

A Survey of the Quantity and Quality of Laboratory Work in British
Columbia High Schools, Effects on Provincial Examination Scores, and
Analysis of Recommended Resources

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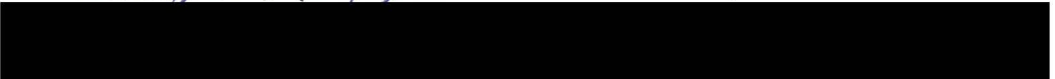
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ABSTRACT

The purposes of this research were to survey the quantity and quality of laboratory work conducted by Grade 11 and 12 Biology students in British Columbia High Schools, to analyze laboratory based questions and student performance on Provincial examinations, and to examine the curriculum for recommended laboratory work. A pilot survey produced a valid survey instrument that identified teachers use of laboratory activities in Biology 11 and 12. Examination and curriculum data were extracted from Ministry of Education documents. Survey data were used to generate statistics on school demographics, teachers, laboratory work, use of technology and constraints of the provincial curriculum and examination. The frequency of laboratory work was low overall, with quantitative activities less frequent than qualitative. Most laboratory exercises were confirmatory rather than investigative, and critical thinking, and formulating hypotheses, was rarely expected of the students. Many teachers reported that simulations of laboratory exercises and computer-based data collection was rarely or never used. Although laboratories are equipped adequately, teachers indicated that the curriculum and provincial examination limit the scope for an inquiry-based course. An analysis of provincial examination results showed that the frequency and type of laboratory work had no effect on scores on lab-based questions. An analysis of the frequency and type of laboratory activities recommended in the syllabus was conducted and revealed that fewer laboratory activities are being conducted than are recommended in the course outline. This study demonstrates that while the current philosophy of teaching science is a constructivist, hands-on, minds-on, authentic

learning experience, little change in classroom practice has occurred in British Columbia schools.

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TABLE OF CONTENTS

Abstract.....	ii
Table of Contents.....	iv
List of Tables.....	vi
List of Figures.....	ix
Acknowledgments.....	x
Frontispiece.....	xi
 CHAPTER 1: INTRODUCTION.....	 1
Problem.....	1
Research Questions.....	1
Rationale.....	2
Purpose of the Study.....	3
Significance.....	4
Context and Theoretical Framework.....	6
 CHAPTER 2: REVIEW OF THE LITERATURE.....	 13
The Traditional Experience.....	14
Surveys of Science Teaching in British Columbia.....	16
The Curriculum.....	23
Curriculum in British Columbia: Present and Future.....	25
Biology 11/12 Curriculum Guide.....	25
Biology 11/12 Integrated Resource Package.....	28
Science Education Reform: The Need for Change.....	32
Science Education Reform in Canada.....	32
Science Education Reform in the United States.....	34
Recommendations for Change.....	37
Inquiry-Based Science Education.....	39
Alternative Approaches to Traditional Teaching and Learning.....	42
The Case Against a Laboratory Approach to Science Education.....	48
Use of Technology.....	51
Assessment of Laboratory Work.....	53
 CHAPTER 3: RESEARCH DESIGN AND PROCEDURES.....	 59
Research Objectives.....	59
Research Method.....	59
Research Design.....	61
Development of the Surveys.....	62
The Pilot Survey.....	63
Validity and Reliability of the Pilot Survey.....	65
Modifications to the Pilot Survey.....	66
The Survey.....	67
Analysis of the Survey Data.....	70
Relationships Tested and Statistical Tests.....	71

Provincial and Scholarship Examination Analysis.....	77
Analysis of Biology 11/12 Curricula.....	79
CHAPTER 4: RESEARCH FINDINGS.....	81
Results of the Pilot Survey.....	82
Analysis of the Pilot Survey.....	87
Results of the Survey.....	90
Demographics.....	92
The Teacher.....	94
Laboratory Work.....	98
Statistical Treatments and Analysis.....	117
Provincial and Scholarship Examination Analysis.....	137
Provincial Examination.....	137
Scholarship Examination.....	142
Analysis of Biology 11/12 Curriculum Guide.....	150
Analysis of Biology 11/12 Integrated Resource Package.....	155
CHAPTER 5: SUMMARY AND DISCUSSION.....	157
The Research Problem.....	157
The Research Method.....	157
Summary and Interpretation of the Results.....	160
The Pilot Survey.....	160
The Survey.....	160
The Provincial Examination.....	180
Examination of Curriculum Guides.....	181
Conclusions.....	183
Recommendations.....	186
References.....	188
Appendix 1 The Pilot Survey.....	200
Appendix 2 The Survey.....	204

LIST OF TABLES

<u>Table 1:</u>	Questionnaire Distribution and Return by School Size.....	91
<u>Table 2:</u>	Distribution of Sizes of Schools in the Survey and the Province.....	92
<u>Table 3:</u>	The Distribution of Teachers in the Province and on the Survey, by Years of Experience.....	96
<u>Table 4:</u>	Frequency of laboratory Work in Grades 11 and 12.....	98
<u>Table 5:</u>	Frequency of Quantitative and Qualitative Laboratory Work	100
<u>Table 6:</u>	Reasons Given by Teachers for Rarely or Never using Lab Simulations or Computer-based Data Collection.....	107
<u>Table 7:</u>	The reasons Given by Teachers For and Against Students Carrying out Individual Lab Work.....	110
<u>Table 8:</u>	Reasons Given by Teachers Against Students Conducting Individual Research Projects.....	112
<u>Table 9:</u>	Reasons Given for not Using an Investigative Approach to Biology Teaching.....	116
<u>Table 10:</u>	Cross Tabulation of Size of School by Frequency of Laboratory Work.....	118
<u>Table 11:</u>	Cross Tabulation of School Year Organization by Frequency of Laboratory Work.....	122
<u>Table 12:</u>	Cross Tabulation of Research Projects in Grade 11 by Frequency in Grade 12.....	125

<u>Table 13:</u>	Cross Tabulation of Laboratories are Well Enough Equipped in Grade 11 by Laboratories are Well Enough Equipped in Grade 12.....	126
<u>Table 14:</u>	Cross Tabulation of Sufficient Time in Grade 11 by Sufficient Time in Grade 12.....	128
<u>Table 15:</u>	Cross Tabulation of Labs are Confirmatory in Grade 11 by Labs are Confirmatory in Grade 12.....	129
<u>Table 16:</u>	Cross Tabulation of Understanding of Scientific Method in Grade 11 by Understanding in Grade 12.....	130
<u>Table 17:</u>	Cross Tabulation of Labs which are Confirmatory in Grade 11 and also Foster Critical Thinking in Grade 11.....	132
<u>Table 18:</u>	The Number of Lab/Data Analysis Questions on Provincial Examinations by Year.....	138
<u>Table 19:</u>	The Provincial Examination: Mean Difficulty Scores on the Multiple Choice Section by Year.....	139
<u>Table 20:</u>	T-tests on multiple Choice Questions for Provincial Examinations, 1990-1994.....	141
<u>Table 21:</u>	T-tests on Provincial Examination Written Section for Overall Means on Lab and Non-lab Questions.....	142
<u>Table 22:</u>	Frequency of Lab Questions on Scholarship Examinations by Year.....	143
<u>Table 23:</u>	Scholarship Examination: Maximum Score, Average Score, and Cognitive Level for Lab and Non-lab Questions.....	144
<u>Table 24:</u>	Scholarship Examination: Lab and Non-lab Question Mean Scores.....	149

<u>Table 25:</u>	Scholarship Examination: Results of t-tests Means of Lab and Non-lab Questions.....	150
<u>Table 26:</u>	The Distribution of Quantitative and Qualitative Labs, Software, and Videotapes, Suggested for Grade 11 Biology.....	151
<u>Table 27:</u>	The Distribution of Quantitative and Qualitative Labs, Software, and Videotapes, recommended for Grade 12 Biology.....	154
<u>Table 28:</u>	The IRP Distribution of Quantitative and Qualitative Labs, Software, Videotapes, Laser disc, and Multimedia for Grade 11 and 12 Biology.....	155

LIST OF FIGURES

<u>Figure 1</u>	Distribution of Teachers on Survey by Qualification.....	97
<u>Figure 2:</u>	Frequency of Labs being Confirmatory and Fostering Critical Thinking.....	102
<u>Figure 3:</u>	Use of Lab simulations and Computer-based Data Collection in Grades 11 and 12.....	105
<u>Figure 4:</u>	The Distribution of Teachers Surveyed by Teaching Pedagogy Practiced.....	115
<u>Figure 5:</u>	Frequency of Lab and Non-lab Questions on Scholarship Examinations, 1990 - 1994.....	148

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My wife, Jane, whose constant support and encouragement has always been a major factor in my life.

*“Science is built of facts the way a house is built of bricks;
but an accumulation of facts is no more science
than a pile of bricks is a house.*

*Jules Henri Poincare
(1854-1912)*

CHAPTER ONE

INTRODUCTION

“Another component deals with students’ abilities in laboratory investigations and their skill at designing scientific investigations, generating and testing hypotheses, controlling variables that influence experimental outcomes, etc.”. (The Performance Component) ¹

The Problem

The quotation above is taken from the British Columbia Assessment of Science Provincial Report (1991) and is one of the fundamental recommendations for a change in approach to science teaching. This study examines whether this recommendation has been embraced in the epistemology and pedagogy of the teachers in British Columbia Grade 11 and 12 Biology classes.

Research Questions

The primary objective of this research was to determine the quantity and quality of laboratory work carried out by Grade 11 and Grade 12 Biology students, in British Columbia High Schools. In addition, the effect of the reported laboratory activities on scores on lab-based, and data analysis

¹ British Columbia Assessment of Science. Provincial Report 1991

questions on the Provincial and Scholarship Examinations was examined.

An analysis of the Biology 11/12 Curriculum Guide and Integrated Resource Package was also conducted in order to determine the number and type of laboratory exercises recommended by the Ministry of Education

Rationale

*"The important part that science must play in the future of the nation and this province, along with the current educational initiatives underway in the province, provides a solid opportunity to develop a program to reform and upgrade science education in the schools of British Columbia."*²

The education system in the province has, in recent years, undergone significant upheaval in terms of the perceived need for change. The 'Year 2000' document³ on educational reform was a primary driving force behind the change in philosophy, syllabus, delivery style, and in particular, changing the focus of education to the individual learner, thereby recognizing that different students have different learning styles and different rates of learning. In discussion with biology teachers at the marking sessions for the provincial examinations, it was a common complaint that there was not sufficient time to adequately cover the course

²British Columbia Assessment of Science. Provincial Report 1991

³ Ministry of Education. Year 2000: A Framework for Learning. 1989

material for Grade 12 Biology. The question was therefore posed, as to what was being omitted from the course, if time was at a premium. Also, teachers marking the provincial examination, felt that generally, students scored less well on experiment or data analysis questions than on factual, recall questions. A verbal poll of the teachers indicated that this was because there was no time to conduct laboratory work. If, as the teachers indicated, there was not sufficient time for laboratory work in Grade 12, was this also the case in Grade 11 Biology classes?

Purpose of the Study

Science Assessment in British Columbia Schools last took place in 1991. The assessment included a survey of current goals in science curricula, and the performance of students in grades 3 to 10, but focused on grades 4, 7 and 10. One conclusion of the survey was that secondary students are not provided with enough opportunities to be engaged in problem solving situations where they are expected to use materials to investigate a problem and speculate about the results of their inquiry. A recommendation from the assessment was that students should be given more opportunity to generate questions and seek answers from their own investigations. No survey has ever been conducted on performance or practice in biology for Grade 11

and 12, as performance is judged by students' scores on the provincial examination.

The primary purpose of this investigation was to determine the quantity and quality of laboratory work in Grade 11 and Grade 12 Biology classes in British Columbia and to relate this to a variety of factors that might influence this. Examples of these factors include, size of school, location of school, and qualifications and the experience of the teachers. The frequency of the use of technology in teaching biology, and the pedagogy of teachers was also determined. Secondary investigations included an analysis of performance on lab-based questions on provincial examinations, and an analysis of the provincial curriculum for the number of recommended laboratory exercises and supporting technologies.

Significance

*"We hope that, through the study of science, our young people will come to know what 'active inquiry' is all about, so that they will learn about their own potential as rational people, and learn to trust their ability to think problems through for themselves."*¹

Research has shown that there has been some disagreement over the value of the science laboratory classroom (Lehman 1989; Tamir, 1989).

¹ British Columbia Assessment of Science. Provincial Report 1991

If students are not carrying out experiments in the laboratory setting, are they in fact, really doing science? One definition of science is the validation or rejection of hypotheses based on experiment. The generally accepted present practice is 'science as inquiry'. Science is a process and if students are not actively engaged in the process, they are not doing science. Much discussion about the teaching of science today revolves around curriculum reform and includes the support for a constructivist approach, the content of the high school course, and the development of science process skills.

Supporting the constructivist perspective, Tobin (1990) states that "Constructivism implies that students require opportunities to experience what they are to learn in a direct way and time to think and make sense of what they are learning." Laboratory activities appeal as a way of allowing students to learn with understanding, and are now central to science epistemology. Hands-on science teaching has been widely promoted through text books, activities manuals, methods courses and workshops for in-service teachers, and it is the key component of student centered instruction. However, this mode of teaching is far from universally employed by teachers (Prather, 1993). Levin (1995) discusses reform in Canadian schools and concludes that secondary education is badly in need of reform and that there is not much sign that the required changes are

occurring. Similarly, the literature on secondary schools gives few examples of fundamental change (Lee, Bryk & Smith, 1993). If there is little laboratory work being carried out, does this have an effect on students' understanding of science? If there is insufficient laboratory work being conducted in the schools, is this a function of the course content alone and the time required to teach it, or are there other factors at work, such as the organization of the school year, availability of equipment, class size, teaching experience or teaching philosophy? This study was designed to examine such relationships. In addition, performance on lab-based questions on the provincial examination was examined to determine whether the frequency of laboratory work influenced scores on these types of examination questions compared with non-lab questions. Also, an examination of the type and amount of laboratory work listed in the curriculum was undertaken in order to investigate whether teachers were conducting the laboratory exercises which are recommended by the Ministry of Education. This would indicate whether a change is needed in the course content or in the present practice of biology teachers.

Context and Theoretical Framework

In a review of biology teaching methods and materials, Hurd, Bybee, Kahle and Yager (1980) reported the following:

Throughout the history of biology teaching, laboratory instruction has been stressed. Still less than half of all biology teachers regularly use laboratory activities, and 25% report that they never, or no more than once a month, use laboratory activities. Eighty percent of primary, 90% of intermediate, and 50% of all teachers base their instruction upon a single textbook. Almost all questions arise from information in the textbook and most centre on terminology and definitions. Students are trained to seek the “right” answers from textbooks.

In commenting on their findings, Hurd et al.,(1980) summarized as follows:

“In short, little evidence exists that inquiry is being used”. And further, “Biology teachers lecture more than 75% of the time, so little time is left for inquiry. How can the process of biological inquiry be taught to high school students? What changes would be needed in the classroom and laboratory procedures? The resolution of this problem would seem to lie in the way in which biology courses are taught. Teaching and textbooks which focus almost entirely on the conclusions of science allow few opportunities for the student to experience the intellectual aspects of science. Laboratory work that is concentrated on verification rather than investigation is also at fault” (p.391). Is the traditional lecture-textbook method the best way to teach?

Lott (1983) found that, when compared with the lecture approach, the

inquiry approach led to a significantly better performance when high levels of thought were considered. Shymansky (1984) compared what he called “new science curricula” with traditional science curricula and showed that new science curricula produced better results across all measures of performance. Costeson and Lawson (1986) investigated the reasons why teachers were not using an investigative approach and determined ten reasons, in order of frequency, given by teachers: time and energy; too slow; reading too difficult; risk is too high; tracking; student immaturity; teaching habits; sequential material; discomfort; too expensive. Teachers risk losing students by boring them day after day with expository teaching and continue to risk the trade off of memorizing unnecessary facts, in exchange for good thinking and problem solving skills (Costeson & Lawson, 1986). There would seem to be strong support for the use of an activity-based or constructivist approach to the teaching of biology.

Leonard (1980) states that, “ it is believed that in order to teach concrete or transitional thinkers formal operational concepts, they need first to work with the principle in concrete terms, especially with manipulative activities provided in a laboratory environment” (p.338). This provides students an opportunity to gradually abstract the principle from it’s concrete exemplars. Most high school biology students are “concrete operational” in the

Piagetian sense while scientific reasoning is guided by “formal operational” reasoning (Lawson & Renner, 1975).

In terms of interpretation of results on the provincial examination, it is interesting to examine the findings of Blosser (1981), who summarized research on integrating laboratory activities into the curriculum and categorized previous studies into eight groups: laboratory vs. no laboratory; laboratory vs. two other methods, which may or may not involve lab work; laboratory via a specific curriculum project; other variations, such as lab/discussion vs. discussion/lab; laboratories involving some student control; studies involving some form of media; studies involving simulations; and studies emphasizing inquiry/discovery. She concluded that, if only acquisition and retention of factual knowledge is desired, one procedure is as good as another.

Research may have failed to demonstrate the benefit of laboratory work in the science curriculum because science educators have had different goals for laboratory instruction at different times. The failure of science educators to subscribe to a set of common objectives for laboratory work may be contributing to questions about the instructional value of laboratory activities (Ivins & Markie, 1989).

The concerns of the assessment team in British Columbia are shared by many authors of papers reporting on the state of biology education in the United States. "The evidence is overwhelming that science education is failing" (Newsweek, 1990). It is reported that by the time U.S. 14 year- olds enter high school, they score 14th from students among seventeen countries, in overall achievement (Barnes, 1990). The science education system of the United States has been criticized as providing a poor preparation for college science, lagging behind other countries such as Japan, Europe and the (former) Soviet Union. The high school biology curriculum, in particular has been criticized (Barinaga, 1990). In biology, U.S. students ranked last - 13th out of 13 countries. Universities and colleges are quick to blame secondary schools for producing students who lack basic skills and it has been suggested that 75% of college students are seriously under-prepared for college (Kelly, 1989; Lord & Rauscher, 1991). The difficulties of preparing college-bound science students are manifold and related to the fact that school students must be prepared for all aspects of society and not just success in taking college science courses (Gibson & Gibson, 1993). Although high school students have laboratory classes, seldom are they actually required to design their own experiments. National Association of Educational Progress statistics show that only 40% of 17 year olds can work

out how to test whether a certain brand of plant food will live up to its claim of making plants grow to enormous sizes (Cratsley. 1991). One of the critical issues identified in National Science Education Standards (1992) is “providing hands-on, minds-on, and authentic learning experiences in science”. Action options for teachers include :

- a) Create more opportunities for students to engage in science learning that is authentic and patterned after the methods that scientists use.
- b) Commit to a professional development program that will enable you to change instructional strategies, adapting them to new methods for teaching.

A thorough understanding of constructivist approaches to learning should be part of that program.

In this research, the responses of biology teachers in the province to survey questions relating, in particular, to the use of laboratory work were collected and analyzed. Data on student scores for lab-based and non-lab-based questions on the Provincial and Scholarship examinations were extracted from government reports and analyzed for statistically significant differences. In addition, this study examined curriculum guides and assessment reports for science in order to identify the expectations of the Ministry of Education in terms of biology education at the secondary level. This research should clarify some of the biology teaching issues and lead to

a greater understanding of the changes necessary to improve the quality of biology instruction in British Columbia High Schools.

CHAPTER TWO

REVIEW OF THE LITERATURE

The literature on reform in science education is both diverse and abundant.

The major purpose of this study, however, is to examine three research questions:

1. The quantity and quality of laboratory work being carried out by Grade 11 and 12 Biology students in British Columbia high schools.
2. The scores on lab-based and data analysis questions compared with non-lab questions, on the Provincial and Scholarship examinations.
3. The quantity and type of laboratory activities conducted in schools compared with the number and type of laboratory exercises recommended in the Biology 11/12 Curriculum Guide (1990) and the Integrated Resource Package (1996)

In order to examine the development of reform in science education at the provincial, national and international level, a review of the current literature was undertaken. It was important to establish what science education is like for the majority of students in a typical classroom, in order to show whether the changes in pedagogy, which have evolved over the past few years have, in fact, been adopted. It would appear that most students are exposed to similar situations and practices. Science education in British Columbia, in

common with other jurisdictions, has been surveyed and assessed on an ongoing basis and an examination of these assessments and, in particular, the recommendations arising from these, provide a contextual base for this research study. It is from assessments such as these that the strong advocacy movement for science reform has arisen, and along with it, a recommendation for a change in pedagogy. The major outcomes of pedagogical reform include active learning with its focus on a hands-on approach to learning. A criticism of this approach was that students may be carrying out hands-on activities but that they were not engaged in any significant thinking processes. There arose therefore, a push towards a constructivist methodology for science teaching and, in particular, the hands-on, minds-on approach. Factors such as the constraints of curriculum, teacher resistance, and the difficulty of assessing laboratory work have, to some extent, limited the growth of this approach to teaching science. The review of the literature will explore each of these areas of reform in greater detail.

The Traditional Experience

What are Biology classes like for most students? Few of the major questions concerning modern society, current scholarship or ongoing science fit neatly into compartmentalized academic disciplines. Efforts to address questions

generated from issues are constrained by definition of an academic discipline. For many people, their memory of biology includes dissecting frogs, memorizing vocabulary and a frustration that came with trying to understand complex diagrams. 'Parts' courses such as parts of the cell, parts of the microscope, parts of the leaf, parts of the brain, neither do justice to the nature of biology nor do they benefit the student (Ost & Yager, 1993). A fundamental quality of science is "free inquiry," i.e. the freedom of science to study whatever is of interest, to question any line of authority or to follow any line of scholarship. In a free society it is believed that ideas and concepts should be judged by reason and rationality. Barber (1952) points out that the modern world thinks the rule of reason more important than the rule of custom or ritual. However, the typical high school biology curriculum is more custom and ritual than reason and rationality. Although the majority of students are not destined to become future biologists, biology programs are designed as if all students needed classical biology content rather than an understanding of life science concepts gained through rational problem solving and reasoning (Ost & Yager, 1993). Classical science laboratory activities are designed to have only one acceptable or correct solution. It is doubtful that students in such classes explore alternative solutions.

