's rotation, revolution, and axis tilt (e.g., seasons, day/night) ❑ describe the celestial sphere in relation to constellations and their locations ❑ explain the apparent motion of constellations, planets, the Sun, the moon, asteroids, and comets ❑ explain and illustrate solar and lunar eclipses

D5 analyse the implications of space travel	❑ identify various possibilities and limitations associated with space travel (e.g., with reference to factors such as time, essential human needs, robots, budget choices, militarization of space) ❑ debate a range of ethical issues related to space travel (e.g., appropriateness of terraforming another planet, exposing humans to risks) ❑ research current ideas or initiatives for further space exploration (e.g., space elevator, colonization of other planets, search for extraterrestrial life)

Grade 10

Common Prescribed Learning Outcomes 1996

Physical Science: Chemicals and Reactions: *It is expected that students will:* research and illustrate the development of our understanding of the structure of matter from early times to the present describe the arrangement of subatomic particles (electrons, protons, neutrons) in elements distinguish among atoms, isotopes, and ions explain how chemical and physical characteristics of substances are due to differences in bonding of their constituent parts demonstrate a knowledge of chemical formulae and balanced chemical equations give evidence for and classify the following chemical reactions: synthesis, decomposition, replacement, and acid-base
Earth and Space Science (Earth Forces) *It is expected that students will:* compare a variety of techniques used to learn about the earth use fossil evidence to illustrate how life forms change over time compare techniques used for establishing geological time scales identify major factors responsible for earthquakes, volcanic eruptions, mountain building, and formation of ocean ridges identify evidence that supports the theory of plate tectonics assess impacts of volcanoes and earthquakes on the environment

Common Prescribed Learning Outcomes 2006

KEY ELEMENTS: PHYSICAL SCIENCE

By the end of the grade, students will have demonstrated understanding of chemical reactions and radioactivity, and explained motion in terms of displacement, time interval, velocity, and acceleration.

Chemical Reactions and Radioactivity

Vocabulary

acids, alpha particle, atomic number, atoms, bases, beta particle, Bohr diagrams, bromothymol blue, catalyst, combustion, compounds, concentration, conservation of mass, covalent bonding, decomposition, electron, fission, fusion, gamma radiation, half-life, indigo carmine, inorganic, ionic bonding, ions, isotope, Lewis diagrams, light, litmus paper, mass number, methyl orange, molecules, neutralization (acid-base), neutron, organic, phenolphthalein, polyatomic, proton, radioactive decay, salts, single and double replacement, surface area, symbolic equations, synthesis, valence electron

Knowledge

- acids, bases, and salts
- common ionic and covalent compounds
- organic and inorganic compounds
- chemical reactions (synthesis, decomposition, single and double replacement, neutralization, combustion)
- conservation of mass
- radioactivity

Skills and Attitudes

- draw and interpret Bohr models
- draw and interpret Lewis diagrams for compounds containing single bonds
- name and write chemical formulae for common ionic and covalent compounds, using appropriate terminology
- use standardized tests for acids and bases
- write and balance chemical equations
- write and balance nuclear equations
- use molecular models
- use the periodic table and ion charts
- demonstrate respect for precision

Achievement Indicators

Grade 10 Physical Science: Chemical Reactions and Radioactivity

Prescribed Learning Outcomes	Suggested Achievement Indicators
It is expected that students will:	*The following set of indicators may be used to assess student achievement for each corresponding Prescribed Learning Outcome.* *Students who have fully met the Prescribed Learning Outcome are able to:*
C1 differentiate between atoms, ions, and molecules using knowledge of their structure and components	❑ demonstrate knowledge of the three subatomic particles, their properties, and their location within the atom (e.g., by creating models) ❑ define and give examples of *ionic bonding* (e.g., metal and non-metal) and *covalent bonding* (e.g., two non-metals, diatomic elements) ❑ with reference to elements 1 to 20 on the periodic table, draw and interpret Bohr models, including protons, neutrons, and electrons, of - atoms (neutral) - ions (charged) - molecules - covalent bonding (e.g., O_2, CH_4) - ionic compounds (e.g., $CaCl_2$) ❑ identify valence electrons using the periodic table (excluding lanthanides and actinides) ❑ distinguish between paired and unpaired electrons for a single atom ❑ draw and interpret Lewis diagrams showing single bonds for simple ionic compounds and covalent molecules (e.g., NaCl, MgO, $BaBr_2$, H_2O, CH_4, NH_3) ❑ distinguish between lone pairs and bonding pairs of electrons in molecules

PRESCRIBED LEARNING OUTCOMES	SUGGESTED ACHIEVEMENT INDICATORS
C2 classify substances as acids, bases, or salts, based on their characteristics, name, and formula	❑ identify acids and bases using indicators (e.g., methyl orange, bromthymol blue, litmus, phenolphthalein, indigo carmine) ❑ explain the significance of the pH scale, with reference to common substances ❑ differentiate between acids, bases, and salts with respect to chemical formulae and properties ❑ recognize the names and formulae of common acids (e.g., hydrochloric, sulphuric, nitric, acetic) ❑ use the periodic table to - explain the classification of elements as metals and nonmetals - identify the relative reactivity of elements in the alkali metal, alkaline earth metal, halogen, and noble gas groups - distinguish between metal oxide solutions (basic) and non-metal oxide solutions (acidic) ❑ use the periodic table and a list of ions (including polyatomic ions) to name and write chemical formulae for common ionic compounds, using appropriate terminology (e.g., Roman numerals) ❑ convert names to formulae and formulae to names for covalent compounds, using prefixes up to "deca"
C3 distinguish between organic and inorganic compounds	❑ define *organic compounds* and *inorganic compounds* ❑ distinguish between organic and inorganic compounds, based on their chemical structures ❑ recognize a compound as organic or inorganic from its name, from its chemical formula, or from a diagram or model
C4 analyse chemical reactions, including reference to conservation of mass and rate of reaction	❑ define and explain the *law of conservation of mass* ❑ represent chemical reactions and the conservation of atoms using molecular models ❑ write and balance (using the lowest whole number coefficients) chemical equations from formulae, word equations, or descriptions of experiments ❑ identify, give evidence for, predict products of, and classify the following types of chemical reactions: - synthesis (combination) - decomposition - single and double replacement - neutralization (acid-base) - combustion ❑ explain how factors such as temperature, concentration, presence of a catalyst, and surface area can affect the rate of chemical reactions

PRESCRIBED LEARNING OUTCOMES	SUGGESTED ACHIEVEMENT INDICATORS
C5 explain radioactivity using modern atomic theory	❑ define *isotope* in terms of atomic number and mass number, recognizing how these are communicated in standard atomic notation (e.g., Uranium-238: $^{238}_{92}U$) ❑ relate radioactive decay (e.g., alpha – α , beta – β , gamma – γ) to changes in the nucleus ❑ relate the following subatomic particles to radioactive decay: - proton ($^{1}_{1}p$) - neutron ($^{1}_{0}n$) - electron ($^{0}_{-1}e$) - alpha particle ($^{4}_{2}\alpha$) ($^{4}_{2}He$) - beta particle ($^{0}_{-1}\beta$) ❑ explain half-life with reference to rates of radioactive decay ❑ compare fission and fusion ❑ complete and balance nuclear equations to illustrate radioactive decay, fission, and fusion