By and large schools and classrooms have retained the same basic structures for the past 50 years or more. Schools operate on a model designed for different times and different purposes. Observers have commented that in the new “information age” or “post modern” era, radically different systems of education are needed to replace outmoded structures and procedures (Wallace & Wildy, 1993). Alvin Toffler (1990), for example, argues for revolutionary forms of education because our mass education systems, based on the old factory model, are largely obsolete. Ashendon (1990) describes schooling as the last of the mass cottage industries, where there is almost no division of labour in teaching, scarcely any technology, and the work group as anything but autonomous. Nowhere is the need for change greater than in school science, where structures and procedures reinforce a positivist, rather than a constructivist, view of teaching and learning (Wallace & Wildy, 1993).

Surveys of Science Teaching in the School System in British Columbia.

In order to give historical context to the reasons for reform in science education in British Columbia, a number of surveys and assessments from 1925 - 1995 were examined. The early surveys focus on recommended changes in science education with a progression towards greater emphasis on science education. The later assessments place greater emphasis on

evaluation, assessment, and the subsequent recommendations for change. In particular, there is increased emphasis on the recommendation of active participation by the learner and a hands-on, minds-on, constructivist pedagogy.

1. Survey of the School System (Putman / Weir, 1925)

This survey assessed the schools in British Columbia and listed a series of recommended changes including:

- (i) science teaching was to be available as a regular, required part of schooling.
- (ii) It was suggested that senior high school include mandatory and discrete biology in grades 10 and 11, with physics being optional in grade 11.
- (iii) No science, required or optional, was required for grade 12.

It was twenty years before these recommendations were implemented.

2. Report of the Royal Commission on Education (Chant, 1960)

The Chant report included three major recommendations which affected science instruction in British Columbia:

- (i) senior science should be two years rather than one year
- (ii) science laboratories in secondary schools should be standardized throughout the province.

(iii) Grade 7 should be moved from secondary to elementary school.

(primarily for economic reasons)

3. A Legacy for Learners: The Report of the Royal Commission on Education. (Sullivan,1988)

Two major themes were set out in the Sullivan report:

- (i) integration of content areas in ways that make meaningful connections.
- (ii) constructivism - knowledge and understanding are matters of interpretive construction.

Three principles of learning were stated:

- 1. the active participation of the learner
- 2. acknowledgment that people learn in a variety of ways
- 3. learning is both an individual and a social process

4. British Columbia Science Assessment Report (1991)

The purposes of this assessment were among other things to:

- (i) inform professionals and the public of some of the strengths and weaknesses of the public school system.
- (ii) assist the Ministry, school districts, and schools in decisions related to the development, review, modification, revision, and

implementation of existing curricula and supporting instructional resource materials.

(iii) provide directions for educational research.

The assessment was reported as a series of components: the classical component; the performance component; the socio-scientific issues component; and the context for science component. While it is outside the scope of this research to examine each component in detail, the key points from the document include the following comments:

“The study produced a picture of uneven science teaching in the schools of British Columbia.”¹ The teachers appeared to be thriving despite a system that provided very little encouragement or support for science.

In secondary classrooms lecturing and recitation was seen, without much student engagement; when hands-on activities were seen in these classrooms, students appeared to be going through the motions rather than being intellectually engaged.

Those who talk about hands-on activity are thus only half correct. Activity for activity's sake is not adequate. We must strive for an engagement of the mind as well as the hands.

¹ British Columbia Science Assessment Report. 1991

Clearly, increased commitment and support will provide the beginning for a renewed mission for science education in the province. However, part of that renewal must also deal with an examination of how, and for what purpose , we teach science in the schools.

Specific Recommendations from the Student Performance Component include:

- (i) given students' demonstrated abilities and interest in the assessment tasks, students should be given more opportunity to generate questions and seek answers from their own investigations.
- (ii) given that students do not report results well, particular attention should be given to this aspect of investigations.
- (iii) It is thought that a wider mode of presentation of student findings in laboratory work be used.
- (iv) teachers are encouraged to use more types of performance tasks in their assessment procedures.
- (v) given the importance of content knowledge in the planning and execution of investigations, it is critical that the use of relevant knowledge be recognized and encouraged.

General Recommendations:

- (i) Schools and school districts should immediately investigate the degree to which science is being taught, and should take measures to ensure that the development of scientific knowledge processes and skills are included in an appropriate amount of instructional time at all levels.
- (ii) It is also recommended that the Ministry of Education and Ministry Responsible for Multiculturalism and Human Rights should immediately form a task force of interested stakeholders, to make comprehensive recommendations for a program to reform and upgrade science education in the schools of British Columbia....

5. British Columbia Assessment of Mathematics and Science. (1995)

This report published in August, 1996 evaluates how well students in Grades 4, 7 and 10 understand various principles of mathematics and science, solve mathematics and science problems, and apply higher level thinking skills to the two fields of study. The assessment also gathers information on teaching practices. The results from the grade 10 science assessment give some indications of the strengths and weaknesses of science and teaching pedagogy at the senior level and appear to confirm the findings of this research.

The major recommendations for science from the report are:

- (i) the Ministry of Education should investigate how students' achievement in science is affected by various timetable systems
- (ii) along with school districts, the education ministry should ensure that teachers have access to sufficient in-service opportunities and resource materials to facilitate hands-on activities to help students improve in the skills and processes of science
- (iii) the education ministry should provide additional resources that focus on the integrated use of computers in the science classroom
- (iv) science teachers should place more emphasis on the safe use of equipment, materials and techniques
- (v) teachers should place more emphasis on independent projects and research, on the concepts and terminology of the life sciences....

From the research conducted in this study of grade 11 and 12 biology teaching, many of the same recommendations apply, as the same weaknesses are detected.

Under the heading "Recommendations to all Science Teachers" it stated that, "substantial numbers of students in this province are lacking in hands-on science experiences and do not seem to be experiencing science resources and learning aids....This is not a situation in keeping with the

intent of the provincial curriculum for any grade, or with the kind of active learning required for students to gain satisfactory knowledge and skills. It is therefore recommended that teachers provide students with more opportunities to engage in varied science experiences" (p. 287).

The Curriculum

Although interest in science curricula by the general public and professional educators may have abated in the 1970's, the post-sputnik (1958) curricula produced beneficial effects on science learning. Data exists to support the idea that science curriculum improvement materials developed after 1955 were successful in promoting student achievement in the use of science process skills, in creativity, and in higher cognitive skills at both the elementary and secondary school levels. Research has focused on programs rather than textbooks, which are the dominant method of instruction in many science classrooms (Blosser, 1985). An extensive research project was conducted by Bredderman (1983) in the use of activity-based programs. He speculated that, if activity-based programs in elementary school science were adopted widely, then student performance on tests of science process, creativity and perhaps intelligence would show increases of 10-20 percentile units. He noted in a follow up study that if students do not continue in such activity-based programs in the higher grades, these

advantages are not sustained. He concluded that the evidence on the science curriculum reform efforts of the past two or three decades consistently suggests that more activity-process-based approaches to teaching science, result in gains over traditional methods in a wide range of student outcomes, at all grade levels. Bredderman's remarks are confirmed by Shymansky, Kyle and Alport (1983) in a report on their large meta-analysis study. They reported,

..." Across all new science curricula analyzed, students exposed to new science curricula performed better than students in traditional courses in general achievement, analytic skills, process skills and related skills, as well as developing a more positive attitude towards science...." (Shymansky, et al., 1983, p387). He also reported that for biology, the mean effect sizes were consistently high. Student performance in the analytic thinking area was higher than for chemistry and approached the performance level of physics (Shymansky, 1984). An abundance of studies have been conducted subsequently, to assess the impact of innovative science curricula.

Curriculum in British Columbia: Present and Future

The surveys and assessments previously described have had an impact on the curriculum. An examination of the Biology 11/12 Curriculum Guide, and Integrated Resource Package for Biology 11/12 was undertaken and included in the literature search, primarily to identify the pedagogical recommendations listed in the goals for the course. Later in this study, the curriculum is analyzed for laboratory activity content.

Biology 11/12 Curriculum Guide 1990

The present curriculum used in Biology 11 and 12 is based on a revision of Biology 11 and 12 for students in British Columbia High schools, which was undertaken and published in 1990. The B. C. Science Teachers Association, in their Biology Teacher Survey Report, (1981) called for the revision. A review of Biology 11 and 12 was also a major recommendation made in the 1982 Provincial Science Assessment Report. This revision took place at a time when, throughout North America, there was a call for renewal and redirection of science education. The 1984 Science Council of Canada report on science education is indicative of the emphasis on re-examination of science curricula at all levels. The Council called for curriculum that presents a more authentic view of science, emphasizes the science-technology-society connection, and acknowledges the Canadian

context, where appropriate (Biology 11/12 Curriculum Guide, 1990). In the Rationale: Why teach Biology?, it states: "Secondary school biology courses must also provide the basis for further academic work and career training for those students who wish to pursue their interests in biological science and related fields after leaving secondary school. Besides providing a knowledge base and assisting the development of critical thinking skills, senior biology aids the further development of social skills such as group cooperation and communications through shared problem solving experiences " (p.6).

The guide defines the scope of biology as the study of living organisms and life processes and as a scientific discipline; biology is also defined by its methods of inquiry. Knowledge in biological science is acquired through the process of carefully observing natural phenomena of structure and function in living organisms, and comparing the data with other relevant information in order to interpret and explain the phenomena. " One specialized form of this process is the well-known "scientific method", which involves several elements: the formulation of answerable questions; development of predictions that are answerable by experiment; interpretation of the experimental results; and forming conclusions which often lead to new questions and predictions" (p.7).

Learning research and teachers' experiences suggest the importance of providing opportunities for students to have direct physical experience with biological materials and living organisms. These experiences should be available in the laboratory and also offered in the field, where organisms can be studied in context.

Biology 11 and 12 Program Goals.

The following four program goals are listed in the curriculum guide.

Goal A: The Biology Curriculum should provide opportunities for students to develop scientific attitudes, and to develop positive attitudes towards science.

These attitudes include curiosity, open-mindedness, objectivity, respect for evidence, and willingness to test one's ideas about the natural world by using the scientific method.

Goal B: The Biology curriculum should provide opportunities for students to acquire the skills and understand the processes of science.

Skills and processes of science include knowing how to use one's senses effectively, and how to manipulate scientific apparatus. More fundamentally, they include the ability to state problems, formulate hypotheses, design and perform properly controlled experiments, collect

and organize data, identify patterns within the data, and generate new hypotheses for further research.

Goal C: The Biology curriculum should provide opportunities for students to increase their understanding of basic concepts and principles of biological science.

Understanding means more than the simple recall level of knowledge. It involves the ability to use conceptual knowledge. It involves the ability to use conceptual knowledge in new situations, in order to analyze, to predict and to organize information.

Goal D: The Biology curriculum should provide opportunities for students to develop critical and abstract thinking abilities.

The curriculum elaborates on critical and abstract thinking. Critical thinking involves the ability to differentiate between facts and assumptions; to reason logically from premises; and to evaluate arguments. Abstract thinking involves the ability to reason using probability and proportionality; and to reason without reference to concrete phenomena, i.e., to work with abstract ideas.

Integrated Resource Package

The need for improvement in science education led to a new provincial syllabus. The Integrated Resource Package (IRP) sets out the provincially

prescribed new curriculum for Biology 11 and 12, and will be implemented in September, 1996 replacing the Curriculum Guide for Biology 11 and 12. The development of the IRP has been guided by the following principles of learning: learning requires the active participation of the student; people learn in a variety of ways and at different rates; learning is both an individual and a group process. The curriculum is structured in terms of curriculum organizers which include provincially prescribed learning outcomes for Biology 11 and 12; suggested instructional strategies for achieving the outcomes; suggested assessment strategies for determining how well students are achieving the outcomes; and provincially recommended resources. This document embraces much of the current thinking on science teaching pedagogy. “The provincial science curriculum promotes an activity-based program where students learn scientific knowledge and processes in a hands-on and ‘minds-on’ way” (p.4). It encourages science teaching which will allow students to develop the capacity to think critically; encourages students’ positive attitudes to science; helps students to become flexible and adaptable rather than focusing on acquiring specialized knowledge; enables students to analyze personal and societal issues critically; cultivates students’ appreciation of the scientific endeavour and their potential to contribute to it. The program

also emphasizes the applications of science to everyday living and the skills needed in the workplace. Students develop the knowledge, skills, and attitudes necessary for scientific literacy through four major processes: working scientifically; communicating scientifically; using science; and acting responsibly.

It states in the IRP that laboratory skills are essential to students of Biology 12. These skills are developed in laboratory activities that focus on the hypothetical as well as the practical. An emphasis on the processes of science is integral to the complete study of Biology 12. Also discussed under Methods of Inquiry, is the importance of providing opportunities for students to have direct physical experience with biological materials, and the use of living organisms. "Students require both laboratory and field experiences to fully develop their science skills and understanding of science processes" (p.3).

In this document the use of laboratory work and the scientific process is strongly advocated and the teachers are assisted by the identification and elaboration of science skills and process (p.6).

A comparison of the Biology 11/12 Curriculum Guide with the Integrated Resource package shows a much greater focus on student-centred learning. This is illustrated by the following extracts from the IRP:

Communicating Scientifically

“Students are expected to draw conclusions, defend their opinions and discuss the limitations of their work. Students should have opportunities to work collaboratively, share insights and understanding, raise questions, debate, keep logs of events and observations, and record and report using various media” (p.4).

Developing Science Skills and Processes

It is suggested that the skills and processes that students use in science courses are the same as those used by scientists at work. The following skills and processes are central to the presentation of all content and the delivery of instruction and assessment activities in the classroom:

- observing - designing experiments
- measuring - interpreting data
- classifying - controlling variables
- inferring - formulating models
- predicting - communicating
- hypothesizing

Working Scientifically

“Students conduct investigations by asking questions, using concrete materials, making observations, processing data, and evaluating findings.

Students should have opportunities to explain, solve problems, hypothesize, design experiments, control variables, interpret data, and formulate models” (p.4).

Using Science

“Students build an understanding of science and technological applications by using science to make connections, explain and apply ideas, and solve problems” (p.4).

The IRP document embraces many of the current philosophies and practices of science education and it will be interesting to follow its implementation in science classes in the province.

The reform of science teaching in British Columbia is not unique and has arisen from a national and international movement. It is of value therefore, to examine the literature more broadly, by reviewing the proposed changes and their historical context for Canada and the United States.

Science Education Reform - The Need for Change

Science Education Reform in Canada

Secondary education in Canada is badly in need of change, primarily because major aspects of the social context have changed. There is not much sign that the required changes are occurring. It has long been recognized that secondary schools were dominated by preparation for post-

secondary education, and especially for university. Many studies and reports have made this point. Critics say that quality has declined, standards have fallen, curricula are trivial, teachers are overpaid, and that faculties of education are irrelevant (Levin, 1995). There is an homogeneity in secondary schools. They offer, for the most part similar courses, similar teaching styles, with a similar pattern of organization. There are various reasons for this homogeneity: provincial regulations prescribing the curriculum, grading requirements and time allocations. Teacher training, staffing policies, and student-teacher ratios are others. The most important factor is history. All of us went to school, all of us know what school looks like. The net result is that schools continue to look much like factories. We largely lack the imagination to envisage something else (Levin, 1995). The literature on secondary schools gives few examples of fundamental change (Lee, Bryk & Smith, 1993). The current efforts of secondary schools to respond to the required changes are quite inadequate. Faced with a changing world dimly perceived, administrators and policy makers fall back on well-worn strategies: do more of the same things and add special programs or target staff to meet the newly seen needs. Blame problems on something else, such as families or governments; make changes at the edge of the organization, leaving untouched the core of what has been done for so long

- teachers instructing groups of students in close settings in the standard secondary school subjects (Levin, 1995).

As a potential solution to these dilemmas, it is proposed to give more authority and autonomy to teachers in order to change the conditions of teaching and thereby improve education (Fullan, 1991). An additional solution is active learning, in order to overcome the abundant evidence that secondary school classrooms continue to be dominated by teachers talking to passive learners. School districts and school administrators have important obligations in promoting a climate of learning about education (Coleman & LaRocque 1990). Fullan (1991) proposes two main strategies for educational change, intensification and professionalization.

Intensification includes reforms such as external accreditation, external examinations, and more rigorous curriculum. He argues that these will improve results. Professionalization, depends on the assumption that education will improve by changing the teaching conditions.

Science Education Reform in the United States

Traditional patterns of science education have remained largely unchanged for most of the last century. In fact, the organization of curricula for high schools has remained essentially constant since the "Committee of Ten" met in 1892 and established the sequence of instruction for the disciplines

within science. Very often, science instruction in the lower grades has lacked a clear focus and has been provided by teachers ill-prepared to deal with science content. The natural curiosity of children, eager to understand their surroundings, is often diminished by instruction that discourages inquiry and discovery. In the upper grades, science instruction becomes increasingly textbook-centered (National Science Education Standards, 1994). Even though laboratory experiences (demonstrations) usually are included, students are rarely encouraged to use scientific methods to solve problems relevant to their perception of the world. In addition, lab-manuals do not provide students with opportunities to formulate useable questions, plan experiments, communicate results (other than short answers to questions), or coordinate a full investigation as recommended in much of the current literature. As a result of these deficiencies lab-manuals do not provide many, if any, opportunities for students to engage in scientific thinking and participate in a scientific inquiry much as a scientist does (Germann, et al., 1996). The typical pedagogical pattern reflects an authoritarian, didactic approach to classroom management. The reasons may be that many teachers have never encountered a learning experience in which they constructed meaning from the experience, and many classrooms present an environment in which students learn by rote and repetition from

teachers who exercise authoritarian control over the learning process. Many educators, who would like to change this approach, lack the support of colleagues, administrators, and parents, who only remember a more traditional approach (National Science Education Standards, 1994).

During the 70's, it was debated whether laboratory work was necessary in order to learn biology. During the 1980's the decline in the economy and subsequent recession placed pressures on schools to reduce the most expensive component in their science programs - laboratory work. In the 1980's, in *Nation at Risk* (1983) and *The Science Report Card* (Mullins & Jenkins, 1988), it was stated that, as a nation, Americans were not scientifically literate. By the mid-80's both the Department of Education and the National Science Foundation were involved in massive efforts to improve science education. Curriculum reformers in the 90's seem united on the necessity of reducing basic coverage in textbooks and curriculum guides (Culotta, 1990). However, there was disagreement on what should be omitted, and regardless of the decisions, it was likely that 75% of the science teachers in middle schools and high schools would be unhappy (Yager, 1992).

Recommendations for Change

The National Committee on Science Education Standards and Assessment (1992) has said that school science education must reflect science as it is practiced, and one goal of science education standards is to prepare students who understand the modes of reasoning of scientific inquiry and can use them. More specifically, students need to have many and varied opportunities for collecting, sorting and cataloging; observing, note taking and sketching; interviewing, polling, and surveying (Rutherford & Algren, 1990). Integral to the understanding of what biology standards will be put forth is the understanding that, “science as inquiry should be recognized as a basic and controlling principle in the ultimate organization and experiences in students’ science education (NRC 1994). The National Science Education Standards (1994) specify that students in high school should develop the ability to:

- Identify the questions and concepts that guide scientific investigations
- Design and conduct scientific investigation
- Use technologies to improve investigations and communications
- Formulate and revise scientific explanations and models using logic and evidence

- Recognize and analyze alternative explanations and models
- Communicate and defend a scientific argument

The National Science Education Standards call for a new vision of science learning which requires that the new paradigm for science learning emphasizes engagement and meaning in ways that are not consistent with past practices. The anticipated outcome of this new approach to teaching is a higher level of student achievement in the sciences. This constructivist teaching and learning model calls for learning that is:

1. ***Hands-On:*** Students are actually allowed to perform science as they construct meaning and acquire understanding.
2. ***Minds-On:*** Activities focus on core concepts allowing students to develop thinking processes and encouraging them to question and seek answers that enhance their knowledge and thereby acquire an understanding of the physical universe in which they live.
3. ***Authentic:*** Students are presented with problem solving activities that incorporate authentic, real-life questions and issues in a format that encourages collaborative effort, dialogue with informed expert sources, and generalization to broader ideas and application.

The challenge is to define the new approach to teaching and learning with sufficient clarity that it becomes a useful vision for educators as they make

their decisions about instructional materials, activities and strategies for teaching.

Inquiry-based Science Education

“If a single word had to be chosen to describe the goals of science educators during the 30 year period that began in the late 50’s, it would have to be inquiry” (deBoer, 1991, p. 206). In a statement of shared principles, the U.S. Department of Education and the National Science Foundation (1992) together endorsed mathematics and science curricula that promote active learning, inquiry, problem solving, cooperative learning and other instructional methods that motivate students.

This inquiry approach recommended by the NRC differs from the old ‘inquiry based’ approaches of the 60’s in that it is targeted for all students. The 60’s approach stimulated the gifted student in biology but overwhelmed the average and low ability students. Also, there was no real effort to reform science curriculum, in spite of the fact that there were more than two dozen national curriculum projects. However, almost all were seen as efforts to improve existing programs by developing new material for the existing curriculum. These efforts resulted in materials that were ‘teacher-proof’. The textbook was regarded as central to teaching in that it made life easy for the teacher and kept the students engaged. Teachers loved the worksheets,

directions for preparing laboratories, suggestions for quizzes, and chapter examinations (Yager, 1992).