Applications of Science Common Prescribed Learning Outcomes 1996

It is expected that students will:

evaluate dangers in particular procedures and equipment, taking responsibility for safety

relate limitations of techniques & instruments to the accuracy & reliability of an investigation

describe some important scientific discoveries that resulted from scientists applying their knowledge and creativity to explore unexpected events

devise appropriate methods of presenting information

analyse data and conclusions that may be subject to bias

describe interactions between scientific developments & the beliefs & values of society

identify and consider ethical implications of scientific investigations

analyse costs and benefits of alternatives in resolving socio-scientific issues

Processes of Science
Common Prescribed Learning Outcomes 2006

KEY ELEMENTS: PROCESSES OF SCIENCE

Estimated Time: integrate with other curriculum organizers

The prescribed learning outcomes related to Processes of Science support the development of attitudes, skills, and knowledge essential for an understanding of science. These learning outcomes should not be taught in isolation, but should be integrated with activities related to the other three curriculum organizers.

Vocabulary

accuracy, compound light microscope, conclusion, control, dependent variables, experiment, hypothesis, independent variables, observation, precision, prediction, principle, procedure, scientific literacy, validity, variable

Knowledge

- metric system (SI units)
- angle measured in degrees
- elements of a valid experiment
- dependent and independent variables
- appropriate scale
- application of scientific principles in the development of technologies

Skills and Attitudes

- recognize dangers
- demonstrate emergency response procedures
- use personal protective equipment
- use proper techniques for handling and disposing of lab materials
- use safe dissection techniques
- use microscopes, triple-beam and electronic balances, thermometers, ray boxes, lenses, mirrors
- make accurate measurements using a variety of instruments (e.g., rulers, balances, graduated cylinders)
- use the Internet as a research tool
- communicate results
- use the appropriate type of graph to represent a given type of data
- use bar graphs, line graphs, pie charts, tables, and diagrams to extract and convey information
- deduce relationships between variables given a graph
- use models to demonstrate how systems operate
- apply given criteria for evaluating evidence and sources of information
- identify main points, supporting or refuting information, and bias in a science-related article or illustration
- demonstrate ethical, responsible, cooperative behaviour
- acquire and apply scientific and technological knowledge to the benefit of self, society, and the environment

Prescribed Learning Outcomes	Suggested Achievement Indicators
It is expected that students will:	*The following set of indicators may be used to assess student achievement for each corresponding prescribed learning outcome.* *Students who have fully met the prescribed learning outcome are able to:*
A1 demonstrate safe procedures	❑ identify a variety of dangers in procedures (e.g., cuts from sharp objects; burns from heating devices; shocks from misuse of electrical equipment) ❑ identify appropriate equipment for an lab activity (e.g., Bunsen burner vs. hotplate) ❑ identify and use appropriate personal protective equipment (e.g., hand and eye protection) and procedures (e.g., hair tied back, clear work area, no loose clothing, no horseplay) ❑ use proper techniques for handling and disposing of lab materials (e.g., using tongs, waste receptacles to handle and dispose of chemical or biological materials) ❑ with teacher support, describe appropriate emergency response procedures (e.g., how to use a fire extinguisher/blanket, eye wash station, first aid for cuts, knowing who to contact and how) ❑ describe safe dissection techniques involved in an actual (or virtual) dissection
A2 perform experiments using the scientific method	❑ describe the elements of a valid experiment: - formulate an hypothesis - make a prediction - identify controlled versus experimental variables - observe, measure, and record using appropriate units - interpret data - draw conclusions ❑ use information and conclusions as a basis for further comparisons, investigations, or analyses ❑ communicate results using a variety of methods

Prescribed Learning Outcomes	Suggested Achievement Indicators
A3 represent and interpret information in graphic form	❑ identify the most appropriate type of graph to represent a given type of data (e.g., pie, bar, table, line graph) ❑ convey information, using appropriate units as applicable, in - bar graphs (e.g., variables in aquatic environments) - line graphs (e.g., mass versus volume) - pie charts (e.g., percentages of water distribution) - tables - diagrams (e.g., of a cell, of systems) ❑ distinguish between dependent and independent variables in a graph ❑ draw a best fit line or curve given a set of data points on a graph ❑ extrapolate and interpolate points on a graph ❑ use appropriate scale and axis to create a graph ❑ extract relevant information from pie charts, bar graphs, line graphs, and tables
A4 use models to explain how systems operate	❑ give examples of how various processes could be modelled (e.g., diagrams or demonstrations of energy transfer, refraction, wave action, phase change) ❑ construct a variety of models (e.g., a cell, the eye, wave components) ❑ describe the relationships between components of the model and what it represents
A5 demonstrate scientific literacy	❑ identify the main points in a science-related article or illustration ❑ describe the qualities of the scientifically literate person, such as - awareness of assumptions (their own and authors') - respect for precision - ability to separate fundamental concepts from the irrelevant or unimportant - recognizing that scientific knowledge is continually developing and often builds upon previous theories ❑ use given criteria for evaluating evidence and sources of information (e.g., identify supporting or refuting information and bias) ❑ explain how science and technology affect individuals, society, and the environment

PRESCRIBED LEARNING OUTCOMES	SUGGESTED ACHIEVEMENT INDICATORS
A6 demonstrate ethical, responsible, cooperative behaviour	❑ describe and demonstrate - ethical behaviour (e.g., honesty, fairness, reliability) - open-mindedness (e.g., ongoing examination and reassessment of own beliefs) - willingness to question and promote discussion - skills of collaboration and co-operation - respect for the contributions of others
A7 describe the relationship between scientific principles and technology	❑ give examples of scientific principles that have resulted in the development of technologies (e.g., pressure—diving equipment, pumps, vacuum cleaners; optics—lasers, eyeglasses, headlights, mirrors) ❑ identify a variety of technologies and explain how they have advanced our understanding of science (e.g. microscopes for observing cell structure)
A8 demonstrate competence in the use of technologies specific to investigative procedures and research	❑ select and carefully use appropriate technologies, including - microscope - balances and other measurement tools (e.g., thermometers) - ray boxes, lenses, mirrors ❑ proficiently use the Internet as a research tool

Appendix F
Teacher Interview questions

Teacher Survey

Checklist:

- ❑ Each teacher has a copy of the Teacher Handouts in the form of a handbook.
- ❑ Science text books:
  - Grade 8: BC Science 8, McGraw-Hill Ryerson (2007)
  - Grade 9: Science Probe 9, Nelson Edition (1995)
    BC Science 9, McGraw-Hill Ryerson (2007)
  - Grade 10: Science Probe 10, Nelson Edition (1996)
    BC Science 10, McGraw-Hill Ryerson (2008)
- ❑ Tape recorder

Prior to Survey Collection:
Handbook and survey questions will be sent in hard copy to each of the participants before the meeting. This will enable each teacher to reflect and perhaps bring along worksheets, lesson plans or a list of their activities, old and new.

Teachers will be asked to produce a name or reference cue other than their own name as a level of anonymity. Each is free to make the request to withhold any information that identifies themselves or their school.

Survey Questions for Grade 8

Questions presented here will be asked verbally in round table discussion. Written answers and offers of additional materials provided are strictly voluntary.

General:

1. The matching learning outcomes for your subject area were based on the BC's Ministry of Education documents. Are there any corrections or additions that you can see as relevant to the discussion group?

2. As conformation, is the older text provided for your Grade level indeed the text you had your students use prior to 2005?

3. Were/ Are there any supplemental texts that you personally used in the classroom to teach you classes? Please elaborate with title and publication date.

4. Were you aware that the Applications of Science and Processes of Science are identical in Grades 8 to 10 in the former curriculum and again in the current PLO's?

5. Number of Years/ classes teaching 1995 curriculum?
6. Number of years teaching new 2006 curriculum?
7. BEd degree or other?
8. Number of years teaching Grade 8?

Curriculum Specific:

Life Sciences:

Of all the PLO's, the 1995 and 2006 Grade 8 life sciences were the least compatible

9. Can you make any comments on these PLO's, and
10. Do you have any suggestions to what PLO's can be changed (added or deleted) based on your teaching experience or science department's agreements?
11. Which PLO's do you currently teach the same as the former course?
12. Which materials (lesson plans, videos, worksheets, reference material) can you name offhand that you still use in your classroom teaching or preparation?
13. With regards to Life Science PLO's only, were there teaching materials or resources that were difficult to attain because of cost pressures or priority?

Physical Science: Energy and Optics:

In the interviewer's opinion, the Physical Science PLO's are quite similar

14. Is this a fair observation?

15. Anything you would like to add?

16. Which materials (lesson plans, videos, worksheets, reference material) can you name offhand that you still use in your classroom teaching or preparation?

17. What new material did you have to develop to teach the current curriculum?

Final General Questions:

18. What new material did you have to develop to teach the current curriculum?

19. How much professional development did you personally undertake to prepare for the new curriculum? Please elaborate in point form on availability, professional development funds or time constraints.

20. In general, were there teaching materials or resources for the 2006 curriculum that were difficult to attain because of cost pressures or priority?

21. In general terms, are the new PLO's easier to follow and implement with the addition of achievement indicators?

22. What is your perception of achievement indicators?

Survey Questions for Grade 9

Questions presented here will be asked verbally in round table discussion. Written answers and offers of additional materials provided are strictly voluntary.

General:

1. The matching learning outcomes for your subject area were based on the BC's Ministry of Education documents. Are there any corrections or additions that you can see as relevant to the discussion group?

2. As conformation, is the older text provided for your Grade level indeed the text you had your students use prior to 2005?

3. Were/ Are there any supplemental texts that you personally used in the classroom to teach you classes? Please elaborate with title and publication date.

4. Were you aware that the Applications of Science and Processes of Science are identical in Grades 8 to 10 in the former curriculum and again in the current PLO's?

5. Number of Years/ classes teaching 1995 curriculum?
6. Number of years teaching new 2006 curriculum?
7. BEd degree or other?
8. Number of years teaching Grade 9?

Curriculum Specific:
Physical Science: Chemistry

In the interviewer's opinion, the Physical Science PLO's are quite similar

9. Is this a fair observation?

10. Anything you would like to add?

11. Which materials (lesson plans, videos, worksheets, reference material) can you name offhand that you still use in your classroom teaching or preparation?

12. What new material did you have to develop to teach the current curriculum?

Astronomy (Earth and Space Science)

In the interviewer's opinion, the Astronomy PLO's are quite similar

13. Is this a fair observation?

14. Anything you would like to add?

15. Which materials (lesson plans, videos, worksheets, reference material) can you name offhand that you still use in your classroom teaching or preparation?

16. What new material did you have to develop to teach the current curriculum?

Final General Questions:

17. What new material did you have to develop to teach the current curriculum?

18. How much professional development did you personally undertake to prepare for the new curriculum? Please elaborate in point form on availability, professional development funds or time constraints.

19. In general terms, are the new PLO's easier to follow and implement with the addition of achievement indicators?

20. What is your perception of achievement indicators?

21. Anything else to add about teaching comparisons of the two courses?

Survey Questions for Grade 10

Questions presented here will be asked verbally in round table discussion. Written answers and offers of additional materials provided are strictly voluntary.

General:

1. The matching learning outcomes for your subject area were based on the BC's Ministry of Education documents. Are there any corrections or additions that you can see as relevant to the discussion group?

2. As conformation, is the older text provided for your Grade level indeed the text you had your students use prior to 2005?

3. Were/ Are there any supplemental texts that you personally used in the classroom to teach you classes? Please elaborate with title and publication date.

4. Were you aware that the Applications of Science and Processes of Science are identical in Grades 8 to 10 in the former curriculum and again in the current PLO's?

5. Number of Years/ classes teaching 1995 curriculum?
6. Number of years teaching new 2006 curriculum?
7. BEd degree or other?
8. Number of years teaching Grade 10?

Curriculum Specific:
Physical Science: Chemistry

In the interviewer's opinion, the Physical Science PLO's are quite similar

9. Is this a fair observation?

10. Anything you would like to add?

11. Which materials (lesson plans, videos, worksheets, reference material) can you name offhand that you still use in your classroom teaching or preparation?

12. What new material did you have to develop to teach the current curriculum?

Plate Tectonics (Earth Science)

13. In the interviewer's opinion, the Earth Science PLO's are quite similar

14. Is this a fair observation?

15. Anything you would like to add?

16. Which materials (lesson plans, videos, worksheets, reference material) can you name offhand that you still use in your classroom teaching or preparation?

17. What new material did you have to develop to teach the current curriculum?

Final General Questions:

18. What new material did you have to develop to teach the current curriculum?

19. How much professional development did you personally undertake to prepare for the new curriculum? Please elaborate in point form on availability, professional development funds or time constraints.

20. In general terms, are the new PLO’s easier to follow and implement with the addition of achievement indicators?

21. What is your perception of achievement indicators?

22. Anything else to add about teaching comparisons of the two courses?

Processes or Applications of Science (POS and AOS)

All teachers, regardless of Grade, will participate verbally in this topic.

Included in this handbook are the PLO's of the Applications of Science, AOS (1996) and the Processes of Science, POS (2008).

1. Any general comments regarding these learning outcomes?

2. What strategies or teaching activities did you or your department develop to address these outcomes in 1996 to 2004?

3. Given the new learning outcomes are more in depth with achievement indicators, has the implementation of the AOS been easier or facilitated more efficiently?