Leonard and Penick (1996) state that most of the nation's students in high school biology learn "encyclopedia" or "vocabulary" biology. A typical high school biology text contains more terms new to a student than does four years of the foreign language they are studying (Yager, 1983).

Science teachers are being challenged to present science as it "really is" rather than promote a mythic, textbook science (Martin, Kass & Brouwer, 1990). Typical laboratory activities poorly represent science and occur less than once a week. The teacher lectures much of the time and students are tested on factual knowledge rather than understanding of biology concepts and science process skills. Students are rewarded for being quiet and doing what the teacher says (Yager, 1992). The outcome of this type of teaching is that students operate from an inductivist-empiricist position (Aikenhead, Fleming, & Ryan, 1987).

Studies of inquiry-oriented teaching (e.g. Mechling & Oliver, 1983; Shymansky et al., 1990), have generally been supportive of inquiry approaches. There is also evidence that inquiry-based learning improves understanding of scientific process and scientific literacy (Lindberg, 1990), critical thinking (Narode et al., 1987), and higher achievement on tests of

procedural knowledge (Glasson,1989). It must also be emphasized that an emphasis on inquiry oriented teaching does not necessarily preclude the use of textbooks or other instructional materials (Haury, 1993).

The exponential growth in biological knowledge and the subsequent inability to cope with the sheer volume of new material propagated, led to the 'less is more' philosophy. This approach argued for fewer topic areas, but teaching them in greater depth. By spending more time on a major concept, meaningful activities can be developed and the students have the luxury of being able to reflect on what they are learning (Speece,1996).

The opportunities to teach the life sciences, as science is done, have never been more focused. The nation, and in fact the entire world have embraced science education reform (Speece, 1996).

Most biology educators agree that a laboratory or field approach should be the major instructional setting in the ideal biology program (Leonard et al. 1991). They recommend that such a program be developed by teams of distinguished biologists, biology educators and talented secondary biology teachers, and that the methodology of the new program be consistent with current theory on cognitive psychology.

Alternative Approaches to Traditional Teaching and Learning

As has already been stated, the challenge is to define the new approach to teaching and learning with sufficient clarity that it becomes a useful vision for educators as they make their decisions about instructional materials, activities and strategies for teaching. In terms of the practical side of science teaching, a number of strategies have been well documented in the literature. These are active learning, constructivism and more recently, the reappearance of learning cycles. A full review of each of these teaching approaches is outside the scope of this research, however, each will be reviewed briefly.

Active Learning

Active learning can be identified in a number of ways. Barnes (1989) has examined the concept of active learning in terms of seven principles: active learning is purposive, reflective, negotiated, critical, complex, situation driven, and engaged. When students are actively engaged in learning in science classes they are not only involved with activities, materials, and experiments - they are involved intellectually. Denegar (1988) has argued that it is the responsibility of the school to teach skills that will enable students to access information on any subject that is intellectually engaging.

Pickering (1980) argues that a good lab course is an exercise in *doing* science and as such it differs totally in mission from a good lecture course, where the object is learning about science. If students are not doing hands-on science then they are not doing science.

Constructivism

Von Glaserfeld (1987,1988) suggests that constructivism can be traced to the eighteenth century and has been a persistent, though not dominant, epistemology since that time.

Constructivism is a theory in which knowledge and understanding are matters of interpretive construction on the part of the experiencing subject. The locus for control of the behaviour rests within the subjects themselves (Magoon, 1977; Glaserfeld,1987). People are seen as “self-constructing” (MacKinnon,1989), as continually striving to make sense of their own experience. The constructed meaning is influenced by beliefs, models, and attitudes already held by the learner (Gunstone & Baird, 1988). New knowledge produced by creativity and imagination is rigorously examined using the methods of inquiry (Cleminson, 1990).

In a study on the epistemological beliefs of science teachers, Hashweh (1994) discovered that teachers holding constructivist beliefs (a) are more likely to detect student alternative conceptions; (b) have a richer repertoire

of teaching strategies; (c) use potentially more effective teaching strategies for inducing student conceptual change; (d) report more frequent use of effective teaching strategies; and (e) highly value these teaching strategies compared with teachers holding empiricist beliefs.

In terms of the students' science learning, Stohr-Hunt (1994) carried out a study to measure the relationship between the amount of time spent experiencing hands-on science and science achievement. She found that students who engaged in hands-on activities every day or once a week, scored significantly higher on a standardized test of science achievement than students who engaged in hands-on science once a month, less than once a month, or never.

The development of reasoning skills, higher level thinking skills, and science process skills are some of the benefits students can realize by participating in inquiry in the science laboratory. The results of the research of Germann, Aram and Burke (1994) indicate that explicit, incremental development of the science process skills of formulating hypotheses and identifying variables, together with model examples, may be a means to facilitate student success in designing science experiments.

A large hiatus exists between the kind of science typical in instructional settings and the type of science valuable to the individual, and to the

broader society. Curricula designed to transmit a knowledge base of the traditional discipline are constraining. The student does not learn how to transmit the principles of biology to problems external to the discipline. Furthermore, it is difficult to recognize a modern philosophy of science, or of life, which is part and parcel of traditional biology courses, limited to discipline-based knowledge. Monod (1971) suggests that science is the only viable constitutive norm for society.

There seems to be some evidence from exemplary programs that even poorly taught hands-on science is more interesting to students than the typical textbook-based program (Penick & Yager, 1988).

Evidence clearly indicates that hands-on activities increase skill proficiency in the processes of science, especially laboratory skills and specific science process skills, such as graphing and interpreting data (Mattheis & Nakayama, 1988). Young people can learn most readily about things that are tangible and directly accessible to their senses ... With experience, they grow in their ability to understand abstract concepts, manipulate symbols, reason logically, and generalize (Rutherford & Algren, 1990).

Almost all the national reports on the conditions of teaching and learning in schools calls for more active learning for students and less passivity; more hands-on, direct opportunities to 'make meaning' (Schmieder & Michael-

Dyer, 1991). The use of hands-on activities is far less frequent than lecture or discussion (Weiss, 1987). Lack of time is a frequently mentioned obstacle to teaching a constructivist course (Morey, 1990; Tilgner, 1990). This is compounded by a tendency of teachers to feel that there is a requirement to 'cover the textbook' (Martens, 1992). In a rapidly changing society with information growing exponentially, it is clearly impossible for teachers to know everything about any discipline. Yet traditional roles of teaching, focusing on the transmission of knowledge and the student as a passive receiver rather than an active participant, continue to be a strong and viable force in our schools, a force that delineates the teacher as the primary person in possession of the knowledge. If schools continue to hold to this model of teaching of science, then there is little hope that education will begin to focus on the student's own active participation in learning. Within this traditional paradigm, the need for restructuring science and mathematics education is paramount (Miller 1993).

Learning Cycles

The learning cycle has many advantages over traditional instructional approaches, especially when the development of thinking skills is an important goal. Because many studies have shown that a large proportion of the secondary and college population have poorly developed thinking skills,

it seems reasonable to conclude that the learning cycle deserves more widespread implementation in science classrooms (Lawson, 1996). Karplus and Their (1967) described a three-phase learning cycle, exploration, invention and discovery. More recently, they have been labeled as exploration, term introduction and concept application (Lawson, 1988). During exploration, students learn through their own actions and reactions in a new situation. They explore new ideas and new materials with minimal guidance. The new experience should raise questions or complexities that they cannot resolve with their accustomed ways of thinking. In this way, exploration provides the opportunity for students to voice potentially conflicting , or at least partially inadequate, ideas. That analysis can then lead to an explicit discussion of ways of testing alternative ideas through the generation of predictions. The gathering and analysis of results may then lead to a rejection of some ideas and the retention of others in the cyclic pattern of self regulation (Lawson, 1995). "Learning cycles can be classified as one of three types: descriptive, empirical-abductive, and hypothetical-deductive. The essential difference among the three is the degree to which students merely attempt to describe nature or explicitly generate and test alternative hypotheses. The three types of learning cycles represent three points along a continuum from descriptive to experimental science. They

place differing demands on student initiative, knowledge, and thinking skills” (Lawson, 1995, p.139).

The Case Against a Laboratory Approach to Science Education.

Not all science educators agree that the laboratory approach to science education is successful. While most authors do not advocate the complete abandonment of laboratory work they are cautious in interpreting its value. Pickering, (1980) questions whether labs are a waste of time. His major arguments are that labs are expensive, not popular with students, and are time consuming for the faculty. He argues that most faculty members in sciences are not clear about what teaching labs can do. In addition, he presents a number of misconceptions about the purpose of labs. Among these misconceptions is that somehow labs illustrate lecture courses; labs do not teach finger skills - the importance of manipulative skills is usually oversold by defenders of labs. He offers as a potential solution to the present problem with most lab courses that the obstacles are organizational, and not inherent in laboratory teaching itself. This is fortunate because reform is possible and reform is cheap. What is needed is more careful planning and precise thinking about educational objectives.

Hofstein & Lunetta (1980) cite several arguments against the use of laboratory activities:

- (i) too few teachers in secondary schools are competent to use the laboratory effectively.
- (ii) too much emphasis on laboratory activity leads to a narrow conception of science.
- (iii) laboratory work in schools is often remote and unrelated to the capabilities and needs of students.

They conclude that, there are insufficient data, from well designed studies, from which to make unequivocal statements on the role and effectiveness of laboratory work in science teaching.

In addition, Hodson, (1990) raised concerns about extravagant claims made for science instruction based on activities and laboratory work. "In my own view, based on twenty years of teaching and teacher-training experience, practical work, as conducted in many schools, is ill-conceived, confused and unproductive. It provides little of real educational value. For many children, what goes on in the laboratory contributes little to their learning *of* science, or to their learning *about* science. Nor does it engage them in *doing* science, in any meaningful sense" (p.33). How scientists know what they know has traditionally not been emphasized in science classes. The how component of science can be taught to students through carefully constructed laboratory experiences. Usually, however, these glorious

educational moments are designed to guide students down an expedient pathway to scientific enlightenment without the detours that scientists took while conducting the research. Therefore, simply teaching the traditional scientific method through cookbook lab activities does not accurately address the complex sociological variables involved in doing actual scientific research. This simplified view of science shortchanges students' understanding, not only *about* science, but *of* science (Abrams & Wandersee, 1995). Laboratory teaching is one of the unique features of education in the sciences, but there is a question as to whether the great expense of maintaining and staffing laboratories is really justified (Giddings and Hofstein, 1980). Furthermore, students' reactions to practical work often confirm the views of critics. It is quite common to hear students say that laboratories are boring, and that they go through the motions of experimentation without stimulation and often without any clear purpose (Gallagher, 1987). Fraser et al.(1993) researched the importance of the psychosocial environment in science laboratories in order to develop an instrument to monitor among other factors, students' views of their laboratory classes.

Though some have raised concerns about science instruction based on activities and laboratory work, there is evidence of interactions among

investigative approaches to science teaching and teaching styles (Lock, 1990).

The Use of Technology

As instructional technology advances, there will be more options for using a variety of materials to enrich inquiry oriented teaching. Use of interactive media in inquiry based learning is being examined (Litchfield & Mattson, 1989) and new materials are being produced and tested (Dawson, 1991).

Use of computerized data bases to facilitate development of inquiry skills has also been studied (Maor, 1991).

The technology of education has changed. We are only starting to realize how much learning is being affected by developments such as television, video, computers, CAI, CD-ROM, data-bases, and the internet. More knowledge is becoming more available, more widely and more interactively. We no longer need an education system that requires standardized mass production organization, where we require all students to do the same thing, at the same time, in the same place. Although most schools have made investments in information technology in recent years, it continues to be peripheral to most of what schools value and has not yet resulted in significant changes in the operation of secondary schools. The definition of technology still remains relatively narrow, focusing on

computers and continues to be largely an add-on, something to be used for reinforcement or enrichment, but not a central focus of school programming. The discussion of how technology can and should change teaching and learning is only just beginning (Levin, 1995).

In British Columbia, the use of a multimedia approach is strongly encouraged in the Biology 11/12 Integrated Resource Package (1996).

Until fairly recently there has been no serious challenge to the belief that some other kind of events or activities might reasonably substitute for the traditional laboratory. With the emergence of increasingly more and better electronic media, especially courseware (instructional software) , this is no longer the case (Ralph 1991). A significant cause for the search for alternatives to traditional biology laboratory activities, in particular dissections, is the increased awareness of ethical issues (Guy & Fisby, 1992; Kinzie et al. 1993). Also in terms of the 'efficiency of learning', Ralph (1996) argues that only about half of the two hours (in a traditional laboratory exercise) is spent actually doing science. The other half commonly, is consumed by the instructor in explaining procedures, handing out papers, collecting reports, repairing or replacing failed or broken equipment, and by the students inefficiently moving among dispensing or observation stations, preparing hand-ins, and cleaning laboratory benches.

He concludes that it is this inefficient use of limited time which is a most compelling reason to invoke new paradigms in laboratory work . “The relative advantage of electronic media over traditional laboratory exercises in the learning of concepts, vocabulary and mechanisms is compelling, in my view, and I am very comfortable in making the deliberate choice to substitute courseware for traditional exercises” (Ralph, 1996 p.143).

Electronic media are particularly effective in enhancing comprehension and permit the generation of greater amounts of data and more variations in experimental design than traditional situations (Fifield & Peifer, 1994). If the primary goal is the acquisition of information, and the testing and understanding of ideas, then the laboratory employing electronic media is as good as the traditional laboratory exercise (Guy & Fisby 1992; More & Ralph, 1993; Strauss & Kinzie 1994).

Assessment of Laboratory Work

One of the major obstacles to the acceptance of activity-based learning has been the difficulty of assessment. Teachers are comfortable assessing knowledge and producing this result as a measure of the students understanding of a given topic. However, this is a paradox since many teachers place great value in science as a practical subject (Bryce & Robertson, 1985). The practical nature of the subject is commonly regarded

as an important source of pupil motivation. Science is taught in laboratories and teachers spend a considerable amount of time in supervising practical work. Yet the bulk of science assessment is traditionally non-practical.

Olsen (1973) highlighted the difficulty of assessing the knowledge gained from a laboratory because of the tacit nature of the skills acquired. Doran and Hejaily (1992) developed instruments to assess laboratory skills of students completing high school courses, in order to address alternatives to the traditional paper and pencil test. Comber and Keesee (1973) reported that practical tasks measured different abilities from those assessed by the more traditional tests, even those designed to assess practical skills without using actual apparatus. Grobman (1970) considered the use of written tests to be highly inappropriate in the assessment of either complex laboratory experiments or basic laboratory tasks.

Teachers must not be held accountable for test score results during the change from traditional to hands-on science, as scores are likely to fall during the transition period (Foster & Dirks, 1993).

Although students can apply certain knowledge when they do science, they cannot necessarily reproduce that knowledge in verbal form on a paper and pencil test or in a discussion with the teacher (Tobin, 1990).

The problem of assessment also constrains the spread of hands-on science. It is relatively easy to test children's knowledge when they have been asked to memorize a list of data from a text. It is much harder to design tests that measure learning derived from direct experience... The challenge before science educators is to design better means of measuring both factual knowledge and the kinds of understanding that students acquire through activities. When that task is accomplished, a major roadblock to science achievement will have been removed (Bennett, 1986). Macroff (1991) suggested that instruction and assessment complement each other to raise the level of learning. He states that this type of assessment does not drive the curriculum but actually grows out of the curriculum, instruction and learning. Just as reading about science phenomena is not the best way or the only way to learn science, most educators agree that filling in bubbles on a standardized test is probably not the most effective way to measure a student's potential understanding of science (Bruder, 1993). Among the new labels being used today is performance-based assessment. Though there are a variety of definitions, it is clear that performance-based assessment does not include multiple choice testing or related paper and pencil approaches (Haury, 1993).

Traditionally, student learning in the science classroom has been assessed using multiple choice and short answer formats. While these formats provide information on students' fact acquisition, they are limited in their capability to assess deeper levels of understanding. Generally, science educators agree that assessment in science should not only measure fact and concept acquisition, but also measure science process skills, scientific thinking and problem solving skills, skills needed to manipulate laboratory equipment, and the ability to apply scientific knowledge (Raizen, Baron, Champagne, Haertel, Mullis & Oakes, 1989). By using alternative assessments to measure these competencies, teachers are better able to make informed instructional decisions as well as do a better job of assigning grades (Berenson & Carter, 1993).

Laboratory practical exams have been used to assess student attainment of science process skills. For individual assessment, each student should perform all the manipulation of equipment and materials to answer questions (Stensvold & Wilson, 1993). In developing a scoring system, performance and not content should be stressed as the most important aspect contributing towards the grade (Doran & Hejaily, 1992). Portfolios are becoming an increasingly important tool in science teaching and

learning. A portfolio is a collection of documents that contain evidence of achievement (Collins, 1992).

Assessment through student writing and portfolios provides a means for teachers to help students take a longer view of their learning in science.

Assessment comes from teacher judgement of the materials with respect to a set of criteria (Flick, 1993). Concept maps may be an effective way to assess hands-on science and are powerful and psychometrically sound tools for evaluation in science education (Markham & Mintzes, 1994). Although students can apply certain knowledge when they do science, they cannot necessarily reproduce that knowledge in verbal form on a paper and pencil test or in a discussion with the teacher (Tobin, 1990).

In conclusion, one might ask who is responsible for the quality of teaching that occurs in biology classrooms? Is it those in the colleges of education and universities, where all teachers take at least one methods class? If 86% of biology teachers are exposed to 1-3 teaching methods courses as undergraduates and 4-6 as graduate students, is that enough? Or is it in the science disciplines, where the majority of classes are taken, that makes a difference? Most university biology departments see their task as career preparation for research not general education. Yet many of their graduates will end up teaching at some level. If one views teacher education as a life-

long process and a joint-venture, then all of the previously mentioned groups are responsible. In addition, the encouragement and financial support of on-going professional development, in particular of young teachers, must be the responsibility of the school and district administration. Above all however, it is incumbent on the individual teacher to identify and pursue professional development opportunities.

CHAPTER THREE

RESEARCH DESIGN AND PROCEDURES

Research Objectives

The objectives of this research were to investigate:

- the quantity and quality of laboratory work being carried out by Grade 11 and 12 Biology students in British Columbia High Schools.
- the scores on lab-based and data-analysis questions compared with non-lab questions, on the Provincial and Scholarship examinations.
- the quantity and type of laboratory activity conducted in schools compared with the number and type of laboratory exercises recommended in the Biology 11/12 Curriculum Guide and Integrated Resource Package.

Research Method

The research method for this study was divided into three major parts:

The survey of Biology teachers in British Columbia High Schools

in order to establish the number and type of lab exercises being conducted by teachers in the province. In addition, the survey provided information

about other factors such as school demographics, the teachers, teaching method, teacher attitudes, and the use of technology in biology classes.

A hands-on analysis of the provincial examination questions for both the provincial and scholarship papers.

The purpose of this analysis was to establish the performance of Grade 12 students on lab-based, and data and analysis questions, in order to see whether there was any significant difference in level of achievement between lab-based and data-analysis questions, and other questions.

An examination and subsequent analysis of the Biology 11 /12

Curriculum Guide, in order to gain information on the number of laboratory exercises in Biology 11/12 which are recommended by the Province of British Columbia as activities for students. These data were then sub-divided and categorized as qualitative and quantitative exercises. The Curriculum Guide was published in 1990 and will be superseded by the Integrated Resource Package (IRP) for biology, which will be implemented in September, 1996. Therefore, in addition to the analysis of the Curriculum Guide, an analysis of the IRP was also conducted in order to establish whether there had been any significant change in the number or types of laboratory exercises and any change in the number and types of learning resources recommended to teachers.

Research Design

Overview

The purpose of this research was to examine the quantity and quality of laboratory work being conducted in biology classes in British Columbia high schools. In order to investigate this, a survey instrument was developed and distributed to schools for completion by teachers of Biology 11 and 12. The survey data was recorded, analyzed, and statistical tests were performed in order to investigate various relationships. In addition, provincial examination papers were examined in order to determine the frequency of laboratory-based, and data-analysis questions, compared with non-laboratory questions. Using the difficulty factor for provincial examination questions and the mean student score for the scholarship examination questions, statistical tests were performed, in order to identify whether there was any significant difference in student performance on the lab-based and non lab-based questions. Finally, the Biology 11/12 Curriculum Guide and the Biology 11/12 Integrated Resource Package were examined for the frequency and type of laboratory activities, so that the quantity and type of laboratory work recommended in these curricula could be compared with what was actually happening in science classrooms in the province.

The Development of the Surveys

The primary instrument used in this part of the research was the survey. This was developed in two phases. The pilot survey was designed as the initial instrument, which was distributed at the January, 1995 marking session for the biology provincial examination, followed by the design of the full-scale survey, distributed to schools in May, 1996. The full survey instrument was based on the results of the pilot survey and the subsequent modifications to it. The purpose of the survey was to gather data on demographics of the schools surveyed, the teachers, the number and type of laboratory exercises being conducted, the effects of the provincial curriculum and examination on the amount of laboratory work, the frequency of use of technology, and the pedagogy used by the teachers. The full survey was designed to be answered in about 10 minutes. Teachers have many demands on their time other than teaching, and it is important that a survey of this type occupies a minimum amount of their time, stimulates their interest to respond, and yet provides adequate information about the key ideas being investigated. The survey required teachers to circle one or more of the choices of answer for each question, enter numerical data or provide very brief written reasons for choices (the latter was kept to a minimum with only four written responses required). A quantitative model

was used along with a process oriented, qualitative evaluation model, in that the purpose of part of the research was to conduct an evaluation without using pre-stated objectives or standards against which the results are compared (Patton, 1990). This type of research model was used, as it is characterized by investigating the unique characteristics of the phenomenon under investigation and in particular, includes the perspectives held by people close to the phenomenon being examined.