4. Which of these learning outcomes do you commonly stress?

5. Which PLO's are still works in progress for you?

6. How much professional development did you receive or were offered for this new set of PLO's in POS?

7. In general terms, are the new PLO's easier to follow and implement with the addition of achievement indicators?

8. Are there any POS that are still difficult to implement because of cost or classroom pressures?

9. Anything else to add to the discussion of POS?

Appendix G
Survey Results

Table G. 1. *Survey questions with highest incorrect answers of the six full sets of questionnaires*

Survey	Statement	# Incorrect	Correct Answer
1.8	Aerosol sprays with chlorofluorocarbons (CFC's) cause acid rain. (Science Fact)	6	T
1.13	I believe we accept scientific knowledge even though it may have errors. (Developmental)	4	T
1.14	If two scientific theories explain a scientist's observations equally well, the simpler theory is chosen. (Parsimonious)	4	T
2.14	There is an effort in science to keep the number of laws, theories, and concepts at a minimum. (Parsimonious)	5	T
2.15	Scientific knowledge is comprehensive as opposed to specific. (Parsimonious)	6	T
3.9	Air pollution by burning fossil fuels causes Ozone depletion. (Science Fact)	4	F
3.15	Scientific knowledge is comprehensive as opposed to specific. (Parsimonious)	4	T

Table G.2. *Participants' scores of modified true or false for each of the three surveys*.

Survey 1	1007	1008	1009	1010	1012	1014
TOTAL KNOWLEDGE /8	7, 1?	6, 1?	6, 1?	6, 1?	7	6
TOTAL OF NOS /10	7	8	7	7, 1?	6, 4?	8
TOTAL RESULTS /18	14, 1?	14, 1?	13, 1?	13, 2?	13, 4?	14
Survey 2						
TOTAL KNOWLEDGE /8	5	7	5, 1?	7, 1?	7, 1?	8
TOTAL OF NOS /10	8	7, 1?	7	5, 3?	7, 2?	7, 1?
TOTAL RESULTS /18	13	14, 1?	12, 1?	12, 4?	14, 3?	15, 1?

Survey 3						
TOTAL KNOWLEDGE /8	7	8	5, 2?	8	7, 1?	7
TOTAL OF NOS /10	10	10	8	7	7, 3?	8, 1?
TOTAL RESULTS /18	16	17	13, 2?	14	13, 4?	14, 1?

Table G.3. *Demographics of pre-service participants and their incorrect answers from table 1.*

	1007	1008	1009	1010	1012	1014
Declared Major	Biology*	Chemistry	Physical Education	Asian Pacific Studies	Biology*	Education
Education Program	n/a	PPDP, Secondary	PPDP, Secondary	Elementary	PPDP, Secondary	Elementary
local community science source	n/a	television newspapers	newspapers	libraries, internet	newspaper, radio and other people	other people
personal resources for science issues	n/a	internet & magazines	internet and other people	internet, libraries	journals, libraries, educated others.	internet, educational background
most reliable sources	n/a	n/a	other people	journals	journals and other people	libraries
Questions identified in Table 1	1.8 1.13** 1.14**	1.8 1.13** 1.14**	1.8 1.14**	1.8 1.13** 1.14**	1.8	1.8 1.13**
	2.14** 2.15**	2.14** 2.15**	2.14** 2.15**	2.14** 2.15**	2.15**	2.14** 2.15**
		3.9	3.15**	3.9 3.15**	3.9 3.15**	3.9 3.15**

*To protect identities, specialized areas of Biology were entered as the general field of Biology.
** Questions identified as NOS.

Table G.4. *Sense-making of scientific newspaper articles for validity and reliability*.

Windy Summer (TC June 7, 2006)	
1007	No, since it is written by a newspaper reporter who's writing to sell papers.
1008	I think this is a good starting point for students to find more accurate and legitimate sources of information about what causes hurricanes and to look into the trend over the past 50 years for them to see if they can find any trends. As a stand alone source it does not have enough information for the students and students should always use more than on source to help to avoid bias.
1009	I feel the article is unbiased. The article quotes a meteorologist from environment Canada and does not include any personal views or views of other non-professionals. Even if it was biased, this would not have any bearing on its legitimacy for student reporting. If the article was heavily slanted in one direction students could still write about it in a report. If they did use it they would have to address the bias presented and write reasons supporting or opposing it. The article gives the student information to work with. The article doesn't provide large amounts of data, but outlines enough leads to do a little research. Students could look at the storm data for the last 40 years and make some hypothesis and then write their own conclusion to the storm issue.
1010	Yes it is legitimate and relatively unbiased. All information that students find for reports are initially legitimate however students need to look at where the information is coming from and what the possible biases are before deciding whether the information is useful for them. The article uses words such as “should” and “predicted” to indicate that the information in the article is not fact or 100% certain. There is report of factual information represented in way that students would be able to check those facts and the article does not take one strong position over another but mentions possibilities without choosing sides.
1012	Maybe if doing unit on hurricane, but wouldn’t do it if subject was climate change. Too much equivocating about climate change already – sick of it. Discussion of hurricanes can seem like a discussion as to whether climate change is occurring – it is misleading. Debate is about hurricane activity and what it will continue to do – not about climate change.
1014	I think it is not unbiased. It seems to lean toward the viewpoint that hurricanes are not related to global warming, and gives very little information on the other viewpoint.

Pesticide use and Parkinson's disease in men. (TC, June 15, 2006)	
1007	No, telephone interviews, as with those with and those without (or undiagnosed), to determine if they had more or less exposure to a pesticide is less than adequate research to make solid statement that pesticide use increases the risk of Parkinson Disease. This type of research is heavily biased, in my opinion, since it is nearly impossible to limit the exposure of a pesticide, herbicide and insecticide since once it is released in the environment it contaminates everything and everybody. As far as presenting information like this to students, I would present it as question to ask and debate and allow them to eventually understand that the effects of contaminates are widespread, a 2.4% difference is less than significant
1008	Larger sample size and more varied sample (not just from one regional area). What sort of exposure did they have? What sort of questions were being asked and how they were being asked. If the person had Parkinson's they may be lead into believing that they were further exposed. If the person had advanced Parkinson's, would they remember their exposures?
1009	The research is a good starting point to argue that pesticides cause Parkinson's. Determine what pesticides were used during the 70's, 80's and 90's. Where they always the same where they different? Family history, did the men with Parkinson's have a family history of Parkinson's? Look at conflicting results of other studies. Did this study follow the same controls as the other studies? Look at what type of questions they asked the subjects. Were the questions specific enough to make the conclusion that they obtained Parkinson's because of pesticide exposure. It mentions that if someone had been exposed to pesticides then they were 2.4 times more likely to get the disease. Does this mean that even if they were only exposed once that they could get the disease? They could create a table displaying amount of exposure and if disease is present or absent. You can always present something to the class whether its right or wrong and then discuss its validity. This might not work with a younger class but a Biology 11 class could handle this.
1010	I don't know who is undertaking the research and who is paying for the research. Who are the investigators, what type of questions were they asking, what is the margin of error in the data. There is a lot of information missing.

1012	Legitimate – inconclusive need to know: % error for statistical result, Survey Construction (Questions), Sample Selection
1014	A study done under similar circumstances, but in a different area. More evidence

Table G.5. *Numerical aspects of the Grade 8 1996 and 2006 Integrated Resource Packages with respect to totals and percentages of prescribed learning outcomes (PLOs).*

Topic	1996		2006			
	No. PLOs	% Total	No. PLOs	% Total	No. of AIs	% total
Applications of Science	9	29.0	8	33.3	34	37.0
Biology	8	25.8	4	16.7	16	17.4
Chemistry	5	16.1	4	16.7	-	-
Physics	6	19.4	5	20.8	30	32.6
Earth Science	3	9.7	3	12.5	12	13.0
Total PLOs	*31*	*100.0*	*24*	*100.0*	*92*	*100.0*

Table G.6. *Numerical aspects of the Grade 9 1996 and 2006 Integrated Resource Packages with respect to totals and percentages of prescribed learning outcomes (PLOs).*

Topic	1996		2006			
	No. PLOs	% Total	No. PLOs	% Total	No. of AIs	% total
Processes of Science	9	26.5	7	30.4	41	39.4
Biology	8	23.5	3	13.0	12	11.5
Chemistry	6	17.6	4	17.4	15	14.4
Physics	5	14.7	4	17.4	19	18.3
Earth/ Space Sci	6	17.6	5	26.1	17	16.3
Total PLOs	34	100.0	23	100.0	104	100.0

Table G.7. *Numerical aspects of the Grade 10 1996 and 2008 Integrated Resource Packages with respect to totals and percentages of prescribed learning outcomes (PLOs).*

Topic	1996		2006			
	No. PLOs	% Total	No. PLOs	% Total	No. of AIs	% total
Processes of Science	8	20.5	7	30.4	41	25.6
Biology	7	17.9	3	13.6	35	21.9
Chemistry/ Radioactivity	6 5	15.4 14.7	4 1	18.2 4.5	31 10	19.4 6.3
Physics	7	17.9	2	9.1	10	6.3
Earth/ Space Science	6	15.4	5	22.7	33	20.6
Total PLOs	39	100.0	22	100.0	160	100.1

Table G.8. *Breakdown of the available science 10 provincial exams available on the government website compared to the topic weightings of the IRP.*

PLOs	Topics	Weighting of exam	Weighting *wrt* PLOs	Weighting *wrt* AIs
A	Processes of Science	*Integrated Throughout*	30%	26%
B	Life Science	26%	14%	22%
C	Physical Science***	48%	32%	32%
D	Earth and Space Science	26%	23%	21%

***** Physical Science includes Chemistry, Physics and Radioactivity.**

Table G. 9. *Comparison of PLOs and AIs between the 1996 and 2006 Grade 8 science IRPs.*

Grade 8 PLOs 1996	Grade 8 PLOs 2006	AIs 2006 *Students who have fully met the PLO are able to:*
Life Science (Social Issues)	**Water Systems on Earth**	
• assess different impacts of using renewable and non-renewable natural resources	D1 explain the significance of salinity and temperature in the world's oceans	describe the world distribution of water (97.2% ocean, 2.8% fresh, 2.15% ice, 0.61% groundwater, 0.01 lakes and rivers, 0.001% atmosphere) identify similarities and differences between salt water and fresh water (e.g., freezing point, density) define *ocean currents* describe how winds and ocean currents influence regional climates (e.g., moderating effects)
• compare and contrast the practical, ethical, and economic dimensions of population growth and polluted environments	D2 describe how water and ice shape the landscape	define weathering and erosion describe how gravity directs the movement of water and ice and transports weathered materials through slow processes (rivers and glaciers) and fast processes (landslides) identify and illustrate various alpine and continental glacial features (e.g., cirques, arêtes, horns, hanging valleys, crevasses, moraines, eskers, outwash, fiords, icebergs, striations, erratics) describe how waves and tides are generated (e.g., waves: wind action; tsunamis: tectonic processes; tides: gravitational pull) describe the impact of water movement (e.g., waves, tides, river flow) on surface features (e.g., weathering, erosion, deposition)
• relate the extraction and harvest of earth's resources to sustainability and reduction of waste		
• evaluate how major natural events and human activity can affect local and global environments and climate change	D3 describe factors that affect productivity and species distribution in aquatic environments	identify various factors that affect productivity and species distribution in aquatic environments (e.g., temperature, nutrients in the water, turbidity, currents, sunlight, salinity, pollutants, water depth, resource extraction, dams) describe how changes in aquatic environments are monitored (e.g., through the use of satellite imagery) relate human activities to the distribution of aquatic species, with specific reference to First Nations peoples in BC (e.g., harvesting technologies, preservation techniques, use of resource)
• critique the hypothesis that the earth is like a living organism		

Grade 8 PLOs 1996	Grade 8 PLOs 2006	AIs 2006 *Students who have fully met the PLO are able to:*
Physical Science (Matter, Properties & Periodic Table) **• use a kinetic particle model to describe the structure and properties of various states of matter**	C6 describe the relationship between solids, liquids, and gases, using the kinetic molecular theory	outline the kinetic molecular theory distinguish between solids, liquids, and gases based on particle arrangement and motion define terms related to changes of state (e.g., temperature, heat, evaporation, condensation, solidification, melting, sublimation)
	C7 determine the density of various substances C8 explain relationship between pressure, temperature, area, and force in fluids C9 recognize similarities between natural and constructed fluid systems (e.g., hydraulic, pneumatic)	for a fixed mass and temperature, describe the differences between volume and density for each of the states of matter describe the effects of changes in temperature on the density of solids, liquids, and gases (e.g., compression and expansion) conduct experiments to calculate the density of regularly shaped objects [D= m/V] and irregularly shaped objects [D= m/(V2-V1)] explain pressure with reference to force and area (i.e., compression and expansion) describe the relationship between temperature, area, and pressure, with reference to the kinetic molecular theory give examples of natural fluid systems (e.g., circulatory and respiratory system) and constructed fluid systems (e.g., hydraulic and air brakes) recognize the scientific principles involved in fluid systems (e.g., fluids can be compressed and flow; pressure differences can cause movement) identify possible problems in natural or constructed fluid systems (e.g., high/low blood pressure)
Physical Science *(Energy)* **• distinguish among reflection, absorption, radiation, and transmission** **• compare and**	C1 demonstrate knowledge of the behaviour of waves	define *waves* and describe their characteristics, using examples and sketches demonstrate wavelength, frequency, and amplitude, with corresponding explanations describe how waves are reflected off a barrier and refracted when passing from one medium to another

contrast reflection and refraction	C2 explain the properties of visible light	connect the behaviour of waves to visible light (e.g., both waves and light reflect and refract) identify and describe properties of visible light (e.g., prism to demonstrate spectrum of colour, pinhole camera to demonstrate how light travels in a straight line) show how light is transmitted and absorbed by different materials (e.g., opaque, translucent, transparent; creation of shadows) demonstrate how visible light is reflected (e.g., relate angle of incidence and angle of reflection for curved and plane mirrors) demonstrate how visible light is refracted (e.g., bending of rays, changes of speed, diverging and converging lenses)
• demonstrate and explain how basic concepts relating to heat and light are used in common applications • demonstrate and explain how colour is perceived in different environments	C3 compare visible light to other types of electromagnetic radiation	differentiate radio waves, microwaves, infrared, visible light, ultraviolet, X-rays, and gamma rays in terms of wavelength, frequency, and energy transferred relate different types of electromagnetic radiation to their daily lives