The Pilot Survey

Design of the Pilot Survey

The purpose of the pilot survey was to field test the questions and thereby establish the validity and utility of the survey instrument. There is a lack of good instruments available for gathering this type of information and therefore it was decided to design an instrument, establish its validity and then, after suitable modifications, to use it as an instrument in the study. No survey has been conducted on senior biology courses in British Columbia. In fact, there have been no in-depth surveys of this type conducted on senior science courses. "The Provincial examination is regarded as the instrument for measuring the effectiveness of teaching at the senior high school level".¹ The pilot survey (Appendix 1) consisted of 28 questions. The questions

¹ Personal communication with official at Ministry of Education, July 22, 1996

were grouped under the headings: demographics, the teacher, laboratory work, and follow up. The purpose of ordering the questions in this way was to provide the teacher with initial questions which were non-threatening and simple to answer. Also, the headings clearly delineated the topic of interest and thereby provided a focus and context for the teachers' answers. In addition, the value in receiving the information on demographics and the teacher was that they could be used later in correlation studies with the laboratory work data in order to see if there was any relationship between for example, location of school and the number of laboratory exercises carried out.

The survey contained questions which gathered numerical data, descriptive data and also asked mainly for a yes/no response on the laboratory section. Since this was a pilot survey, it was felt that a simple yes/ no response would suffice rather than a Likert-type scale, in order to determine whether the study was appropriate for further investigation. Also it allowed teachers to complete the survey with the minimum of time and effort - in that they were involved with the marking of examination papers and would complete the survey when they had a break.

Validity and Reliability of the Pilot Survey

The face validity of the pilot survey was high in that it appeared, to the teachers surveyed, to measure the factors it was designed to measure (Borg and Gall, 1989). In terms of content and construct validity and reliability, the pilot survey appeared to be acceptable, with some modifications which are listed below, along with the reasons for the changes. Content validity was deemed acceptable because there were very few questions not answered on the survey and there seemed to be a clear understanding of the nature of the question being asked. It was deemed therefore, by virtue of common sense, to exhibit clarity, readability, and utility. Teachers were invited to make suggestions regarding the improvement of the survey and apart from a few minor formatting changes it appeared that no-one felt that it needed any significant alteration. The reliability of the survey was difficult to measure as there are no standard tests with which to compare it. However, a number of the teachers who had completed the survey were consulted and stated that the results clearly reflected the commonly expressed concerns of many teachers about the lack of lab work. It would seem therefore that it was a reliable instrument (This would also support the construct validity of the pilot survey).

Modifications to the Pilot Survey

- While simple yes/no responses were satisfactory for the pilot survey, it was felt that a more discrete measure of response was necessary. The questions were altered to solicit responses on a Likert-type scale, (e.g. always, frequently, rarely, never)
- Question 5 was added to the survey as it was thought that the number of hours of instruction per year would have an impact on the amount of laboratory work undertaken.
- Question 9: Do you feel that the labs you use require the students to think ‘scientifically’? It was felt that the term ‘scientifically’ was ambiguous and that the question would be improved by changing it to “Do you feel that overall, the labs which you assign, foster critical thinking in the students”?
- Question 15 was added because it was felt that students’ understanding of scientific method would be an indicator of familiarity with the processes of laboratory work.
- Questions 17 and 18 were added to the survey because it was felt that the use of technology was an important aspect of education in today’s schools. Question 17 inquired about lab-simulations using video, compact disc or computer. It was thought that these might be replacing

actual 'hands on labs' because of their ease of use, convenience and repeatability. Question 18 inquired about the use of computer-based data collection and was introduced to measure how many schools were now using this up to date technology.

- Question 19 was added to determine why teachers would not be using technology in their biology classes.
- Question 27 was added to sample teachers attitudes towards inquiry-based courses and what their preference would be if they could choose between a traditional course² an inquiry-based course. This question was thought to be important in order to establish a preference in isolation from all the other constraints which might force the individual teacher into a particular pedagogy or teaching style.
- a number of questions were modified to show a clearer distinction between Grade 11 and 12 data.

The Survey

The survey (Appendix 2) was the primary instrument in this part of the study and was constructed on the basis of modifications to the pilot survey which was deemed to have validity and reliability.

² a traditional course is defined as primarily a teacher centered course, which relies heavily on lecture but has some supporting laboratory activities.

The two major modifications were:

- a clearer distinction between questions applying to Grade 11 and 12 courses
- the design of question responses to be answered on a Likert-type scale.

The survey was mailed to biology teachers in 248 schools in the Province³, 216 public schools and 32 independent schools. The schools selected consisted only of those which would teach Grade 11 and 12 biology courses. These include Secondary schools - defined as schools offering education programs for students enrolled in Grades 8 to 12 and secondary ungraded education, and Senior Secondary Schools are defined as those for Grade 11 and 12 students only. No distinction was made between these two categories in the survey distribution. The schools selected were representative of all of the 75 School Districts in the Province. Teachers were given the option to return the completed surveys by mail, fax or e-mail.

The survey consisted of 34 questions divided by the following sub-headings:

³ Public and Independent Schools Book. Province of British Columbia. 1995

Demographics

In this section of the survey, teachers were asked about size of school, location of school, numbers of students, organization of the school year and hours of instruction. These are neutral questions but may have an important relationship to other aspects of the study (e.g. a relationship between size of school and number of laboratory exercises carried out by students in a school year).

The Teacher

This section of the survey required no modification and elicited responses from teachers regarding years of experience, specialist training and qualifications.

Laboratory Work

This is one of the key areas of the survey in that it addresses the primary purpose of the research, viz. the quality and quantity of laboratory work in British Columbia High Schools. The questions covered topics such as: the frequency of lab exercises in Grade 11 and 12; the distinction between the number of qualitative and quantitative labs undertaken in Grade 11 and 12; the use of hypotheses and the students' understanding of scientific method; the use of technology both for instruction and computer-based data collection; and time for teaching the provincial course. Teachers' attitudes

towards the courses, in terms of the content effect on a lab-based approach to teaching, were also important issues .

Assessment was touched upon with just two questions on the use of laboratory examinations and the incorporation of lab-based questions into class tests.

The final few questions dealt with the issue of the teachers' present method of instruction and attitudes towards not teaching an investigative lab-based course. Feedback on the results of the survey was offered to the teachers if they were interested, and in addition, they were asked whether they and / or their students would be willing to be interviewed in a follow up study.

Analysis of the Survey Data

The questionnaire frequency responses were recorded in an Excel spreadsheet for subsequent analysis and generation of descriptive and inferential statistics. In order to explore proposed relationships, hypotheses were subjected to a Chi-square analysis, and where appropriate, t-tests or ANOVA were used as tests of statistical significance. The level of significance was set at 0.05. This was considered to be strict enough as the reliability of the responses on questionnaires is often not consistent because of teacher perceptions of how they as individual teachers, and their schools, will be measured against others. In addition, the frequency of responses to

open-ended questions was recorded and analyzed for recurring patterns of words, phrases or sentences in order to construct hypotheses regarding teacher attitudes to such activities as the use of computer-based data collection, and individual student research.

The relationships tested and the statistical tests utilized

The following relationships were examined using contingency tables and their significance was investigated by Chi-square analysis with a significance level of 0.05. In cases where the contingency tables were very large an ANOVA was used as a test of significance ($p = 0.05$). For some relationships, correlation coefficients were calculated and their significance assessed ($p = 0.05$).

1. Size of school.

This was thought to be of interest in that larger schools often have better facilities, a larger budget, and a greater number of teachers in the department, with greater experience, than those in small schools. These factors may possibly have an influence on the frequency and type of laboratory activities used.

The following relationships with size of school were examined:

- i) number of quantitative labs in grade 11
- ii) number of quantitative labs in grade 12

- iii) frequency of laboratory work
- iv) number of qualitative labs in grade 11
- v) number of qualitative labs in grade 12
- vi) laboratories are well enough equipped for a lab-based course in grade 11
- vii) laboratories are well enough equipped for a lab-based course in grade 12
- viii) teachers feel that the provincial course outline for grade 11 limits lab work
- ix) teachers feel that the provincial course outline for grade 12 limits lab work
- x) teachers feel that provincial examination limits lab work
- xi) a lab exam is given in grade 11
- xii) a lab exam is given in grade 12
- xiii) the teaching style of teachers

2. Location of the school

The location of the school, described in the survey by the teachers as urban, rural or remote, was thought to be a possible influence on the frequency and type of laboratory activities.

The following relationships were examined: frequency of laboratory work

- i) frequency of quantitative labs in grade 11
- ii) frequency of quantitative labs in grade 12
- iii) frequency of qualitative labs in grade 11
- iv) frequency of qualitative labs in grade 12
- v) labs well enough equipped for a lab-based course in grade 11
- vi) labs well enough equipped for a lab-based course in grade 12
- vii) frequency of labs is limited by grade 11 provincial course outline
- viii) frequency of labs is limited by grade 12 provincial course outline
- ix) frequency of labs is limited by provincial examination
- x) whether a lab exam is given in grade 11
- xi) whether a lab exam is given in grade 12
- xii) the effect on teaching style

3. Organization of School Year

The way in which the school year was organized was thought to have a possible effect on a variety of factors. The relationships examined are listed below:

- i) the number of labs performed in a year
- ii) the number of quantitative labs in grade 11
- iii) number of quantitative labs in grade 12
- iv) the number of qualitative labs in grade 11

- v) the number of qualitative labs in grade 12
- vi) sufficient time for a lab-based course in grade 11
- vii) sufficient time for a lab-based course in grade 12
- viii) the provincial course outline in grade 11 limits the scope for individual student research
- ix) the provincial course outline limits the scope for individual student research in grade 12
- x) the provincial examination limits the opportunities to provide a lab-based course in grade 12
- xi) a lab examination is given in grade 11
- xii) a lab examination is given in grade 12
- xiii) the teaching style

The following miscellaneous relationships were also examined and the rationale for their possible relationship is discussed.

- i) labs are well enough equipped for grade 11 compared with the lab exercises are confirmatory in grade 11. This question was posed because it was hypothesized that there might be a relationship as follows: if the labs were not very well equipped then one would expect the lab exercise to be primarily confirmatory and conversely if the labs were well equipped one would expect

greater opportunity for research based labs - provided that other factors such as teacher style were randomly spread among the sample data

- ii) labs are well enough equipped in grade 12 and lab exercises are confirmatory. The same rationale as for grade 11 is appropriate here, and in addition, one would expect research labs to be even more likely in grade 12 because of the greater lab experience of the students.
- iii) qualifications of the teachers and teaching style
- iv) the scope for individual lab work in grade 11 and grade 12 is limited by the provincial course outline
- v) the frequency of individual student lab work in grade 11 and 12
- vi) labs are well enough equipped for grade 11 and 12
- vii) sufficient time for the course in grade 11 and 12
- viii) the understanding of scientific method in grade 11 and 12
- ix) the labs in grade 11 and 12 are confirmatory rather than investigative
- x) the labs in grade 11 are confirmatory and foster critical thinking
- xi) the labs in grade 12 are confirmatory and foster critical thinking

- xii) the use of lab simulations in grade 11 and the reasons for not using them
- xiii) the use of lab simulations in grade 12 and the reasons for not using them
- xiv) the use of computer-based data collection in grade 11 and the reasons for not using this technique
- xv) the use of computer-based data collection and the reasons for not using this technique in grade 12

The correlations between years of teaching and the following were explored:

- i) frequency of labs
- ii) frequency of quantitative labs in grade 11
- iii) frequency of quantitative labs in grade 12
- iv) frequency of qualitative labs in grade 11
- v) frequency of qualitative labs in grade 12
- vi) sufficient time to teach a lab based course in grade 11
- vii) sufficient time to teach a lab based course in grade 12
- viii) limitations on lab work of the course outline in grade 11
- ix) limitations of the course outline on lab work in grade 12
- x) limitations of the provincial examination on lab work

- xi) frequency of use of computer based data collection in grade 11
- xii) frequency of use of computer based data collection in grade 12
- xiii) choice of an inquiry based course in grade 11 rather than a traditional course
- xiv) choice of an inquiry based course in grade 12 rather than a traditional course
- xv) style of teaching

The following two correlations were also thought to be worth exploring:

- i) the frequency of quantitative labs in grade 11 and the frequency in grade 12
- ii) the frequency of qualitative labs in grade 11 and the frequency in grade 12

The Provincial and Scholarship Examination Analysis

The Provincial and Scholarship examinations are written as many as four times a year depending on the discipline. The two sessions in which the majority of students write are in January and June, in order to align with the majority of schools which are either linear or semestered, while the other sessions are in November and April. Only examinations from the January and June sessions were examined as the sample size in these was significantly greater than either of the other two sessions. Each Provincial

examination paper was examined by hand and lab-based questions were distinguished from non lab-based questions for the 52 multiple choice questions and for the 11 written questions. Data analysis questions were also grouped with lab-based questions provided that they included a set of quantitative data which required interpretation and analysis by the student. The primary reason for adding these was that they require the same skills and knowledge as lab-based questions in the analysis phase. A secondary reason was that the sample size of the lab-based questions alone was very small and would not have provided sufficient data for a significant comparison between lab-based and non lab-based questions. In the Scholarship examination there are no multiple choice questions, only questions requiring written responses. In the same manner as for the Provincial examination, lab-questions were distinguished from non-lab questions using the same criteria.

The data collected from this sampling of examination papers was analyzed and descriptive and inferential statistics generated. T-tests were used to estimate the statistical significance of the differences between mean scores on lab-based questions and non lab-based questions on the Provincial multiple choice section, written section, and on the Scholarship examination papers. Each Provincial examination data set was subjected to a two-tailed

t-test in order to establish whether there was a significant difference in mean scores between lab and non-lab questions.

In each case:

- H_0 - there is no difference between the mean scores for lab and for non-lab questions
- H_1 - there is a significant difference in mean scores

As there are 52 multiple choice questions on every Provincial examination and two data sets, then the degrees of freedom is constant at 50 $[(n_1 + n_2) - 2]$ and therefore the value of t_{critical} remains constant also at 2.009 at a significance level of 0.05.

For the written section of the provincial paper the number of lab questions was very small, often just one question, or in some years, there were no lab questions (Table 8, Chapter 4). Therefore it was decided to use the grand means for all lab questions and all non-lab questions and perform a t-test on these data in order to establish whether there was a significant difference.

The Analysis of the Biology 11/12 Curricula

The Biology 11/12 Curriculum Guide (1991) was examined for the number of qualitative and quantitative laboratory activities as well as the software and videotapes which were listed, and therefore recommended, by the

Learning Resources Branch. The syllabus is divided into a Core curriculum which is mandatory and occupies approximately 70 hours and an Options section which requires students to choose from 22 topic areas and covers a further 30 hours. The philosophical basis for the options section is that it allows teachers to design their courses around local interest or expertise.

The Biology 12 course consists of an 80 hour core with the requirement that an additional 20 hours be selected from six possible options.

In the new Biology 11/12 Integrated Resource Package (1996) due to be implemented in September, 1996 for grade 11 and September 1997 for grade 12, the situation has been simplified by the removal of all options from the course. A similar count was made for the number and types of laboratory activities recommended as well as the supporting technological resources, such as videotapes, videodiscs, and software.

Descriptive statistics were generated for the data for the Biology 11/12 Curriculum Guide and the Integrated Resource Package for Biology 11/12.

CHAPTER FOUR

RESEARCH FINDINGS

The following is a synopsis of the data generated from the pilot survey, the survey itself, the analysis of provincial examination papers, government reports on examinations, and the laboratory content of provincial syllabuses.

These findings reflect documented evidence of specific aspects of public school structure, the practice of biology teaching in the province as well as perspectives held by teachers of biology at the Grade 11 and 12 level.

The data are organized such that they provide answers to the research questions posed by this study. The research questions as stated in Chapter 1 are:

- What is the quantity and quality of laboratory work being carried out by Grade 11 and 12 Biology students in British Columbia High Schools.?
- What effect does the amount of lab work being carried out have on scores of lab-based and data-analysis questions on the provincial examination?
- How does the quantity of laboratory work being carried out compare with the number and type of laboratory exercises recommended in the course outline?

The Results of the Pilot Survey

Seventeen pilot surveys were completed and returned (See Appendix 1).

The surveys were completed by teachers from 17 schools which represented 17 different school districts in the Province of British Columbia (Ministry of Education, 1995).

Demographics

Teachers from six (35.3%) large, ten (58.8%) medium and one (5.9%) small schools responded and included seven (41.2%) schools described as urban and ten (58.8%) as rural. None of the schools were reported by the respondents as remote .

Eight (68.8%) of the schools were on a semester system, three (18.8%) on a quarter system, three (18.8%) on a linear system and two (12.5%) described as other.

The number of students taking Biology 11 ranged from 60 to 240 with a mean of 137.9. (s.d.=57.25), while in Grade 12 the range was 40 to 180 with a mean of 80.6. (s.d.=38.37)

The Teacher

While personal questions tend to be avoided on surveys of this type it was felt that it was important to gather information on three facets of the individual teachers, as these might have an effect on their teaching style and

frequency of use of laboratory work in their teaching. These questions ask about number of years of teaching, specialist training and qualifications.

The years of teaching ranged from six to 32 years with a mean of 17.9 years (s.d.=7.41). Fourteen (82.4%) of the teachers had specialist training in Biology and eight (47.1%) held a B.Sc., five (29.4%) held an M.Ed, three (17.6%) an M.Sc. and 1 (5.9%) an Ph.D.

Laboratory Work

One of the critical questions on the pilot survey was “On average, how frequently do you use labs?” For Grade 11 students, eight (47.1%) of the teachers responded that they used less than one lab per week or cycle. A cycle here is defined as the timetable rotation time when the school teaches on other than a five day cycle. e.g. a six, seven or even eight day cycle. Five teachers reported that they used one lab per week or cycle. Cumulatively, therefore, 81.3% of the teachers used one or less labs per week, with the majority using less than one. One (5.9%) teacher reported using two labs per cycle and two (11.8%) reported using more than two labs per cycle. The mean number of labs used per cycle was 1.81 labs per cycle (s.d.=1.047). For Grade 12 students, 12 (75%) of teachers reported using less than one lab per week or cycle and a further two (12.5%) one lab per week or cycle. i.e. 87.% of teachers reported using one or less labs per week or cycle. One

(6.3%) teacher reported using two per cycle and one (6.3%) more than two per cycle in Grade 12.

The survey then asked for a count of labs per year in Grades 11 and 12 but this time, with a differentiation between qualitative¹ and quantitative labs.²

The results for qualitative labs showed a range of 0 to 23 labs per year in Grade 11 with a mean of 10.47 (s.d.= 5.558). In Grade 12, the number of labs ranged from 0 to 17 with a mean of 4.58 labs per year (s.d.=4.139)

The results for quantitative labs in Grade 11 showed a range of 0 to 5, with a mean of 2.6 labs per year (s.d.=1.4). In Grade 12, the range was 0 to 7 labs per year with a mean of 2.4 quantitative labs carried out per year.

When asked about the nature of the labs undertaken being mainly confirmatory rather than investigative, the teachers were unanimous in their response that they were confirmatory rather than investigative for Grade 11, and for Grade 12, (88.2%) responded in the same way.

Thirteen (76.5%) teachers responded that the labs which they used did not require the students to think 'scientifically'.

Seventy-seven percent of teachers stated that students entering their biology classes in Grade 11 did not understand scientific method, whereas only 18.8% thought that to be the case for Grade 12 students.

¹ A qualitative lab was defined on the survey as "observation rather than measurement".

² A quantitative lab was defined on the survey as " measurement rather than observation".

When asked whether they expected students to formulate an hypothesis before beginning a lab³ 5.9% responded that they always expected students to do so; 29.4% responded 'frequently'; 52.9% responded 'rarely' and 11.8% 'never'.

Of the teachers, 64.7% established that their students do not have good laboratory skills upon entering Grade 11, but 88.2% stated that they possess these skills in Grade 12.

All of the teachers surveyed felt that the labs which were conducted in Grade 11 supported the intended learning outcomes of the provincial course outline but only 75% indicated that this was the case in Grade 12 .

In terms of the time allowed to teach the course, 47.1% of teachers felt that they did not have sufficient time to teach a lab-based course in Grade 11, whereas this increased significantly to 94.1% for teachers of Grade 12.

In terms of how well equipped laboratories were, there was once again an interesting dichotomy in that 62.5 % of Grade 11 teachers agreed that their labs were well enough equipped to pursue an inquiry based course, while 62.5% felt that this was not the case for Grade 12

The provincial course outline was seen to limit the scope for individual student research in Grade 11 by 64.7% of teachers for Grade 11 and 94.1%

³ In this case the question was answered on a Likert-type scale: viz. Always; frequently; rarely; never.

of teachers for Grade 12. In addition, 94.1 % of teachers of Grade 12 agreed that the provincial examination limited the scope for individual student research. Also, for Grade 11 students, 64.1 % of teachers noted that their students do not carry out any individual lab-based research whereas 100% of teachers of Grade 12 stated this to be the case.

All of the teachers agreed that in Grade 11 and 12 there was not enough time for lab based, individual, research. The second reason was a lack of resources, which was given in five cases as a secondary cause. Some teachers indicated that in Grade 11 some individual work is possible, ranging from 3-4 hours, to being optional. One school indicated that diploma International Baccalaureate students were expected to produce one piece of individual work.

When asked whether conducting an in-depth, individual piece of research would be an exercise valuable to students' scientific development, 93.8% responded positively. The reasons given included: explore the scientific method; think for themselves; see a project through to completion; research is an important component of science; students need to practice reasoning and logical thinking; would get a better feel for the scientific process; it's real science; so much is learned in so many areas as research is conducted; need to explore references and critically assess data.