	C4 explain how human vision works	illustrate the parts of the eye, including sclera, cornea, retina, lens, optic nerve and blind spot, iris, and pupil describe the cornea-lens-retina system describe common defects in human vision (e.g., near-sighted, far-sighted) describe several ways of correcting or extending human vision (e.g., contact lenses, laser surgery, binoculars) identify similarities and differences between the eye and another optical system (e.g., microscopes, telescopes)

Table G.10. *Comparison of PLOs and AIs between the 1996 and 2006 Grade 9 science IRPs.*

Grade 9 PLOs 1996	Grade 9 PLOs 2006	AIs 2006 *Students who have fully met the PLO are able to:*
Physical Science **Elements, Compounds, and Reactions** • describe how elements are characterized by the nature of their particles	**Atoms, Elements & Compounds** C1 use modern atomic theory to describe the structure and components of atoms and molecules	describe the development of atomic theory, including reference to Dalton, Rutherford, and Bohr distinguish between atoms and molecules identify the three subatomic particles, their properties, and their location within the atom
• predict the properties of elements based on their position in the periodic table	C2 use the periodic table to compare the characteristics and atomic structure of elements	explain the organization of the periodic table of elements (e.g., atomic number, atomic mass, properties, families) distinguish between metals, non- metals, and metalloids use the periodic table to predict the properties of a family of elements (e.g., alkali, alkaline earth, halogens, and noble gases) draw Bohr models of each atom up to atomic number 20 (include only protons & electrons)
• write formulae and names for simple compounds **• identify the effects of various factors on the rate of chemical reactions**	C3 write and interpret chemical symbols of elements and formulae of ionic compounds	differentiate between elements &compounds write chemical symbols for atoms & ions differentiate between atoms and ions in terms of structure, using Bohr models write chemical formulae for ionic compounds, including those involving metals with non- metals, multivalent metals, and polyatomic ions name ionic compounds, given the chemical formula

• compare and contrast physical and chemical changes **• infer the Law of Conservation of Mass through experimentation**	C4 describe changes in the properties of matter	identify physical properties of matter, including mass, volume, density, state at room temperature, colour, melting/boiling point, and conductivity differentiate between physical and chemical changes, citing observable evidence name the changes of state of matter, and describe how the kinetic molecular theory explains those changes
The Solar System and the Universe • describe a variety of remote sensing techniques for assessing conditions beyond Earth • compare distances of objects in space	**Space Exploration** D1 explain how technologies have advanced under-standing of universe & solar system	identify and describe a range of instruments that are used in astronomy (e.g., telescopes, spectroscopes, satellites, probes, robotic devices) give examples of how astronomers use astronomical and space exploration technologies to advance understanding of the universe and solar system (e.g., using red shift to support the idea of an expanding universe, using parallax to measure distance)
• describe the organization of the solar system • describe the characteristics by which stars are classified • compare the life cycles of stars of different sizes	D2 describe the major components and characteristics of the universe and solar system	identify galaxies, star clusters/types, planets, constellations, nebulae according to their distinguishing characteristics relate mass to stages in the life cycle of stars describe theories on the nature of the solar system (e.g., Ptolemy, Copernicus, Kepler) describe the formation of the solar system (e.g., condensing nebula) and its components (e.g., planets, moons, comets, asteroids, the Sun) and the formation of the universe (e.g., Big Bang) describe the processes that generate and events that distribute the energy of the Sun and other stars (e.g., nuclear fusion, solar flares and prominences, sun spots, solar wind)

• explain, with examples, the relationship between astronomical discoveries and current understanding of the universe	D5 analyse the implications of space travel	identify various possibilities and limitations associated with space travel (e.g., with reference to factors such as time, essential human needs, robots, budget choices, militarization of space) debate a range of ethical issues related to space travel (e.g., appropriateness of terra-forming another planet, exposing humans to risks) research current ideas or initiatives for further space exploration (e.g., space elevator, colonization of other planets, search for extraterrestrial life)

Table G.11. *Comparison of PLOs and AIs between the 1996 and 2006 Grade 10 science IRPs.*

Grade 10 PLOs 1996	Grade 10 PLOs 2006	AIs 2006 *Students who have fully met the PLO are able to:*
Physical Science: Chemicals and Reactions*:* research and illustrate the development of our understanding of the structure of matter from early times to present describe arrangement of subatomic particles (electrons, protons, neutrons) in elements explain how chemical and physical characteristics of substances are due to differences in bonding of their constituent parts	C1 differentiate between atoms, ions, and molecules using knowledge of their structure and components	demonstrate knowledge of the three subatomic particles, their properties, and their location within the atom (e.g., by creating models) define and give examples of *ionic bonding* (e.g., metal and nonmetal) and *covalent bonding* (e.g., two nonmetals, diatomic elements) with reference to elements 1 to 20 on the periodic table, draw and interpret Bohr models, including protons, neutrons, and electrons, of - atoms (neutral) - ions (charged) - molecules covalent bonding (e.g., O_2,CH_4) - ionic compounds (e.g., $CaCl_2$) identify valence electrons using the periodic table (excluding lanthanides and actinides) distinguish between paired and unpaired electrons for a single atom draw and interpret Lewis diagrams showing single bonds for simple ionic compounds and covalent molecules (e.g., NaCl, MgO, $BaBr_2$, H_2O, CH_4, NH_3) distinguish between lone pairs and bonding pairs of electrons in molecules
demonstrate a knowledge of chemical formulae and balanced chemical equations **give evidence for and classify the following chemical reactions: synthesis, decomposition, replacement, and acid-base**	C4 analyse chemical reactions, Including reference to conservation of mass and rate of reaction	define and explain the *law of conservation of mass* represent chemical reactions and the conservation of atoms using molecular models write and balance (using the lowest whole number coefficients) chemical equations from formulae, word equations, or descriptions of experiments identify, give evidence for, predict products of and classify the following types of chemical reactions: - synthesis (combination) - decomposition - single and double replacement - combustion - neutralization (acid-base) explain how factors such as temp, concentration, catalyst, and surface area can affect rate of reactions