Of the teachers surveyed, 49.7% give a lab exam in Grade 11, and 29.4% in Grade 12, and 52.9% of all teachers, regularly incorporated lab-based questions into tests.

In describing their teaching method, 82.4% of teachers described themselves as using primarily a lecture approach with some lab work. Only 5.9% described themselves as using primarily an investigative approach with theory as a backup, while a further 11.8% stated that they used primarily a lecture approach but would like to try an investigative approach. The reasons given by teachers for not using an investigative approach included: time constraints; class size; lack of equipment and space; lack of flexibility in time-tabling; need greater resource budget; present emphasis on provincial examination; it really should be a separate course; level of student competency; the kids get bogged down; insufficient time to research myself- I need more ideas; quality of lab equipment.

Analysis of the Results of the Pilot Survey

1. Most schools (47.1 %) were on a semester system - teaching every day and therefore, in fact, the proportion of time spent on lab-work was significantly less than those students on a linear system, if they reported only one or less labs per week or cycle.

11 teachers were divided fairly evenly between enough time, 52.9%, and not enough time, 47.1%. Of teachers of Grade 12, 70.6% stated that there was not sufficient time for a lab based course.

- there was a significant difference between Grade 11 and 12, in terms of whether it was felt that the provincial curriculum limited the teachers scope for having students perform individual research. In Grade 11, 64.7% of teachers felt that it did, compared with 94.1% of teachers of Grade 12.

Using t-tests for paired samples it was found that:

- there was no significant difference between Grade 11 and 12 in terms of the number of quantitative labs performed in a year (Two tailed t-test). The mean for Grade 11 was 2.6 labs per year while for Grade 12, the mean was 2.4.
- there was a significant difference between Grade 11 and 12 in terms of the number of qualitative labs performed in a year. The mean for Grade 11 was 10.47 labs per year while in Grade 12 the mean was 4.58 labs per year (two-tailed $p=0.00$).

In response to whether students understood scientific method it was noted that for Grade 11, 76.5% of teachers responded 'no', yet in Grade 12 only

18.8 % responded 'no'. If there is no significant increase in the number of labs being conducted it is interesting to speculate on how a significant number of students gain an understanding of scientific method.

Another anomaly was that 64.7% of teachers responded that they rarely or never expect students to formulate an hypothesis and yet they claim that 81.3% of Grade 12 students understand scientific method. Again, it is interesting to speculate on the validity of the students understanding of this process. In addition, teachers claimed that students entering their Grade 12 class had good practical skills and yet 50% of these same teachers reported that they use less than one lab per week/cycle, and no teachers reported that students carry out individual lab-based research.

The Results of the Survey

Two hundred and forty surveys were mailed out to schools and 108 were returned, which represents a 45% return rate.

All except one were returned by mail, one survey return was faxed and none were returned by e-mail. A summary of the survey returns appears in Table 1.

Table 1
Questionnaire Distribution and Return by School Size.

School Size	No. distributed	% of distribution	No. Received	% Return by Size of school	% Received
Large (>800)	107	43.14	41	38.32	38
Medium (500-800)	68	27.42	36	52.94	33.3
Small <500	73	29.44	31	42.42	28.7
Totals	248	100	108		100

As the sample size was significantly greater for the survey than the pilot survey the validity of the survey should also increase significantly, assuming that the teachers returning surveys represent a typical cross section of schools in the province. The returned sample represented 108 schools, from 51 out of the 75 school districts in the province. No schools which were in the pilot survey were included unless a full survey was completed.

Each of the questions asked on the survey was examined along with the response frequencies from the teachers. Details of the types of response solicited can be seen on the survey document itself. (Appendix2)

Demographics

Q1. What is the size of your school?

Teachers from 41 (38%) large , 36 (33.3%)medium and 31 (28.7%) small schools responded to the survey. This compares favourably with the distribution of all schools in the province.

The ratio of the school sizes in the sample and the province is shown in

Table 2

It is noticeable that the percentage return from large schools is under-represented as a whole but is acceptable overall in terms of return, relative to medium and small schools.

Table 2

Distribution of Sizes of Schools in the Survey and Province

Size of School	Large	Medium	Small	Total	s.d.
Number in Survey	41	36	31	108	5
Number in Province	103	55	52	210	28.6
Sample ratio	1.32	1.16	1		
Provincial ratio	1.99	1.06	1		
Return %	39.80	65.50	63.30		

Q2. How would you describe the location of your school?

The location of the schools, described as urban, rural or remote showed that 54.2% were urban, 38.3% were rural and 7.5% were remote. This categorization was selected by the teachers on a Likert-type scale.

Q3. How many students take Biology 11, Biology 12?

The number of students taking Biology 11 ranged from 2 to 540 in the 108 schools returning surveys, with a mean of 109.4 students (s.d. = 113.36) and a modal value of 150. In Grade 12, the schools reported between 0 and 360 students with a mean of 68.61 (s.d.= 76.62) and a modal value of 50. The mode was deemed an important statistic here as it gives a measure of the situation in most schools.

Q4. How is your school year organized?

Ten (9.3%) of the schools were on a quarter system, 59 (55.1%) on a semester system, 33 (30.8%) on a linear system and 5 (4.7%) were on a system other than these. (Some of the schools in the province have adopted a modified Copernican system). It was noted that 85.2% of the schools responding to the survey were on either a linear or semester system.

Q5. Approximate number of hours of instruction per Biology course for Grade 11, Grade 12

Hours of instruction were solicited and in Grade 11, a range of 64 -194 hours per year was reported ⁴ with a mean of 105.88 hours (s.d.= 14.37) and a major mode of 100 hours, with 29.3% of schools reporting this value. In addition, there were two minor modes at 110 hours (20.2%) and at 120 hours (12.1%).

For Grade 12 students the range was 84 - 194 hours with a mean of 105.61 hours (s.d.= 20.63) and a major mode of 100 hours. In this case, there was also a minor mode at 110 hours (19.2%) and at 120 hours (14.1%).

The Teacher

While personal questions tend to be avoided on surveys of this type, it was felt that it was important to gather information on three facets of the individual teachers, as these might have an effect on their teaching style and pedagogy, and frequency of use of laboratory work in their teaching. These questions ask about number of years of teaching, specialist training and qualifications.

⁴ Nine teachers did not respond to this question

Q6. How many years have you been teaching?

The number of years experience for the teachers on the survey was thought to be possibly, an important factor in whether they would use more or less labs. This applied to both the novice teacher and the very experienced teacher.

On the survey, teaching experience ranged from 1 year to 35 years with a mean of 20.0 years (s.d.= 17.82). These data compare favourably with the data for the whole province which also showed a mean of 20.00 years (s.d.=11.95). The survey data showed fewer teachers in the 1 to 4 year group and significantly more in the 20+ category. (This may be because only one survey was sent to each school and it may have been answered by the senior teacher or Head of Department.)

The term Educator includes classroom teachers and administrative officers (principals, vice-principals and directors of instruction). Not all educators teach classes.⁵ The term teacher refers to those individuals who are actively teaching Biology 11 and 12 and returned completed surveys (Table 3).

⁵ Ministry of Education (1993/94) Statistical Supplement to the Annual Report. Province of British Columbia

Table 3**The Distribution of Teachers in the Province and on the Survey by Years of Experience.**

Years of experience	<1	1-4	5-9	10-19	20+	Total
Provincial Distribution	868	6872	6013	12,223	9,236	35,212
% of total	2.47	19.5	17.08	34.71	26.23	100
Survey Distribution	0	10	15	33	49	107
% of total	0	9.35	14.02	30.84	45.79	100

Mean years of experience for the Province = 20 years (s.d.= 11.95)

Mean years of Experience for teachers on Survey = 20 years (s.d.= 17.82)

Average age of teachers in the Province = 42.6 years

Q7. Was your specialist training in Biology?

In a number of schools, in particular in rural and remote areas, it is the practice to use non-specialist teachers to teach senior science courses.

Biology, as with Chemistry and Physics brings with it the requirement for not only fundamental knowledge but also a depth and breadth of knowledge.

One hundred and one (93.5%) teachers who responded to the survey had received specialist training in Biology while only 6 (5.6%) responded that

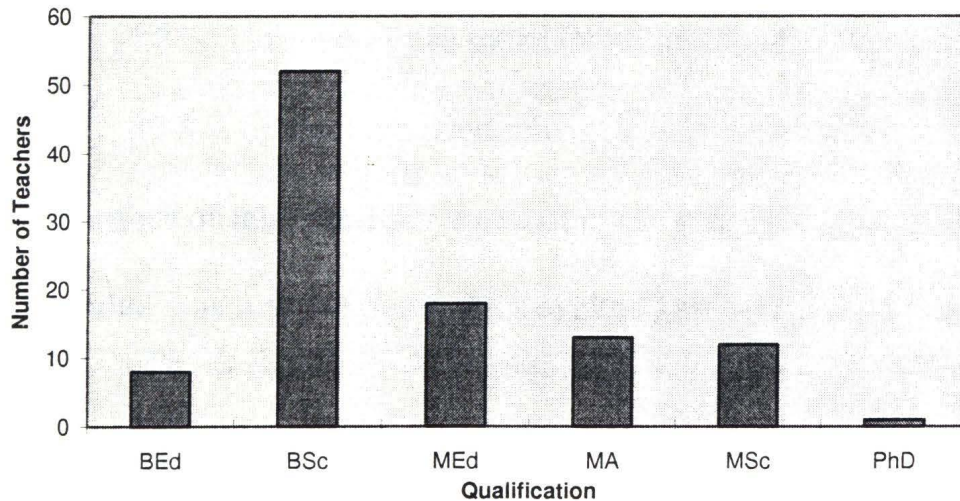
they had not.

Q8. Qualifications

Of the teachers who responded to the survey, 8 (7.5%) held a B. Ed, 52 (49.1%) held a B.Sc. with specialist training in Biology, 18 (17%) held an M.Ed. , 13 (12.3%) held an M. A. and 12 (11.3%) held an M Sc. One teacher (0.9%) held a Ph.D.

It is interesting to note that in this sample of Biology teachers, 41.6% held graduate degrees, 29.3% in Education and 12.3% in Biology (Figure 1).

Figure 1: The Distribution of Teachers on Survey by Qualification



Laboratory Work

Q9. On average, how frequently do you use labs?

One of the critical questions on the survey was the number of laboratory activities the students performed in Grades 11 and 12. In fact, this is a premise central to this study. Teachers were asked to give the number of laboratory activities performed in a week or cycle. A cycle was defined as the timetable rotation period. e.g. a six day cycle. Fifty teachers (48.1%) responded that they used, on average, less than one lab per week or cycle. Thirty four (32.7%) of teachers stated that they used one lab per week or cycle, while 15 (14.4%) reported using two labs per week or cycle. Five teachers, (4.8%) claimed to use more than two labs per week or cycle. In summary, 80.8% of teachers used one or less labs per week or cycle. The mean number of labs used per week or cycle was 1.76. (s.d.=0.88) but the modal value was one lab per week / cycle. (Table 4)

Table 4:

Frequency of Laboratory Work in Grades 11 and 12

Lab Frequency	<u>Number of Labs used per week/cycle</u>				<u>M</u>	<u>SD</u>
	<1	1	2	>2		
Teachers Response %	48	32.7	14.4	4.8	1.76	0.88

Q10. How many quantitative labs do you use in a year? (i.e. measurement rather than solely observation)

Quantitative exercises in laboratory sciences are an integral part of the process of scientific learning. The distinction between the number of quantitative laboratory exercises and the number of qualitative exercises was thought to be one important measure of the sophistication of the scientific learning undertaken by the students.

The results for the number of quantitative labs in Grade 11 showed a range of 0 to 20 with a mean of 4.21 labs per year (s.d.=3.77) and a modal value of 2 (23.1%). Of the teachers of Grade 11 students, 81.7% used ≤ 5 quantitative labs per year. In Grade 12 the range was 0 to 10 with a mean of 2.69 labs per year (s.d.=2.06) and a modal value of 2 (25.8%) quantitative labs per year.⁶ Of the teachers of Grade 12 students, 93.5% used ≤ 5 quantitative labs per year. Fifteen teachers did not respond to this question.

Q11. How many qualitative labs do you use in a year? (observation rather than measurement)

For many students the majority of their laboratory experiences in biology involve qualitative exercises. These are usually prescriptive in nature and

⁶ Fifteen teachers did not respond to this question. Valid percentages are stated.

while they are part of the scientific experience of students, it would appear that students in biology equate labs with this type of situation.

For qualitative laboratory exercises for Grade 11, a mean of 14.66 labs per year was reported (s.d.=8.87) with a range of 0 - 40 labs per year. The modal value was 10 labs per year (18.8%). A total of 46.9% of grade 11 teachers used ≤ 10 qualitative labs per year. For Grade 12 students, the mean was 5.84 qualitative labs per year (s.d.=5.06) with a range of 1 - 30 labs per year. The modal value was 4 qualitative labs per year⁷ (15.2%). A total of 89.0% of Grade 12 teachers used ≤ 10 qualitative labs per year (Table 5). Twelve teachers did not respond to this question for Grade 11 and 16 for Grade 12.

Table 5

Frequency of Quantitative and Qualitative Laboratory Work

	Grade	Mean number of labs per year	s.d.	<5 labs per year (%)	<10 labs per year (%)
Quantitative Labs	11	4.21	3.77	81.7	93.5
	12	2.69	2.06	93.5	100
Qualitative Labs	11	14.66	8.87	10.4	46.9
	12	5.84	5.06	59.8	89.1

⁷ Sixteen teachers did not respond to this question.

Q12. Are the labs that you use usually confirmatory rather than investigative?

Investigation and exploration by the student are the key to the constructivist philosophy of scientific education. It is therefore worthwhile to ask this question, in order to determine what practices teachers are using in their approach to laboratory work and subsequently, why they maintain these practices in the light of their own philosophies as expressed in answers to question 30

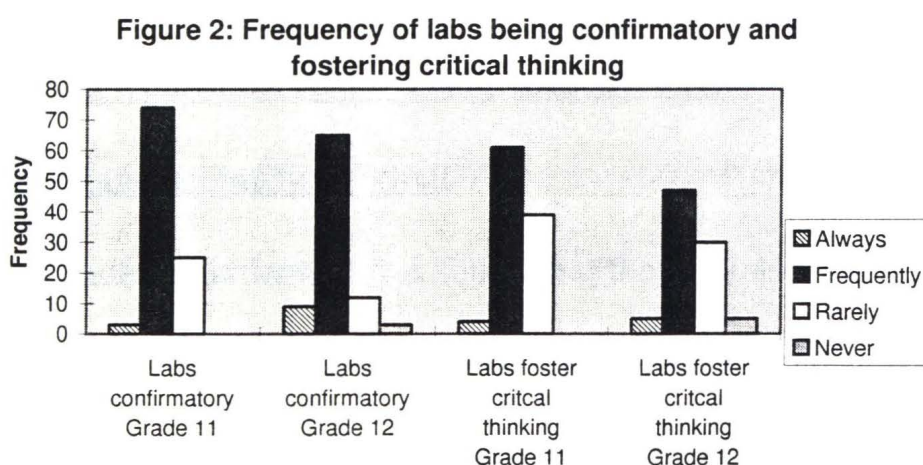
In response to the question of whether the labs conducted were usually confirmatory rather than investigative for Grade 11 students, 3 (2.9%) teachers answered 'always', 74 (72.5%) answered 'frequently' and 25 (24.5%) answered 'rarely'. Of teachers of Grade 11 students., 75.5% answered that their labs are confirmatory rather than investigative. For Grade 12 students, 9 (10.1%) teachers responded 'always', 65 (73%) 'frequently', 12 (13.5%) 'rarely' and 3 (3.4%) never.⁸ Of teachers of Grade 12 students, 83.1% reported that their labs are 'always or frequently' confirmatory rather than investigative (Figure 2). It is interesting to note that the number of labs which are confirmatory increases between Grade 11 and Grade 12, when one would expect that as the level of sophistication of

⁸ Nineteen teachers did not respond to this question. Valid percentages are stated.

the students' knowledge increases, they would receive greater responsibility for their approach to the investigations.

Q13. Do you feel that overall, the labs which you assign foster critical thinking in the students?

In all grades, across all subjects, there is a recognition of the importance of students' ability to successfully think through the challenges posed by the curriculum. A student is attempting to think critically when he or she intends to reach a reasoned judgment about what it would be reasonable or sensible to believe or do in a given situation. Thinking critically is not a matter of reaching a pre-determined correct answer, but rather of thinking that embodies, to varying degrees, the attributes of good thinking.



When asked whether the labs they assigned fostered critical thinking in their students, for Grade 11, 4 (3.8%) teachers responded 'always', 61 (58.7%)

‘frequently’ and 39 (37.5%) thought ‘rarely’.⁹ No teachers reported that their labs never fostered critical thinking in their students. In Grade 12, 5 (5.7%) reported ‘always, 47 (54.0%) reported ‘frequently’, 30 (34.5%) reported ‘rarely and 5 (5.7%) reported that their labs fostered critical thinking in their students (Figure 2). It is interesting to note that 21 teachers did not respond to this question.

Q14. Do you require students to formulate hypotheses before beginning a lab?

In response to whether their students are required to formulate hypotheses before beginning a lab, 13 (12.4%) responded ‘always’, 29 (27.6%) responded ‘frequently’, 50 (47.6%) ‘rarely’ and 13 (12.4%) responded ‘never’. In summary, 60.0% responded ‘rarely or never’.

Q15. Do you think that overall, students entering your class understand scientific method?

For Grade 11 students it was found that the response was 5 (4.7%) ‘always, 55 (50.9%) ‘frequently, 42 (38.9%) ‘rarely and 4 (3.7%) ‘never’. i.e. 43% responded, ‘rarely or never’. For Grade 12 students, the response frequency was, 12 (14.5%) ‘always’, 62 (74.7%) ‘frequently’, 9 (10.8%) ‘rarely’.

⁹ Six teachers did not respond to this question. Valid percentages are stated.

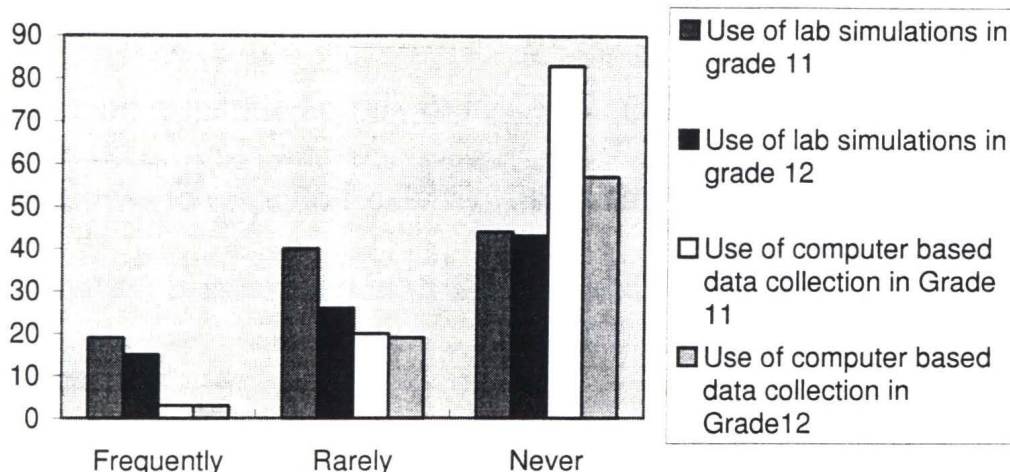
Q16. Do you feel that the labs that you use support the intended learning outcomes in the course outline?

When asked whether the labs used supported the Intended Learning Outcomes as designated in the syllabus, teachers of Grade 11 indicated, 'always' in 56 cases (51.9%), 'frequently' in 48 cases (45.7%) and 'rarely' in one case (1%) . No teacher reported that the labs never supported the ILO's, and 96.3% of teachers reported 'always or frequently'. Of Grade 12 teachers, 45 (54.9%) claimed that the labs they used always supported the ILO's, 34 (31.5%) reported 'frequently', 2 (2.4%) 'rarely' and one (1.2%) 'never'. Again, it is interesting to note that for this question 26 teachers did not respond.

Q17. Do you use lab simulations e.g. video, CD or computer?

Teachers reported that for Grade 11 students, 19 (18.4%) used this technology frequently, 37 (38.8%) rarely and 44 (42.7%) never. In total, 81.5% of teachers of Grade 11 reported using this type of technology rarely or never. For teachers of Grade 12, 15 (17.9%) reported using lab simulations with this type of technology, frequently, 40 (38.8%) reported rarely using this technology, and 44 (42.7%) reported never using this type of technology for lab simulations. i.e. 81.5% of teachers responding used this type of technology rarely or never. (Figure 3)

Figure 3: Use of Lab Simulations and Computer-based Data Collection in Grades 11 and 12



Q18. Do you use computer based data collection e.g. measurement of temperature/pH over time.?

When asked about the use of computers for data collection for Grade 11 students, one (2.8%) teacher responded 'frequently', 20 (18.9%) of teachers responded, 'rarely', and 83 (78.3%) 'never' i.e. 97.2% reported that they rarely or never use computer based data collection. For teachers of Grade 12, three (3.8%) teachers reported using computers frequently, 19 (23.8%) reported 'rarely' and 57 (71.3%) reported never using computer based data collection in Grade 12 . i.e. 95.1% of teachers of Grade 12 who responded to the survey rarely or never use computer based data collection. Again, it is interesting to note that 28 teachers did not respond to this question on the survey.

Q19. If you answered rarely or never to questions 17 and 18, the primary reason is:

If teachers responded rarely or never to questions 17 /18 they were given the opportunity to respond freely by listing their primary reasons. This information is summarized in Table 6, and the reasons given are ranked by frequency.

Q20. Do you have sufficient time to teach a lab-based course (i.e. inquiry based or constructivist approach) ?

Time is always a critical factor in teaching a senior science course in which the material to be taught is dictated by a syllabus. This question arose as a result of the constant 'crie de coeur' of many teachers, that they do not have enough time to teach the course, primarily because of the volume of material to be covered. This appears to be the case here, in particular for the Grade 12 course.

For the Grade 11 course, 47 (45.2%) teachers responded that they did not have enough time to teach a lab-based or inquiry-based course. Fifty-seven teachers (54.8%) responded that they had enough time to teach a course of this type. For the Grade 12 course the pattern of responses was dramatically reversed. Ninety (88.2%) of the teachers indicated that they did not

have sufficient time to teach an inquiry or lab-based course. Only 12 (11.8%) teachers thought that they had sufficient time.

Table 6

Reasons given by teachers for rarely or never using lab simulations or computer based data collection.

Response	Frequency
no equipment	82
no experience	37
no interest	11
no time	8
would rather student experience measurement	3
no resources	2
no software	2
too expensive (lack of funding)	2
does not fit with Bio 12 labs	1
does not foster critical thinking	1
no good videos for Bio	1
hate computers	1
not appropriate	1

Q21. Are your labs equipped well enough for students to pursue a lab-based course?

One of the limiting factors commonly stated for not teaching lab-based courses are the availability of equipment and the limitations of the course outline.

When asked whether their laboratories were well enough equipped to pursue a lab-based course, 35 (33%) teachers responded that for Grade 11 the labs were not well enough equipped while 71 (67%) responded that they were. For the Grade 12 course, 47 (46.5%) teachers indicated that their labs were not well enough equipped while 54 (53.5%) claimed that they were.

Q22. Do you feel that the provincial course outline limits the scope for individual student research?

The content of courses taught in British Columbia is dictated by the Provincial government (Biology 11/12 Curriculum Guide, 1990). In terms of the course outline being a significant factor in limiting the scope for individual students research, 55 teachers (54.5%) agreed that it did while 46 (45.5%) thought that it did not. The teachers of Grade 12 are subjected not only to a specific course outline but also, the students write an external examination at the end of the course. This examination represents 40% of a student's final mark. In addition, it would seem that teachers are, to some

extent, judged by the performance of their students on the provincial examination. It is therefore not surprising, that with these constraints placed upon them, 93 (93%) of the teachers of Grade 12 students stated that they felt that the course outline limited the scope for teaching a lab-based course. Only 7(7.0%) stated that it did not.

Q23. Do you feel that the provincial examination limits your opportunities to provide a good, investigative lab-based course?

In terms of the provincial examination limiting the opportunities for teaching a lab-based course, 95 (93.1%) of the teachers agreed that it did, while only 6 (5.9%) felt that it did not.

Teachers have stated frequently that the course content has too great a volume to cover in the time allowed and therefore they find themselves hard pressed to even complete the course and cannot afford the time for labs if their students are to be successful on the provincial examination. As stated previously, part of the evaluation and perception by the school administration and parents of the teacher's effectiveness, is based on the students' results on the provincial examination. If the students do well, then the teacher is regarded as a 'good' teacher, regardless of any other factors in the students' education.

Q24. Do your students carry out any individual, lab-based research?

Why / Why not?

Individual lab-based research, as distinct from library-based or text-based research is an important element in developing the 'skills of science'.

For Grade 11 students, 14 (13.2%) of the teachers stated that their students frequently carried out individual, lab-based research; 48 (45.3%) stated rarely and 44 (41.5%) of the teachers indicated never. In summary, 86.8% declared that their Grade 11 students rarely or never carry out individual lab-based research (See Table 7).

Table 7

The reasons given by teachers for and against students carrying out individual lab work

Response	Frequency
no equipment	82
no experience	37
no resources	2
no time	8
no interest	11
does not fit with Bio 12 labs	1
no software	2
too expensive (lack of funding)	2
does not foster critical thinking	1
no good videos for Biology 11	1
hate computers	1
not appropriate	1
would rather students experienced measurement	3
no good videos for Bio 11	1

For Grade 12 classes only one (1%) teacher indicated using individual student research frequently; 27(27.6%) reported rarely and 69 (70.4%) never. A total of 98% of the teachers rarely or never used this approach with Grade 12 students.

Q25. If the answer to Question 24 is yes, approximately how much time are students allowed for this activity?

Only twenty-one teachers responded to this question which is not a surprise considering that 86.8% teachers of Grade 11 and 98% of teachers of Grade 12 answered that their students did no individual lab-based research. The answers for the time allowed for individual lab-based research varied from one hour to seven weeks.

Qu26. Do you think that conducting an in-depth, individual research project would be an exercise valuable to students' scientific development? Why /Why not?

The responses to this open ended question are summarized in Table 8.

Table 8**The reasons given by teachers for and against students conducting individual research projects**

<u>Response</u>	<u>Frequency</u>
<u>Why Not</u>	
no time	56
curriculum geared towards government exam	22
no equipment	8
no space	3
lack of student self-motivation	3
low interest	3
no experience	2
still becoming familiar with the course	2
too difficult to monitor and manage	2
low skills	1
lack of student background	1
low reading level	1
<u>Why</u>	
shows them what real research is like	1

Q27. Assuming that you had a well-equipped lab and given sufficient time, would you teach an inquiry based course rather than a traditional course?

In this question, the attitude of the teachers towards an inquiry-based and traditional course was solicited.

Eighty-six (86.9%) of the teachers indicated that they would teach an inquiry-based course in preference to a traditional course to their Grade 11

classes whereas 13 (13.1%) stated that they would not. For Grade 12 classes, 68 (73.1%) teachers suggested that they would prefer an inquiry-based course while 25 (26.9%) indicated that they would not. There were 15 missing cases for this question

Q28. Do you give a lab exam?

For Grade 11 students, 49 (46.7%) teachers did not give a lab exam whereas 56 (53.3%) claimed that they did. This is curious since 48% of the teachers also reported for Grade 11 that they give less than one lab per week or cycle, 80.8% give ≤ 1 lab per week or cycle and 41.7% use less than one lab a year.

For Grade 12 classes, 81(81%) of the teachers answered 'no' to this question with 19 (19%) responding 'yes'.

Q29. Do you incorporate lab-based questions into your class tests?

Forty-six teachers (45.1%) regularly incorporated lab-based questions into their tests while 22 (20.4%) reported rarely using this type of test item and one (0.9%) reported never using lab-based questions on tests. At the other end of the scale, 15 (14.7%) indicated that they frequently used these items and 18 (17.6%) stated that they always used lab-based questions on tests.

For Grade 12 classes, 27(27.6%) teachers revealed that they used lab-based questions regularly on tests. Forty-six (46.9%) teachers reported rarely or

never using this type of question on tests and 12 (12.2%) used them frequently. Thirteen (13.3%) teachers indicated that they always used lab-based questions on Grade 12 tests.

Six teachers did not respond to this question for Grade 11 and ten for Grade 12

Q30. Would you describe yourself as a teacher who: (circle one answer below)

- a) uses primarily a lecture approach with some lab work
- b) uses primarily an investigative approach with some lab work
- c) uses primarily a lecture approach and would not use an investigative approach
- d) uses primarily a lecture approach but would like to try an investigative approach.

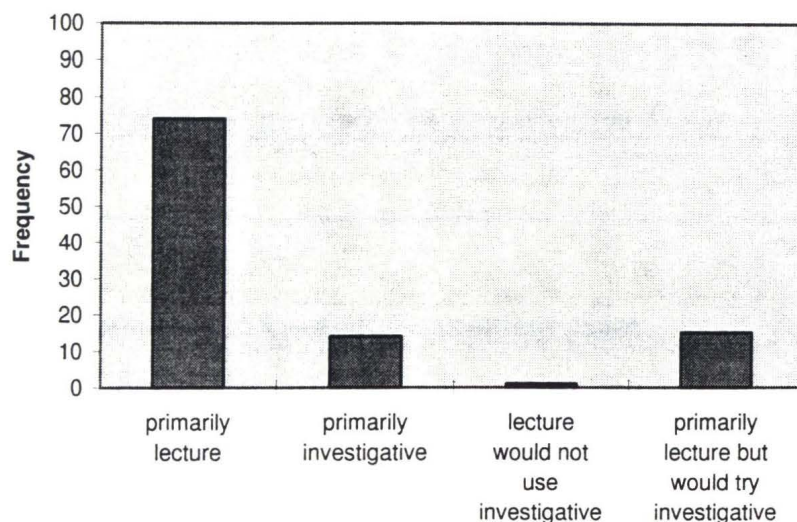
In response to this question 74 (71.2%) of the teachers surveyed selected option a) i.e. they use primarily a lecture approach to their teaching.

Fourteen (13.5%) chose option b) and 15 (14.4%) use a lecture approach but would like to try an investigative approach. One teacher (1%) chose option c).

Four teachers did not respond to this question.

A distribution of these approaches to senior Biology is shown in Figure 4.

Figure 4: The Distribution of Teachers Surveyed by Teaching Pedagogy Practiced



Q31. List briefly, the main factors that would cause you not to use an investigative approach.

The responses in this open-ended question were collected from the survey sheets and then ranked by frequency. All teachers answered this question. (See Table 9).

Q32. Would you like to receive a summary of the results?

Sixty three (72.3%) of the teachers wanted to receive a summary of the results of the survey. Fourteen teachers did not respond to this question.

Q33. Would you be willing to be interviewed in a follow up study?

Fifty-five (61.1%) of participants were willing to be interviewed in a follow up survey. Eighteen teachers did not respond to this question and thirty-five

(38.9%) responded that they would not be willing to be interviewed. Eighteen teachers did not respond to this question.

Table 9

Reasons Given for not Using an Investigative Approach to Biology Teaching

<u>Reason</u>	<u>Frequency</u>
curriculum geared towards government exam	38
prep in limited time period	
no time to organize	35
no materials/facilities	22
limited funding	13
no experience (teacher)	6
students' background deficiencies	5
student attitude	5
needed outcome	3
no lab technicians	3
other effective ways to teach	3
understanding concepts and grasping basics	3
students need to be trained in this before Grade 11	2
no good lab guide	2
student disrespect to specimens	1

Q34. Would you be willing to allow your students to participate in a survey about attitudes to Biology and lab work?

In terms of allowing their students to be interviewed, 63 (68.5%) teachers responded positively and 29 (31.5%) negatively. Sixteen teachers did not respond to this question.

Statistical Treatments and Supplemental Analysis

The results of the cross tabulations listed in Chapter 3 are summarized, for those relationships that are significant. Contingency tables, cross tabulations, and statistical data for relationships which are not significant are reported in Appendix 2. In order to explore the proposed relationships the hypotheses were subjected to a Chi-square analysis and tested with the level of significance set at 0.05. Where the contingency table was greater than 2 by 3 an ANOVA was also run.

Table 10**Cross tabulation of size of school by frequency of laboratory work**

			<u>Frequency of labs</u>				
			Count	<1/week	1/week	2/week	>2/week
				1.00	2.00	3.00	4.00
							RowTotal
Large	1.00	Observed		20	11	5	4
		Expected		19.2	13.1	5.8	1.9
Medium	2.00	Observed		9	17	7	1
		Expected		16.3	11.1	4.9	1.6
Small	3.00	Observed		21	6	3	0
		Expected		14.4	9.8	4.3	1.4
Column	Total			50	34	15	5
	%			48.10	32.7	14.40	4.80
			$\chi^2 = 16.592$	DF = 6	$p = 0.0109^*$		

* $p < .05$ **Size of school.**

This was thought to be of interest in that larger schools often have better facilities, a larger budget and a larger number of teachers in the department- a number of whom would have greater experience. These factors may possibly have an influence on the frequency and type of laboratory activities used.

The following relationships with size of school were examined:

Frequency of laboratory work

H_0 the frequency of laboratory work is independent of the size of school

H_A the frequency of lab work is not independent of the size of school

The Chi-square on these data was 16.592 ($p = 0.011$) which is significant at the 0.05 confidence level

Therefore H_0 was rejected

The difference between observed and expected values in large schools is very small whereas it increases significantly in medium and small schools.

None of the following relationships with size of school were found to be statistically significant:

- i) number of quantitative labs in Grade 11
- ii) number of quantitative labs in Grade 12
- iii) number of qualitative labs in Grade 11
- iv) number of qualitative labs in Grade 12
- v) laboratories are well enough equipped for lab-based course in
Grade 11

vi) laboratories are well enough equipped for a lab-based course in
Grade 12

vii) teachers feel that the provincial course outline for Grade 11 limits
lab work

viii) teachers feel that the provincial course outline for Grade 12 limits
lab work

ix) teachers feel that provincial examination limits lab work

x) a lab exam is given in Grade 11

xi) a lab exam is given in Grade 12

xii) the teaching style of teachers

Location of the school

The location of the school, described in the survey by the teachers as urban, rural or remote, was thought to be a possible influence of the frequency and type of laboratory activities.

The following relationships were examined but none was found to be statistically significant:

- i) frequency of laboratory work
- ii) frequency of quantitative labs in Grade 11
- iii) frequency of quantitative labs in Grade 12
- iv) frequency of qualitative labs in Grade 11

- v) frequency of qualitative labs in Grade 12
- vi) labs well enough equipped for a lab-based course in Grade 11
- vii) labs well enough equipped for a lab-based course in Grade 12
- viii) frequency of labs is limited by Grade 11 provincial course outline
- ix) frequency of labs is limited by Grade 12 provincial course outline
- x) frequency of labs is limited by provincial examination
- xi) whether a lab exam is given in Grade 11
- xii) whether a lab exam is given in Grade 12
- xiii) the effect on teaching style

Organization of the School Year

The organization of the school year was thought to have a possible influence on a number of the items on the questionnaire.

The number of labs performed in a year (Table 11).

H_0 - there is no relationship between the organization of the school year and the frequency of laboratory work.

H_A - there is a relationship between these two factors.

The Chi-square on these data was 18.876 ($p=0.026$) which is significant at the 0.05 confidence level.

Therefore H_0 was rejected. The difference between observed and expected values in semestered schools showed that the number observed in schools

with < 1 lab per week or cycle was much lower than the expected values. Conversely, the number observed in linear schools was higher than the expected values.

Table 11

Cross tabulation of school year organization by frequency of laboratory work.

			<u>Frequency of Labs</u>					
			Count	<1/week	1/week	2/week	>2/week	Row
				1.00	2.00	3.00	4.00	Total
Quarter	1.00	Observed	5	3	0	1		9
		Expected	4.4	3	1.2	0.4		
Semester	2.00	Observed	18	25	10	3		56
		Expected	27.2	18.5	7.6	2.7		
Linear	3.00	Observed	25	4	3	1		33
		Expected	16	10.9	4.5	1.6		
Other	4.00	Observed	2	2	1	0		5
		Expected	2.4	1.7	0.7	0.2		
Column	Total		50	34	14	5		103
	%		48.50	33.00	13.	4.90		100.00
$\chi^2 = 18.876$			<u>DF</u> = 9	<u>p</u> = 0.026*				

* p < .05

None of the following relationships were found to be statistically significant:

- i) the number of quantitative labs in Grade 11
- ii) the number of quantitative labs in Grade 12
- iii) the number of qualitative labs in Grade 11
- iv) the number of qualitative labs in Grade 12
- v) sufficient time for a lab-based course in Grade 11
- vi) sufficient time for a lab-based course in Grade 12
- vii) the provincial course outline in Grade 11 limits the scope for individual student research
- viii) the provincial course outline limits the scope for individual student research in Grade 12
- ix) the provincial examination limits the opportunities to provide a lab-based course in Grade 12
- x) a lab examination is given in Grade 11
- xi) a lab examination is given in Grade 12
- xii) teaching style

A number of relationships were explored which looked at possible relationships within Grade 11, within Grade 12 and between Grade 11 and Grade 12

(i) The frequency with which Grade 11 and Grade 12 students perform research projects (Table 12).

- H_0 there is no relationship between Grades 11 and 12 in terms of the frequency with which they perform research projects.
- H_A such a relationship does exist

The Chi-square for these data was 32.190 ($p=0.001$) which is significant at the 0.05 confidence level.

Therefore H_0 was rejected

The difference between observed and expected values in rarely or never performing research projects in Grade 12 was considerable while the descriptive data indicated that 87% of Grade 11 students and 98% of Grade 12 students rarely or never perform individual research projects.

Table 12**Cross tabulation of Frequency of Research Projects in Grade 11 by Frequency in Grade 12**

				<u>Frequency of Research Projects in</u>			
				<u>Grade 12</u>			
				Frequently	Rarely	Never	Row
Count				1.00	2.00	3.00	Total
<u>Frequency of</u> <u>Research Projects</u> <u>in Grade 11</u>	Frequently	1.00	Observed	1	5	8	14
			Expected	0.1	3.9	9.9	
	Rarely	2.00	Observed	0	21	19	40
			Expected	0.4	11.3	28.3	
	Never	3.00	Observed	0	1	41	42
			Expected	0.4	11.8	29.8	
Column		Total		1	27	68	96
		%		1.00	28.10	70.80	100.00
$\chi^2 = 32.190$				<u>DF</u> = 4		<u>p</u> = 0.0000*	

*p < .05

(ii) labs are well enough equipped for Grade 11 and 12 (Table 13).

- H_0 there is no relationship between whether the laboratories are well enough equipped for Grade 11 and for Grade 12
- H_A there is such a relationship

Table 13

Cross tabulation of Laboratories are Well enough Equipped in Grade 11 by Laboratories are Well enough Equipped in Grade 12

<u>Labs well enough equipped in Gr 12</u>					
			No	Yes	Row Total
			Count	0	1
<u>Labs well</u>	No	0	Observed	33	1
			Expected	16	18
<u>enough equipped</u>					
<u>in Gr 11</u>	Yes	1	Observed	14	52
			Expected	31	35
	Column	Total		47	53
		%		47.00	53
					100
					100
$\chi^2 = 51.82$			D.F. = 1		p = 0.0000*

* $p < .05$

The Chi-square for these data was 51.82 ($p=0.001$) which is significant at the 0.05 confidence level

Therefore H_0 was rejected

The difference between observed and expected values indicated that most teachers thought that their laboratories were well enough equipped for Grade 11 but not for Grade 12

(iii) sufficient time for the course in Grade 11 and 12 (Table 14).

- H_0 there is no relationship between Grade 11 and Grade 12 in terms of whether teachers have sufficient time to teach a lab-based course.
- H_A there is such a relationship

The Chi-square for these data was 6.848 ($p=0.009$) which is significant at the 0.05 confidence level.

Therefore reject H_0

It was noted in the descriptive data that teachers reported that there was sufficient time in Grade 11 but not in Grade 12

Table 14**Cross tabulation of sufficient time in Grade 11 by sufficient time in Grade 12**

<u>Sufficient time for the course in gr 12</u>							
				No	Yes	Row	
				Count	0	1	Total
<u>Sufficient time</u> <u>for the</u> <u>course in gr 11</u>	No	1	Observed	42	1	43	
			Expected	37.8	5.2		
	Yes	2	Observed	45	11	56	
			Expected	49.2	6.8		
	Column	Total		87	12	99	
		%		87.90	12	100	

$\chi^2 = 6.848$

D F = 1

p = 0.0089*

* $p < .05$

(iv) relationship between Grade 11 and Grade 12 in terms of whether labs are confirmatory rather than investigative (Table 15).

- H_0 there is no relationship between Grade 11 and Grade 12 in terms of whether labs are usually confirmatory rather than investigative
- H_A there is such a relationship between Grade 11 and Grade 12

The Chi-square for these data was 25.423 ($p < 0.001$) which is significant at the 0.05 confidence level.

Therefore reject H_0 .

Teachers used labs which were confirmatory rather than investigative with similar frequency in Grade 11 and 12

Table 15

Cross tabulation of Labs are Confirmatory in Grade 11 by Labs are Confirmatory in Grade 12

<u>Labs are confirmatory in Grade 12</u>								
				Always	Frequently	Rarely	Never	
Count				1	2	3	4	Row Total
<u>Labs are</u> <u>confirmatory</u> <u>in</u> <u>Grade 11</u>	Always	1	Observed	1	1	0	0	2
			Expected	0.2	1.5	0.3		
	Frequently	2	Observed	7	54	3	1	65
			Expected	6.7	47.8	8.2	2.2	
	Rarely	3	Observed	1	9	8	2	20
			Expected	2.1	14.7	2.5	0.7	
	Never	4	Observed	0	0	0	0	0
			Expected	0	0	0	0	
Column Total				9	64	11	3	87
%				10.30	73.	12.60	3.40	100
$\chi^2 = 25.423$				<u>D F</u> = 6		p = 0.00029*		

*p < .05

v) understanding of scientific method in Grade 11 and 12 (Table 16)

- H_0 there is no relationship between Grade 11 and Grade 12 students in their understanding of scientific method when they enter the course
- H_A there is such a relationship

Table 16

Cross tabulation of Understanding of Scientific Method in Grade 11 by Understanding in Grade 12

<u>Understanding Scientific method in Grade 12</u>								
				Always	Frequently	Rarely	Row Totals	
				Count	1.00	2.00	3.00	5
<u>Understanding</u> <u>Scientific method</u> <u>in Grade 11</u>	Always	1.00	Observed	5	0	0		
			Expected	0.7	3.7	0.6	41	
	Frequently	2.00	Observed	5	36	0		
			Expected	6.1	30.4	4.6		
	Rarely	3.00	Observed	2	22	8	32	
			Expected	4.7	23.7	3.6		
	Never		Observed	0	2	1	3	
			Expected	0.4	2.2	0.3		
Column	Totals		12	60	9	81		
	%		14.80	74.10	11.10	100.00		
$\chi^2 = 43.601$			<u>D F</u> = 6		p=0.0000*			

*p < .05

The Chi-square on these data was 43.602 ($p < 0.001$) which is significant at the 0.05 confidence level.