distinguish among atoms, isotopes, and ions	C5 explain radioactivity using Modern atomic theory	define *isotope* in terms of atomic number and mass number, recognizing how these are communicated in standard atomic notation (e.g., Uranium 238: 238*U*92 relate radioactive decay (e.g., alpha, beta, gamma) to changes in the nucleus relate the following subatomic particles to radioactive decay: - proton - neutron - alpha particle - electron - beta particle explain half life with reference to rates of radioactive decay compare fission and fusion complete and balance nuclear equations to illustrate radioactive decay, fission, and fusion
Earth and Space Science (Earth Forces) compare a variety of techniques used to learn about the earth use fossil evidence to illustrate how life forms change over time compare techniques used for establishing geological time scales identify major factors responsible for earthquakes, volcanic eruptions, mountain building, and formation of ocean ridges identify evidence that supports the theory of plate tectonics assess impacts of volcanoes and earthquakes on the environment	D4 analyse processes and features associated with plate tectonics	define *plate tectonics*, *plate boundary*, *earthquake*, *trench*, *volcano*, *spreading ridge*, *subduction zone*, *hot spot* relate tectonic plate movement to the composition of the following layers of the Earth, as determined by seismic waves (primary, secondary, and surface waves): - crust - mantle - lithosphere - outer core - asthenosphere - inner core describe tectonic plate boundaries, including: - transform boundaries - divergent boundaries - convergent boundaries (oceanic-oceanic crust, oceanic-continental-crust, and continental-continental crust) identify tectonic mapping symbols explain how plate movement produces the following features: - epicenters and shallow focus to deep focus earthquakes - volcanism at subduction zones (e.g., volcanic island arcs, Volcanic belts) and at spreading ridges - mountain ranges and mid ocean ridges - hot spot chains (e.g., Hawaiian Islands, Yellowstone) identify sources of heat within the Earth that produce mantle convection and hot spot activity (i.e., heat within the core and excess radioactivity within the mantle) explain how mantle convection and ridge push and slab pull are believed to contribute to plate motion

	D5 demonstrate knowledge of evidence that supports plate tectonic theory	Describe evidence for continental drift theory (e.g., fossil evidence, mountain belts, paleoglaciation) relate the following to plate tectonic theory: - the world distribution of volcanoes, earthquakes, mountain belts, trenches, mid ocean ridges, and rift valleys - hot spot and subduction zone eruptions - magnetic reversals and age of rocks relative to, spreading ridges

Table G.12. *Applications (1996) and Processes (2006-2008) of Science for Grades 8 to 10 science.*

1996 8 to 10 Applications of Science *It is expected that students will:*	Present Grades 8 to 10 Processes of Science	
	Prescribed Learning Outcome (PLO) *It's expected that students will:*	Suggested Achievement Indicators *Students who have fully met the PLOs are able to:*
evaluate dangers in particular procedures and equipment, taking responsibility for safety	A1 demonstrate safe procedures	identify a variety of dangers in procedures (e.g., cuts from sharp objects; explosions or burns from handling chemicals or heating materials) identify appropriate equipment for an lab activity (e.g., Bunsen burner vs. hotplate; glassware for chemicals) identify and use appropriate personal protective equipment (e.g., hand and eye protection) and procedures (e.g., hair tied back, clear work area, no loose clothing, no horseplay) use proper techniques for handling and disposing of lab materials (e.g., using special containers for caustic chemicals) describe appropriate emergency response procedures (e.g., how to use a fire extinguisher/blanket, eye wash station, first aid for cuts and burns, knowing who to contact and how)

analyse data and conclusions that may be subject to bias	A2 perform experiments using the scientific method	describe the elements of a valid experiment: formulate an hypothesis make a prediction identify controlled versus experimental variables observe, measure, and record using appropriate units interpret data draw conclusions use information and conclusions as a basis for further comparisons, investigations, or analyses communicate results using a variety of methods
devise appropriate methods of presenting information	A3 represent and interpret information in graphic form	identify and use the most appropriate type of graphic, model, or formula to convey information, including Bohr model or diagram convection model or diagram Lewis diagrams chemical formulae line graphs of displacement, time interval, and velocity diagrams (e.g., food webs/pyramids, nutrient cycles, plate boundaries) distinguish between dependent and independent variables in a graph use appropriate scale and axis to create a graph extrapolate and interpolate points on a graph extract information from maps, bar graphs, line graphs, tables, and diagrams (e.g., periodic table)

Table G.13. *Classification of learning verbs for 1996 and 2006 Grade 10 science IRPs.*

1996 PLOs	2006 PLOs	2006 AIs
Physical Science: Chemicals & Reactions*:* research (U/H) and illustrate (U) describe (K) explain (U)	C1 differentiate (H)	demonstrate (U) define (K) and give examples (K) draw (K) and interpret (U) identify (K) distinguish(H) draw (K) and interpret(U) distinguish (H)
demonstrate (U) give evidence for (U) and classify (U)	C4 analyse (H)	define (K) and explain (K) represent (U) write (K) and balance (U) identify(K), give evidence (K), predict(H) and classify(U) explain (U)
distinguish (H)	C5 explain (U)	define (K) relate (H) relate (H) explain (U) compare (U/H) complete (H) and balance(U) to illustrate(U)
Earth & Space Science (Earth Forces) • compare (U) • illustrate (U), • compare(U) • identify (K) • identify (K) • assess(H)	D4 analyse (H)	define (K) relate(H): describe (K): identify(K) explain (U): identify(K) explain (U)
	D5 demonstrate (U)	Describe (K) Relate (H)

Table G.14. *Summary of Common learning outcomes across old and present curriculum and junior science Grades.*

	No. common new IRPs bolded (*old IRPs common, italicized*)	Percentage of commonality (%) Common IRPs /total IRPs****	No. of AIs associated with present IRPs *****(% of IRP)
Grade 8	Biology **3** (*5*) Phys. Science **8** (*5*)	**11/24 (46%)** *[10/31 (32%)]*	**27/92 (29%)**
Grade 9	Chemistry **4** (*6*) Astronomy **3** (*6*)	**7/23 (30%)** *[12/34 (32%)]*	**25/ 104 (24%)**
Grade 10	Chemistry **3** (*6*) Earth Science **2** (*6*)	**5/22 (23%)** *[12/39 (31%)]*	**57/160 (36%)**
Grades 8-10	Application/Processes of Science **7** (*8*)	**Grade 8 7/24 (29%)** *[8/31(26%)]* **Grade 9 7/23 (30%)** *[8/34 (24%])* **Grade 10 7/22 (32%)** *[8/39 (21%])*	**40/92 (43%)** **40/104 (38%)** **40/160 (25%)**

Appendix H
Released Provincial biology questions and answers.

Table H.1. *Expected Knowledge and Vocabulary of the three Biology 10 Learning Outcomes.*

GRADE 10

KEY ELEMENTS: LIFE SCIENCE

By the end of the grade, students will have assessed the significance of natural phenomena and human factors within ecosystems.