Therefore reject H_0 .

From the descriptive data 51% of Grade 11 students understood scientific method on entering the course whereas 74% of Grade 12 students did so

(vi) labs in Grade 11 are confirmatory and foster critical thinking

(see Table 17).

- H_0 there no relationship between the frequency of confirmatory labs in Grade 11 and whether teachers believe that the labs foster critical thinking.
- H_A a relationship between these two statistics exists

The Chi-square on these data was 10.833 ($p < 0.0285$) which is significant at the 0.05 confidence level

Therefore reject H_0

Table 17**Cross tabulation of Labs which are Confirmatory in Grade 11 also Foster Critical Thinking in Grade****11**

			<u>Labs foster critical thinking in Grade 11</u>				
				Always	Frequently	Rarely	
			Count	1.00	2.00	3.00	RowTotal
<u>Labs are</u> <u>Confirmatory</u> <u>in Grade 11</u>	Always	1.00	Observed	0	0	3	3
			Expected	0.1	1.8	1.1	
	Frequently	2.00	Observed	2	41	31	74
			Expected	2.9	43.2	27.8	
	Rarely	3.00	Observed	2	18	4	24
			Expected	1	14	9	
	Column	Total		4	59	38	101
		%		4.00	58.40	37.60	100.00
$\chi^2 = 10.832$			<u>D F</u> = 4		p = 0.0285*		

*p < .05

Therefore reject H_0 .

Teachers who gave their students in Grade 11, labs which were primarily confirmatory, also thought them to foster critical thinking.

From the descriptive data, 75.5% of the teachers thought that the labs they assigned in Grade 11 were confirmatory rather than investigative while

62.5% of the same teachers also claimed that their labs fostered critical thinking in their Grade 11 students.

The following relationships were not statistically significant:

- i) laboratories are well enough equipped for Grade 11 and the lab exercises are confirmatory in Grade 11.
- ii) laboratories are well enough equipped in Grade 12 and lab exercises are confirmatory.
- iii) qualification of teachers and teaching style
- iv) the scope for individual lab work in Grade 11 and Grade 12 is limited by the provincial course outline
- v) the labs in Grade 12 are confirmatory and foster critical thinking
- vi) the use of lab simulations in Grade 11 and the reasons for not using them
- vii) the use of lab simulations in Grade 12 and the reasons for not using them
- viii) the use of computer-based data collection in Grade 11 and the reasons for not using this technique
- ix) the use of computer-based data collection and the reasons for not using this technique in Grade 12

The correlations between years of teaching and the following were explored:

Frequency of qualitative labs in Grade 12

The correlation coefficient was 0.2176 ($p=0.037$) which is positive and significant at the 0.05 significance level; two tailed significance)

This positive value indicates that as the years of experience increases then the frequency of qualitative labs in Grade 12 increases. The relationship is not very strong.

The following correlations with years of teaching experience were found not to be statistically significant:

- i) frequency of labs
- ii) frequency of quantitative labs in Grade 11
- iii) frequency of quantitative labs in Grade 12
- iv) frequency of qualitative labs in Grade 11
- v) sufficient time to teach a lab based course in Grade 11
- vi) sufficient time to teach a lab based course in Grade 12

- vii) limitations on lab work of the course outline in Grade 11
- viii) limitations of the course outline on lab work in Grade 12
- ix) limitations of the provincial examination on lab work
- x) frequency of use of computer-based data collection in Grade 11
- xi) frequency of use of computer-based data collection in Grade 12
- xii) choice of inquiry based course in Grade 11 rather than traditional course
- xiii) choice of an inquiry based course in Grade 12 rather than a traditional course
- xiv) style of teaching

The correlation between the number of quantitative labs in Grade 11 and Grade 12 was investigated.

The correlation coefficient was 0.4254 which is positive and significant ($p = 0.000$) at the 0.05 significance level; two tailed significance.

Grade 11 and 12 teachers reported using very few quantitative labs in a year. The range for Grade 11 was between 0 and 20 with a modal value of two labs per year and a mean of 4.2; the range for Grade 12 was 0 to 10

quantitative labs per year with distinct mode at two labs per year and a mean of 2.7.

The correlation between the number of qualitative labs in Grade 11 and Grade 12 was investigated.

The correlation coefficient was 0.4021 which is positive and significant ($p=0.000$) at the 0.05 significance level; two tailed significance.

More qualitative labs than quantitative labs were used in a year in both Grades 11 and 12 , but again fewer labs were used in Grade 12 than in Grade 11. The range for Grade 11 was 0 to 40 and a mean of 14.7 labs per year and a mode of 10 labs per year (16%); for Grade 12 the range was 0 to 30 with a mean of 5.8 labs per year and a mode of 4 labs per year. From the descriptive data 10.4% of teachers reported using ≤ 5 labs per year for Grade 11 compared with 59.8% for Grade 12.

Provincial and Scholarship Examination Analysis

The Provincial Examination

The provincial examination papers were examined to establish the number of lab/ data analysis questions in the multiple choice and the written section. The results for January, 1990 to January, 1995 are summarized in Table 18. The Ministry of Education report TRAX 1279 lists the difficulty factor ¹⁰ for each of the multiple choice questions on the Provincial examination paper. Each of the scores for the lab and non-lab questions was noted and the mean scores for each of these types of questions was calculated for each examination paper (Table 19).

¹⁰ Difficulty: the proportion of examinees answering the item correctly

Table 18

The Number of Lab/Data Analysis Questions on Provincial Examinations
by Year

Year	Month	Multiple Choice Section	Written Section
1990	January	4	0
	June	5	1
1991	January	3	1
	June	3	0
1992	January	7	0
	June	4	0
1993	January	3	0
	June	2	1
1994	January	6	1
	June	2	0
1995	January	5	1
	June	1	0

Mean = 3.75

Mean = 0.5

Table 19**The Provincial Examination: Mean Difficulty Scores on the Multiple Choice Section by Year**

<u>Date</u>	<u>Mean Difficulty Scores</u>	<u>Mean Difficulty Scores</u>
	<u>for Lab-based Questions</u>	<u>for Non Lab-based Questions</u>
Jan/90	0.609	0.611
Jun/90	0.41	0.59
Jan/91	0.604	0.634
Jun/91	0.709	0.672
Jan/92	0.574	0.65
Jun/92	0.483	0.636
Jan/93	0.468	0.682
Jun/93	0.723	0.654
Jan/94	0.607	0.696
Jun/94	0.793	0.659

Each Provincial examination data set was subjected to a two-tailed t-test in order to establish whether there was a significant difference in mean score between lab and non lab questions.

In each case:

- H_0 - there is no difference between the mean scores for lab and for non lab questions
- H_A - there is a significant difference in mean scores

As there are 52 multiple choice questions on every Provincial Examination and two data sets, then the degrees of freedom is constant at 50 $[(n_1 + n_2) - 2]$ and therefore the value of $t_{critical}$ remains constant also at 2.009 at a significance level of 0.05.

In none of the cases was $t_{obtained} > t_{critical}$ and therefore each time, H_0 was not rejected. i.e. there is no significant difference between the mean difficulty scores on lab questions and non lab questions.

The results of the t-tests on multiple choice difficulty scores for each examination are shown in Table 20.

The written section of the provincial examination was examined and the mean scores for each paper for lab and non-lab questions were calculated.

The number of lab questions in this case was small, although proportionally represented a greater part of the whole paper. In some examination years no lab questions or data-analysis questions were asked. It was decided that a comparison of pooled means for all lab and non-lab questions was a more

practical approach to the test of significance for a difference between these two means. These data are summarized in Table 21.

Table 20

T-tests on Multiple Choice Questions for Provincial Examinations 1990-1994

LAB QUESTIONS				NON-LAB QUESTIONS					
<u>Date</u>	<u>n</u>	<u>Mean</u>	<u>S D</u>	<u>n</u>	<u>Mean</u>	<u>S D</u>	<u>t value</u>	<u>p</u>	<u>D F</u>
Jan 90	4	0.609	0.014	48	0.611	0.196	3.812	0.976	50
Jun 90	5	0.41	0.145	47	0.591	0.179	2.776	0.046	50
Jan 91	3	0.604	0.343	49	0.634	0.201	4.303	0.41	50
Jun 91	3	0.709	0.233	49	0.672	0.173	4.303	0.808	50
Jan 92	7	0.574	0.18	45	0.65	0.176	2.365	0.328	50
Jun 92	4	0.483	0.269	48	0.636	0.19	3.182	0.341	50
Jan 93	3	0.468	0.146	49	0.681	0.176	4.303	0.117	50
Jun 93	2	0.723	0.091	50	0.654	0.151	12.706	0.467	50
Jan 94	8	0.607	0.145	44	0.696	0.162	2.365	0.147	50
Jun 94	2	0.793	0.019	50	0.659	0.172	12.706	0.000	50

Table 21: T-test on Provincial Examination Written Section for Overall Means on Lab and Non lab Questions

Lab			Non-lab					
<u>n</u>	<u>Mean</u>	<u>S D</u>	<u>n</u>	<u>Mean</u>	<u>S D</u>	<u>t-calc</u>	<u>t-crit</u>	<u>D F</u>
6	2.968	0.876	128	4.2	1.946	0.014	1.97	132

Ho - there is no difference between means for lab questions and non-lab questions

H_A - there is a difference between means.

As $t_{calc} < t_{crit}$ then Ho was not rejected.

i.e. there is no significant difference between mean scores on lab and non-lab questions on the written section of the provincial examinations

The Scholarship Examination

For scholarship examinations the number of lab and data-analysis questions was counted. It should be noted that the total number of questions for this examination is between six and eight. Therefore, although the number of lab questions may appear few, they represent a greater proportion of the examination mark overall.

Table 22**Frequency of Lab Questions on Scholarship Examinations by Year**

Year	Month	No.Lab/Data Questions
1990	January	1
	June	2
1991	January	2
	June	1
1992	January	1
	June	3
1993	January	3
	June	2
1994	January	2
	June	3
Total = 20		
Mean = 1.889		
s.d.= .817		

The data following is extracted from the Ministry of Education Report 1278A7 and list the maximum score possible for each question, the average score on the question attained by examination candidates, and the cognitive level of each question. All of the Scholarship questions are claimed to be at

an Understanding or Higher Level Thinking cognitive level, although many teachers feel that some of the questions are more correctly placed in the Knowledge category, in that they require recall, but in greater detail than on the provincial examination.

These data are summarized in Table 23.

Table 23
Scholarship Examination - Maximum Score, Average Score and
Cognitive Level for Lab and Non lab Questions

Year	Question	Maximum Score	Average Score	Cognitive Level
<u>Jan 1990</u>				
LAB BASED	6	12	4.44	H
NON-LAB BASED				
	1	6	2.57	H
	2	10	6.89	H
	3	8	5.6	H
	4	8	5.6	H
	5	5	2.07	H
<u>June 1990</u>				
LAB BASED	2	6	2.95	H
	5	10	2.81	U
NON-LAB BASED				
	1	8	4.11	U
	3	6	2.95	U
	4	4	1.6	U
	6	6	2.35	H
	7	10	4.32	U

Jan 1991

LAB BASED	2	5	2.85	U
	5	5	2.79	U

NON-LAB
BASED

1	5	3.39	U
3	9	5.78	U
4	8	4.22	U
6	4	1.65	U
7	4	1.46	U
8	10	3.5	U

June 1991

LAB BASED	1	8	6.05	U
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NON-LAB BASED	2	10	4.41	U
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3	6	3.76	U
4	4	1.42	U
5	4	2.34	U
6	8	2.93	H
7	5	2.81	U
8	5	1.82	U

Jan 1992

LAB BASED	3	9	4.3	H
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NON-LAB
BASED

1	10	3.18	H
2	8	4.71	H
4	6	2.43	H
5	5	2.14	H
6	6	1.87	H
7	6	4.63	U

June 1992

LAB BASED	2	5	3.87	U
	4	5	1.2	H
	5	8	5.67	H

NON-LAB
BASED

1	12	5.88	U
3	9	3.88	U
6	5	1.99	H
7	6	2.15	H

Jan 1993

LAB BASED	4	8	4.07	H
	6	6	3.15	H
	7	12	4.12	H

NON-LAB
BASED

1	10	6.79	H
2	4	1.79	U
3	4	2.3	U
5	6	2.52	H

June 1993

LAB BASED	3	9	4.34	H
	6	8	4.96	H

NON-LAB
BASED

1	6	1.88	U
2	8	4.76	H
4	8	4.39	H
5	8	4.23	H
7	3	1.96	U

Jan 1994

LAB BASED	5	6	3.42	H
	8	6	4.79	H

NON-LAB
BASED

1	7	3.56	H
2	6	3.03	H
3	6	3.86	H
4	5	2.86	U
6	7	2.12	H
7	7	2.85	H

June 1994

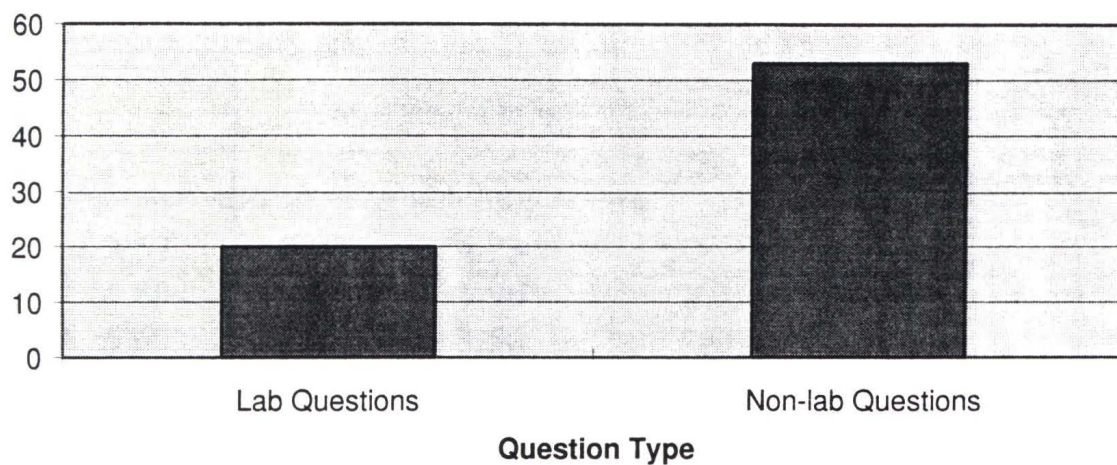
LAB BASED

2	5	2.65	H
5	7	5.13	H
7	5	3.12	U

NON-LAB
BASED

1	7	3.28	U
3	7	4.78	H
4	6	2.9	H
6	9	6.79	H
8	4	2.71	U

Figure 5: Frequency of Lab and Non-lab Questions on Scholarship Examinations 1990-1994



On Scholarship examinations between January 1990, and June 1994, 27% of the questions were either lab or data-analysis. This would seem appropriate for an examination of this nature.

The means for the average scores for each Scholarship examination paper were calculated. (Table 24)

Table 24**Scholarship Examination - Lab and Non-Lab Question Mean Scores**

Lab Means		Non-Lab Means	
4.44	2.57	2.93	4.23
2.95	6.89	2.81	1.96
2.81	5.6	1.82	3.56
2.85	5.6	3.18	3.03
2.79	2.07	4.71	3.86
6.05	4.11	2.43	2.86
4.3	2.95	2.14	2.12
3.87	1.6	1.87	2.85
1.2	2.35	4.63	3.28
5.67	4.32	5.88	4.78
4.07	3.39	3.88	2.9
3.15	5.78	1.99	6.79
4.12	4.22	2.15	2.71
4.34	1.65	6.79	
4.96	1.46	1.79	
3.42	3.5	2.3	
4.79	4.41	2.52	
2.65	3.76	1.88	
5.13	1.42	4.76	
3.12	2.34	4.39	
Grand mean=3.384		Grand mean=1.464	

The mean scores recorded in Table 24, were used to calculate the grand means for the t-test in Table 25.

Table 25**Scholarship Examination: Results of t-test on Means of Lab and****Non- lab Questions**

	<u>n</u>	<u>Mean</u>	<u>SD</u>	<u>t</u>	<u>D F</u>
<u>Lab questions</u>	20	3.384	1.181	0.19	71
<u>Non-lab questions</u>	53	3.392	1.464		

Analysis of the Biology 11 /12 Curriculum Guide

The Curriculum Guide was examined for the number of qualitative and quantitative labs as well as the software and video which was listed, and therefore recommended, by the Learning Resources Branch. The syllabus is divided into a Core curriculum which is mandatory and occupies approximately 70 hours and an Options section which requires students to choose from 22 topic areas and covers a further 30 hours. The philosophical basis for the options section is that it allows teachers to design their courses around local interest or expertise.

The Biology 12 course consists of an 80 hour core with the requirement that an additional 20 hours be selected from six possible options.

The analysis of lab suggestions, software and videos for Grade 11 Biology is summarized in Table 26.

Table 26

The distribution of quantitative and qualitative labs, software and video resources suggested for Grade 11

Topic	Qualitative Labs	Quantitative Labs	Total Labs	Software	Video
<u>Core</u>	59	2	61	3	38
<u>Options</u>					
Microscopy	3	0	3	0	0
Mycology	4	0	4	0	1
Bryophytes and ferns	4	0	4	0	2
Invertebrate Zoology	12	0	12	0	4
Parasitology	0	0	0	0	1
Vertebrate Zoology	6	0	6	0	10
Fisheries Biology	2	0	2	0	7
Wildlife Biology	1	0	1	0	5
Freshwater Biology	15	0	15	0	8
Population/Community Ecology	4	0	4	0	9
Animal Behaviour	2	0	2	0	12
Evolution and Fossil Record	4	0	4	0	5
Mendelian Genetics	4	0	4	0	6

Table 26 (cont).

Silviculture	3	0	3	0	3
Bioethics	0	0	0	0	5
Careers in biology	0	0	0	0	0
Population Genetics	2	1	3	0	4
Terrestrial habitats and Succession	0	0	0	0	6
Intertidal/Marine Biology	0	0	0	0	4
Aquaculture	0	0	0	0	2
Plant Development and Control	2	0	2	0	2

Total (options)	68	1	69	0	96
Mean	3.238	0.048	3.286	0	4.571
s.d.	3.872		14.61		3.295

On examining these data for Grade 11 it is apparent that 98% of the laboratory exercises listed are qualitative, leaving only 2% quantitative labs. Also, analysis reveals that in the options section 40% of the labs are confined to two topic areas, viz. Invertebrate Zoology and Freshwater Biology. If teachers choose not to cover these options then the mean number of labs per optional topic is reduced from 3.238 to 1.7. It is also

interesting to note that the percentage of qualitative labs is the same (98%) for the core, optional labs and labs overall.

The analysis for the Grade 12 biology course laboratory activities and supporting materials is summarized in Table 27

These data show that, as for Grade 11, the number of qualitative labs far exceeds the number of quantitative labs, with 81% qualitative and 11 % quantitative. Qualitative labs represent 84% of the core curriculum. There are no quantitative labs listed for the options section.

In the new Integrated Resource Package, due to be implemented in September, 1996 for Grade 11 and September 1997 for Grade 12, the situation has been simplified by the removal of all options from the course.

Table 27:

The distribution of quantitative, and qualitative labs, software and videotapes recommended for Grade 12 Biology

Topic	Qualitative Labs	Quantitative Labs	Total Labs	Software	Video
Core	32	6	38	6	66
Options					
Immunology	0	0	0	0	3
SkeletalSystem & Muscles	3	0	3	0	5
Reproduction & Embryology	5	0	5	0	9
Genetic Engineering & Disorders	0	0	0	2	2
Cancer	0	0	0	0	0
Senses	5	0	5	0	6
Total	13	0	13	2	25
Mean	2.16	0	2.16	0.33	4.16

Analysis of Biology 11/12 Integrated Resource Package

Table 28 summarizes the IRP labs, software, video, laser disc and multimedia which have been recommended for Grades 11 and 12.

Table 28:

The IRP distribution of quantitative labs, qualitative labs, software, videotapes, laser disc, and multimedia for Grade 11 and 12 Biology

<u>Grade</u> <u>11</u>	Quantitative	Qualitative	Total	Software	Video	Laser	Multimedia
	Labs	Labs	Labs			disc	
Number	3	17	20	5	14	2	2

<u>Grade</u> <u>12</u>	Quantitative	Qualitative	Total	Software	Video	Laser	Multimedia
	Labs	Labs	Labs			disc	
Number	7	22	29	4	13	3	2

It is interesting to note that the number of quantitative lab exercises has not changed significantly and that the number of videotapes, particularly in Grade 12, has decreased significantly.

The number of quantitative labs increases between Grade 11 and Grade 12 from 15% to 24% and in terms of the total number of labs by 31%.

Differences between Grade 11 and Grade 12 for other resources, i.e. software, video, laser disc and multimedia are not significant.

A comparison of the Biology 11/12 Curriculum Guide with the Integrated Resource package shows that the number of quantitative labs remains the same for Grade 11 at 3 labs, and increases to seven from six for Grade 12. The number of qualitative labs in Grade 11 is reduced dramatically from 127 (including 59 for the core and 68 for the options) to 20, while in Grade 12 the number has decreased from 45 (32 on the core and 13 in the options) to 22. These reductions are caused by the removal of the options from the courses. There is however, a 71% decrease in qualitative labs for Grade 11 on the core alone and an overall 43% decrease in labs recommended for Grade 12.