Vocabulary

abiotic, aeration, adaptive radiation, bioaccumulation, biodegradation, biome, biotic, climax community, carbonate, commensalism, decomposers, denitrification, ecological succession, ecosystem, food chains, food pyramids, food webs, heavy metals, keystone species, lightning, mutualism, nitrification, natural selection, nutrients, parasitism, PCBs, pesticides, pH, phosphorus, photosynthesis, potassium, predation, proliferation, symbiosis, trophic levels

Knowledge

- abiotic and biotic elements in ecosystems
- cycling of carbon, nitrogen, oxygen, and phosphorus
- ecosystems with similar characteristics in different geographical locations
- effects of altering an abiotic factor
- species adaptation
- food webs and pyramids
- mechanisms and possible impacts of bioaccumulation
- traditional ecological knowledge (TEK)
- impact of natural phenomena, foreign species, disease, pollution, habitat destruction, and exploitation of resources on ecosystems

Skills and Attitudes

- use given criteria for evaluating evidence and sources of information (e.g., identify supporting or refuting information and bias)
- formulate a reasoned position
- demonstrate ethical behaviour
- relate cause to effect
- assess human impact
- show respect and sensitivity for the environment
- conduct experiments

Table H.2a. *Provincial exam answer keys & cognitive designation for biology unit for exam A.*

1996 Grades 8 to 10 Applications of Science *It is expected that students will:*	Present Grades 8 to 10 Processes of Science	
	Prescribed Learning Outcome (PLO) *It's expected that students will:*	Suggested Achievement Indicators *Students who have fully met the PLOs are able to:*
identify and consider ethical implications of scientific investigations describe some important scientific discoveries that resulted from scientists applying their knowledge and creativity to explore unexpected events	A4 demonstrate scientific literacy	identify the main points in a science related article or illustration describe qualities of the scientifically literate person, such as awareness of assumptions (their own and authors') respect for precision ability to separate fundamental concepts from the irrelevant or unimportant recognizing that scientific knowledge is continually developing and often builds upon previous theories recognizing cause and effect use given criteria for evaluating evidence and sources of information (e.g., identify supporting or refuting information and bias) explain how science and technology affect individuals, society, and the environment
analyse costs and benefits of alternatives in resolving socio-scientific issues	A5 demonstrate ethical, responsible, cooperative behaviour	describe and demonstrate ethical behaviour (e.g., honesty, fairness, reliability) open mindedness (e.g., ongoing examination and reassessment of own beliefs) willingness to question and promote discussion skills of collaboration and co-operation respect for the contributions of others
describe interactions between scientific developments & the beliefs & values of society	A6 describe the relationship between scientific principles and technology	give examples of scientific principles that have resulted in the development of technologies (e.g., velocity/acceleration—technologies related to transportation and athletics) identify a variety of technologies and explain how they have advanced our understanding of science (e.g., seismographic instruments and GPS—plate tectonics and Earth's layers)
relate limitations of techniques & instruments to the accuracy & reliability of an investigation	A7 demonstrate competence in the use of technologies specific to investigative procedures and research	select and carefully use balances and other measurement tools (e.g., thermometers, timing devices, electronic devices) proficiently use the Internet as a research tool.

Science 10

Sample Exam A

Provincial Examination — Answer Key

Cognitive Processes
- **K** = Knowledge
- **U** = Understanding
- **H** = Higher Mental Processes

Question Types
80 = Multiple Choice (MC)

Topics		Prescribed Learning Outcomes (PLOs)	Weightings
1.	Processes of Science	A	Integrated Throughout
2.	Life Science	B	26%
3.	Physical Science	C	48%
4.	Earth and Space Science	D	26%

Question Number	Keyed Response	Cognitive Process	Mark	Topic	PLO	Question Type
1.	D	K	1	2	B1	MC
2.	A	K	1	2	B1	MC
3.	D	K	1	2	B1	MC
4.	C	K	1	2	B1	MC
5.	D	U	1	2	B1	MC
6.	D	K	1	2	B1	MC
7.	A	H	1	2	B1	MC
8.	A	U	1	2	B1	MC
9.	D	U	1	2	B1	MC
10.	D	U	1	2	B1	MC
11.	D	U	1	2	B2	MC
12.	C	U	1	2	B2	MC
13.	D	K	1	2	B3	MC
14.	D	U	1	2	B3	MC
15.	A	U	1	2	B3	MC
16.	D	H	1	2	B3	MC
17.	A	U	1	2	B3	MC
18.	C	U	1	2	B3	MC
19.	A	U	1	2	B3	MC
20.	B	U	1	2	B3	MC
21.	D	U	1	2	B2	MC

Table H.2b. Provincial exam answer keys and cognitive designation for biology unit for exam B.

Science 10

Sample Exam B

Provincial Examination — Answer Key

Cognitive Processes
K = Knowledge
U = Understanding
H = Higher Mental Processes

Question Types
80 = Multiple Choice (MC)

Topics		**Prescribed Learning Outcomes (PLOs)**	**Weightings**
1.	Processes of Science	A	Integrated Throughout
2.	Life Science	B	26%
3.	Physical Science	C	48%
4.	Earth and Space Science	D	26%

Question Number	Keyed Response	Cognitive Process	Mark	Topic	PLO	Question Type
1.	A	K	1	2	B1	MC
2.	A	K	1	2	B1	MC
3.	D	H	1	2	B1	MC
4.	D	K	1	2	B1	MC
5.	C	U	1	2	B1	MC
6.	B	U	1	2	B1	MC
7.	D	U	1	2	B1	MC
8.	C	U	1	2	B1	MC
9.	D	U	1	2	B1	MC
10.	B	U	1	2	B1	MC
11.	B	U	1	2	B1	MC
12.	D	K	1	2	B1	MC
13.	A	U	1	2	B1	MC
14.	B	K	1	2	B1	MC
15.	C	U	1	2	B1	MC
16.	A	U	1	2	B2	MC
17.	D	U	1	2	B1	MC
18.	A	U	1	2	B3	MC
19.	B	H	1	2	B3	MC
20.	A	U	1	2	B3	MC
21.	D	K	1	2	B3	MC

Table H.2c. *Provincial exam answer keys and cognitive designation for biology unit for Form A 2008-2009.*

Science 10
2008/09 Released Exam
June 2009 — Form A
Provincial Examination — Answer Key

Cognitive Processes	Weightings	Question Types
K = Knowledge	32%	80 = Multiple Choice (MC)
U = Understanding	59%	
H = Higher Mental Processes	9%	

Topics	Prescribed Learning Outcomes (PLOs)	Weightings
1. Processes of Science	A	*Integrated Throughout*
2. Life Science	B	26%
3. Physical Science	C	48%
4. Earth and Space Science	D	26%

Question Number	Keyed Response	Cognitive Process	Mark	Topic	PLO	Question Type	Question Source
1.	C	K	1	2	B1	MC	
2.	A	U	1	2	B1	MC	
3.	A	U	1	2	B1	MC	
4.	D	K	1	2	B1	MC	
5.	B	K	1	2	B1	MC	
6.	C	K	1	2	B1	MC	
7.	C	K	1	2	B1	MC	
8.	D	U	1	2	B1	MC	
9.	B	U	1	2	B1	MC	
10.	A	U	1	2	B1	MC	
11.	B	U	1	2	B1	MC	
12.	D	U	1	2	B1	MC	
13.	D	K	1	2	B1	MC	
14.	C	U	1	2	B1	MC	
15.	A	U	1	2	B2	MC	
16.	C	H	1	2	B3	MC	
17.	B	U	1	2	B3	MC	
18.	B	U	1	2	B3	MC	
19.	A	U	1	2	B3	MC	
20.	A	U	1	2	B1	MC	
21.	A	H	1	2	B3	MC	

Notes for Vita, Copyright License, Withholding Form:
On the following pages complete the blanks fields. If additional entries are needed, just press the enter key and add another. Caution, long entries may cause fields to the right to shift to the next line. If this happens, simply adjust the tab spacing for that paragraph from the ruler or Format – Tabs… dialog.]