CHAPTER FIVE

SUMMARY AND DISCUSSION

The Research Problem

The objective of this research was to investigate:

- the quantity and quality of laboratory work being carried out by Grade 11 and 12 Biology students in British Columbia High Schools.
- the scores on lab-based and data analysis questions compared with non-lab questions on the Provincial and Scholarship examinations.
- the quantity and type of laboratory activity conducted in schools compared with the number and type of laboratory exercises recommended in the Biology 11/12 Curriculum Guide and Integrated Resource Package.

The Research Method

The research method for this study was divided into three major parts:

1. the survey of Biology teachers in British Columbia High Schools

in order to establish the number and type of labs being conducted by teachers in the province. In addition, the survey provided information about other factors such as school demographics, the teachers, teaching method, teacher attitudes and the use of technology in biology classes.

2. a hands on analysis of the provincial examination questions for both the provincial and scholarship papers.

The purpose of this analysis was to establish the performance of Grade 12 students on lab-based and data-analysis questions in order to see whether there was any significant difference in level of achievement between lab-based and data analysis questions, and other questions.

3. An examination and subsequent analysis of the Biology 11 /12

Curriculum Guide, in order to gain information on the number of laboratory exercises which are recommended by the Province of British Columbia as activities for students. These data were then sub-divided and categorized as qualitative and quantitative exercises. In addition to the analysis of the Curriculum Guide, an analysis of the Integrated Resource Package was also conducted in order to establish whether there has been any significant change in the number or types of laboratory exercises and any change in the number and type of learning resources recommended to teachers.

The primary instrument used in the first part of the research was a survey, which was generated in two phases, a pilot survey and the survey itself. The latter was based on the pilot survey and subsequent modifications to it. The purpose of the pilot survey was to field test the questions and thereby

establish the validity of the survey instrument - which it did for face, content and construct validity. The questions were grouped under the headings: demographics, the teacher, laboratory work, and follow up. The survey, mailed to 248 schools in which Biology 11 and 12 is taught, contained questions which gathered numerical data and descriptive data. The data collected were used to generate descriptive statistics, and inferential statistics using Chi-square, t-tests, and ANOVA. Open ended questions were also analyzed for common response patterns.

Provincial and Scholarship examinations from January, 1990 to June, 1994 were examined by hand and lab-based questions were distinguished from non-lab questions for both the multiple choice and written sections of the papers. The data were analyzed and descriptive and inferential statistics generated. For multiple choice questions, the difference between mean difficulty scores on lab and non-lab questions was tested and for the written section of the provincial examination and the Scholarship examination, the mean, student scores were used.

The examination and subsequent analysis of the Biology 11 /12 Curriculum Guide yielded information on the number of laboratory exercises which are recommended by the Ministry of Education, Curriculum Branch, in the Province of British Columbia. These data were then sub-divided and

categorized as qualitative and quantitative exercises. In addition, an analysis of the Biology 11/12 Integrated Resource Package was conducted in order to establish whether there had been any significant change in the number or types of laboratory exercises or in the number and type of learning resources recommended.

Summary and Interpretation of the Results.

The Pilot Survey

Seventeen pilot surveys were completed and returned (See Appendix 1). The surveys were completed by teachers from 17 schools which represented 17 different school districts in the Province of British Columbia. The results from the pilot survey indicated that the survey needed minor modification but was overall, deemed to be a valid instrument.

The Survey

Two hundred and forty surveys were mailed out to schools and 108 were returned. The returned sample represented 108 schools from 51 out of the 75 school districts in the province. No schools which were in the pilot survey were included unless a full survey was completed. The results of the questionnaire distribution and return are summarized in Table 1.

It was felt that it was important to the context of the research to establish some demographic data about the schools so that possible relationships of these data with other factors could be examined.

The distribution of schools sizes on the sample of returned surveys corresponds favourably with the distribution of school sizes for the province, although the number of large schools is under-represented (Figure1). It was felt that this would not alter the outcome significantly as the overall sample size was satisfactory. (Care was taken, however, to consider this factor in establishing relationships between size of school and other factors such as whether labs are well enough equipped.) The location of the schools on the returned surveys showed 54.2% were urban, 38.3% were rural and 7.5% remote. These data are representative of the data for the province.

The number of students taking biology in various schools ranged from 2 to 540 in Grade 11 with a mean number of 109 students per school. Grade 12 student numbers ranged from 0 to 360, with a mean of 68.61 students per school. These data are similar to data for the whole province.

Eighty-five percent of the schools responding to the survey were on either a linear or semester system, with 55% on semester and 31% linear. Data was not readily available on this distribution for the province.

The recommended hours of instruction for a senior science course in British Columbia is 120 hours. The survey data indicated that Grade 11 students received between 64 and 194 hours per year with a mean of 106 hours. For Grade 12 the range was 84 - 194 hours per year with a mean value of 106 hours.

Lack of time for instruction is probably the most common complaint by biology and other high school science teachers, and there certainly appears to be considerable variation in the time allowed for biology instruction by various schools around the province. The Ministry of Education has recognized the time difficulties faced by teachers and the IRP for Biology shows a reduced number of learning outcomes in both grade 11 and 12. The number of intended learning outcomes (ILO's) for the core curriculum for grade 11 has been reduced from 166 to 84 - a reduction of 49%. For the core curriculum for grade 12, the number of ILO's has been reduced from 149 to 113 - a reduction of 24%. It will be interesting to 'track' the effect of the reduced number of learning outcomes on the amount of laboratory work conducted in schools.

British Columbia, in common with other jurisdictions has an aging population of teachers. The average age for teachers in British Columbia is 42.6 years with a mean of 20 years of teaching experience. The distribution

for biology teachers answering the survey showed a bias towards an older population, with 45.79% having taught for 20+ years compared with 26.23% for all teachers in the province. The “less experienced” teachers are similarly under-represented in biology teachers compared with teachers for the province as a whole. On the survey, teaching experience ranged from 1 - 35 years with a mean of 20 years.

In a number of schools, in particular in rural and remote areas, it is the practice to use non-specialist teachers to teach senior science courses.

Biology, as with Chemistry and Physics brings with it, at the senior level in particular, the requirement for not only fundamental knowledge but also a depth and breadth of knowledge. It is encouraging to note that 93.5% of teachers who responded to the survey had received specialist training in Biology, that 49.1% held a B.Sc. and 41.6% held graduate degrees. The qualifications of the teachers bodes well in terms of communicating the course content, and indicates that it is not the lack of knowledge which discourages the use of laboratory work as an approach to teaching, as is often the case at the elementary level.

The number of laboratory exercises performed in a year was one of the fundamental questions in this research, along with the division of the labs into qualitative and quantitative exercises. The survey results indicated that

81% of the teachers used one or less labs per week or cycle, with 48% using less than one lab. The literature indicates that there is abundant evidence that secondary school classrooms continue to be dominated by teachers talking to passive learners. This has obvious implications in that it contradicts the recommendations of every assessment carried out in the province, which actively promote the use of hands-on, activity based, constructivist approaches to sciences at all levels from elementary school through to college and university. The active promotion and use of science process skills is currently, strongly supported in the literature. There is evidence that these teaching approaches generally produce significantly greater educational gains than the traditional approaches. There is, in addition, some evidence that students can be taught to improve their use of formal operational thought through the use of concrete, manipulative laboratory exercises. Also, it is indicated that the more direct the student's involvement in all aspects of the laboratory activity, the more the student appears to learn. When science process skills and science concepts are taught simultaneously, gains appear to be even greater. If these arguments are valid, then students in British Columbia are not receiving maximum benefit from their biology instruction.

Quantitative exercises in laboratory sciences are an integral part of the process of scientific learning. The distinction between the number of quantitative laboratory exercises and the number of qualitative exercises was thought to be one important measure of the sophistication of the scientific learning undertaken by the students. The results for the number of quantitative labs in Grade 11 showed a range of 0 to 20 with a mean of 4.21 labs per year. Eighty-two percent of teachers of Grade 11 students used ≤ 5 quantitative labs per year. In Grade 12 the range was 0 to 10 with a mean of 2.69 labs per year. Ninety-four percent of teachers of Grade 12 students used ≤ 5 quantitative labs per year. Fifteen teachers did not respond to this question.

For many students, the majority of their laboratory experiences in biology involve qualitative exercises. These are usually prescriptive in nature and while they are part of the scientific experience of students, it would appear that students in senior biology classes equate labs with this type of situation, rather than an investigative model.

For Grade 11, a mean of 14.66 labs per year was reported with a range of 0-40 labs per year. Forty-seven percent of teachers of Grade 11 students used ≤ 10 qualitative labs per year. For grade 12 students, a mean of 5.84 qualitative labs per year with a range of 1 - 30 labs per year was reported.

Eighty-nine percent of teachers of Grade 12 students used ≤ 10 qualitative labs per year. Overall, Grade 11 students perform more labs in a year than Grade 12 students.

The low frequency of all lab work and the lack of quantitative exercises in particular, indicate that students spend a great deal of their time listening to a teacher talk about science rather than doing science for themselves.

Science is a process which requires, therefore, action on the part of the scientist. In a well designed science course, the intellectual process is that of real scientific research. Pickering (1980) expresses it well in arguing that, "After the students see how difficult it is to obtain unambiguous data , the result will be a healthy skepticism about purported "facts" that have not been confirmed and reconfirmed. Too few lab courses offer any sort of confrontation with the unknown. The student is expected to produce a verification of something that he already knows, and so ends up trained to ask what a result is supposed to be, not what it in fact, is. The element of creative surprise is almost completely missing. The results of an experiment should be ambiguous enough so that a student is compelled to think through the bearing of his results on the possible conclusions."

Investigation and exploration by the student are the key to the constructivist philosophy of scientific education. It was therefore worthwhile to ask

whether the lab work conducted by students was primarily confirmatory or investigative, in order to determine what practices teachers are using in their approach to laboratory work and subsequently why they maintain these practices in the light of their own philosophies as expressed in answers to question 30 on the survey.

In response to the question of whether the labs conducted were usually confirmatory rather than investigative, 75.5% of teachers of Grade 11 students answered that their labs are always or frequently confirmatory rather than investigative, while 83.1% of teachers of Grade 12 students reported that their labs are always or frequently confirmatory rather than investigative. It is interesting to note that the number of labs which are confirmatory increases between Grade 11 and Grade 12, when one would expect that, as the level of sophistication of the students' knowledge increases, they would receive greater responsibility for approach to the lab design and therefore, it would contain more investigative elements.

In all grades, across all subjects, there is a recognition of the importance of the student's ability to successfully think through the challenges posed by the curriculum. A student is attempting to think critically when he or she intends to reach a reasoned judgment about what it would be reasonable or sensible to believe or do in a given situation. Thinking critically is not a

matter of reaching a pre-determined correct answer, but rather of thinking that embodies, to varying degrees, the attributes of good thinking.

When asked whether the labs they assigned fostered critical thinking in their students, for Grade 11, 63% of teachers responded, “always or frequently” and 37.5% thought “rarely”. No teachers reported that their labs never fostered critical thinking in their students. For Grade 12, 60% of teachers reported that their labs always or frequently fostered critical thinking in their students, while 40% reported “rarely or never”. It is interesting to note that 21 teachers did not respond to this question. One would question, with so few labs being conducted, and that of those, few are quantitative, why teachers believed that their labs fostered critical thinking.

Teaching students, to use reason to solve problems has long been a concern at all levels of education. Critical thinking has become a popular “buzz word” in education, but whatever the label, it implies a recognition of the importance of developing a student’s ability to think through challenges posed by the curriculum. These challenges may involve problem-solving, decision making, issue analysis or inquiry. Through the application of various processing models emerging from cognitive science research regarding metacognition, cognitive development and the construction of knowledge, educators have recognized the possibilities of teaching to

enhance thinking. Students need to be encouraged to integrate their thinking about their own thinking with knowledge that is worth thinking about (Yore, 1989). Costa (in Brandt, 1988) indicated that results are disappointing when only content is taught leaving students to themselves to learn to think and equally, teaching thinking skills in isolation is equally unproductive. It would seem that much more could be done to integrate this type of thinking process into science courses, particularly in view of the increasing volume of material which students are expected to understand. The construction of a framework around which to build their knowledge makes more sense than the loose aggregation of disjointed information so commonly found in high school students.

In response to whether their students are required to formulate hypotheses before beginning a lab, 27.6% responded "frequently", but 60.0% responded 'rarely or never' The latter figure is hardly surprising if, as reported, most of the labs undertaken are qualitative and require little or no critical thinking. One would question, at the senior level, whether students are really 'doing science' if they are not testing hypotheses, in that hypothesis generation and testing is a key component of the 'central dogma' of scientific method. It would seem that much of their lab time is occupied with either casual observation or superficial, confirmatory exercises.

Do the students beginning a senior biology class understand scientific method? Scientific method is the process of science in which problems are perceived or questions are asked, hypotheses are generated, hypotheses are tested by experiment, data are collected and then hypotheses evaluated. This model of scientific method is the one most frequently thought of by most teachers representing a sequential lock-step linear model. This model does not fully describe the scientific enterprise, demonstrate the creative personal dimension, and if taught explicitly does not lead to effective scientific thinking (Yore, 1989). For grade 11 students it was found that the response was 56% "always or frequently" and 43% responded, "rarely or never". For grade 12 students, the response frequency was 90% "always or frequently" and 10% "rarely". Most students stay in the same school for their final two years of high school and therefore one would expect that, even if students do not understand scientific method when they enter a senior class, possibly from a junior high school, they would do so after two years. Scientific method is a topic on the core curriculum for both Grades 11 and 12. In Grade 11, students are expected to be able to identify, define and formulate hypotheses; contrast data with facts; list 'rules' which may be used to assess the validity of an experiment; describe appropriate procedures for testing, confirming or rejecting an hypothesis, formulate conclusions from

experimental observations and data; demonstrate an ability to work with SI units; identify valid steps in an experiment, and criticize or defend an entire experiment in terms of validity of methods. In Grade 12, under the topic heading, “Experimental Design”, students are expected to be able to differentiate between inductive and deductive reasoning; suggest alternative experiments to test an hypothesis; discriminate between hypothesis and theory; explain the role of control(s) in an experiment; design an experiment using the generalized steps of scientific inquiry. It would be interesting to know how these topics are taught - whether in isolation on a lecture basis or as an integral part of the lab experience. This research indicates that in most cases, the former is true. One would also speculate on the degree of students’ real understanding of scientific method beyond a basic knowledge of the words used to describe the process, in view of the fact that they experience so little lab work.

When asked whether the labs their students performed supported the intended learning outcomes of the course outline, 96% for Grade 11 and 87% for Grade 12 responded “always or frequently”. It is interesting to note that 26 teachers did not respond to this question. One would, of course, expect teachers to answer in the affirmative, otherwise why would they conduct the experiment?

The technology of education has changed. Developments such as television, video, computers, CAI, CD-ROM, databases, and the internet have allowed direct and interactive access to a vast quantity of information. Although many schools have made investments in information technology in recent years, the use of technology continues to be a peripheral activity and has not resulted in significant changes in teaching styles or the operation of most secondary schools. It is rarely the central focus of school programming and Levin (1995) suggests that we are only beginning the discussion on how technology can and should change teaching and learning. However, for those who have utilized the technology there would appear to be very strong support for its use. Electronic media are particularly effective in enhancing comprehension and retention (Fifield & Peifer, 1994; Farragher & Pauline, 1995), and as a substitute for the traditional laboratory activity (Ralph, 1988; 1993).

When surveyed about the use of technology, two types of activity were queried. First the use of lab. simulations such as the use of video or CD, then the use of computer-based data collection. In terms of the use of lab simulations, 82% of teachers for Grade 11 and 12 reported rarely or never utilizing these technologies and, on average, 96% of teachers reported that

they rarely or never used computer-based data collection. (It is interesting to note that 28 teachers did not respond to this question.) Eighty-two percent of teachers responded that the primary reason for not utilizing these technologies was a lack of equipment; 37% cited “no experience” as a cause; 11% no interest and 8% no time. It was interesting to note that responses included: “does not foster critical thinking”; “hate computers”, and “not appropriate”. Another factor may be the inconvenience of having to ‘reserve’ computers because they are not conveniently available in the science laboratory. This ‘inconvenience factor’ may be a greater obstacle to the use of computer-based data collection than the present research would indicate. The results of the Provincial Technology Survey (1995) indicate that, at the secondary level, computers are used primarily for writing, publishing, word processing, and keyboarding. No mention is made in the survey of the use of technology in science laboratories. However, data from secondary schools indicate that high in-service priorities include learning to use telecommunications, integrating telecommunications into the curriculum, and dealing with the role of technology in educational change. Time is always a critical factor in teaching a senior science course in which the material to be taught is dictated by an imposed syllabus and a Provincial examination. This question arose as a result of the constant ‘*crie de coeur*’

of many teachers, that they do not have sufficient time to teach the senior biology course, primarily because of the volume of material to be covered. This appears to be the case in Biology, particularly for the Grade 12 curriculum.

For the Grade 11 course, 45.2% of teachers responded that they did not have enough time to teach a lab-based or inquiry-based course while 54.8% responded that they had enough time to teach a course of this type. For the Grade 12 course the pattern of responses was dramatically reversed. Eighty-eight percent of the teachers indicated that they did not have sufficient time to teach an inquiry or lab-based course. The primary reason given by teachers of Grade 12 is that they cannot cover the volume of material expected for the provincial course and prepare students for the provincial examination in the time allowed, let alone, as one of the teachers expressed it, “have time for any real scientific investigation or thinking about what we are doing”.

The limiting factors commonly stated for not teaching lab-based courses are the availability of equipment and the limitations of the course outline. In this research, the majority of teachers of both Grades 11 and 12 responded that their labs were well enough equipped to teach a lab-based course.

The content of courses taught in British Columbia is dictated by the provincial government (Biology 11/12 Curriculum Guide, 1990). In terms of the course outline being a significant factor in limiting the scope for individual students research, in Grade 11, 54.5% agreed that it did while 45.5% thought that it did not. The teachers of Grade 12 are subjected not only to a specific course outline but also, the students write an external examination at the end of the course. This examination represents 40% of a student's final mark. In addition, it would seem that teachers are, to some extent, judged by the performance of their students on the provincial examination. It is therefore not surprising, that with these constraints placed upon them that 93% of the teachers of Grade 12 students related that they felt that the course outline limited the scope for teaching a lab-based course. In terms of the provincial examination limiting the opportunities for teaching a lab-based course, 93.1% of the teachers agreed that it did, while only 5.9% felt that it did not. Teachers have stated frequently that the course content has too great a volume to cover in the time allowed and therefore they find themselves hard pressed to even complete the course and cannot afford the time for labs if their students are to be successful on the provincial examination. As stated previously, part of the evaluation and perception by the school administration and parents of the teacher's

effectiveness, is based on the students' results on the provincial examination. If the students do well then the teacher is regarded as a 'good' teacher, regardless of any other influences on the students education.

Individual lab-based research, as distinct from library - based or text-based research is an important element in developing the 'skills of science'. For Grade 11 students, 86.8% declared that their students rarely or never carry out individual lab-based research. For Grade 12 classes, 98% of the teachers used this approach 'rarely or never'. It is curious that the primary reason given by teachers for not having their students carry out this type of activity was a lack of equipment (82%) and yet in a previous question on the survey they indicated that their labs were well enough equipped to conduct an inquiry-based course. The second most common reason given was that the teacher lacked experience in this type of approach (37%). In spite of these problems the majority of teachers thought that this type of exercise would be valuable to students' scientific development.

Teachers were asked whether they would choose to teach an inquiry-based course in preference to a traditional course, provided that they had sufficient time and a well equipped lab. In this question the attitude of the teacher's towards an inquiry based and traditional course was solicited.

Eighty-seven percent of the teachers indicated that they would teach an inquiry based course in preference to a traditional course to their Grade 11 classes. For grade 12 classes, 73.1% of teachers suggested that they would prefer an inquiry based course while 26.9% indicated that they would not.

There were 15 missing cases for this question. It would seem, therefore, that teachers are willing to teach and are interested in inquiry-based courses but that the other constraints, such as time and experience, dissuade them from actually doing so.

Fifty-four percent of the teachers of Grade 11 students claimed that they gave a lab examination. This is curious in that 48% of the teachers also reported for Grade 11 that they give less than one lab per week or cycle, 80.8% give ≤ 1 lab per week or cycle and 41.7% use less than one lab a year.

For grade 12 classes, 81% of the teachers answered 'no' to this question, which seems to concur more closely with the data for the number of labs performed in a year.

Another anomaly, in the light of the small number of labs performed, was that 45.1% of teachers of Grade 11 regularly incorporated lab-based questions into their tests whereas for Grade 12 classes, 27.6% of teachers

revealed that they used lab-based questions regularly on tests. Forty-seven percent reported rarely or never using this type of question on tests.

Teachers were asked to describe their approach to teaching on a Likert-type scale as follows:

- a) uses primarily a lecture approach with some lab work
- b) uses primarily an investigative approach with some lab work
- c) uses primarily a lecture approach and would not use an investigative approach
- d) uses primarily a lecture approach but would like to try an investigative approach.

In response to this question 71.2% of the teachers surveyed selected option

a) i.e. they use primarily a lecture approach to their teaching, 13.5% chose option b) and 14.4% use a lecture approach but would like to try an investigative approach. This confirms the answers given to previous questions and in particular that the majority of teachers are using a “chalk and talk” approach to their teaching in spite of a willingness to change.

The reasons given, that would cause teachers not to use an investigative approach were primarily, the fact that the curriculum is geared towards the government examination and that teachers have no time to organize such a course. Secondary reasons given included, no materials/facilities and

limited funding. Again, these reasons confirm the previously expressed concerns of teachers.

A closer analysis of the survey data allowed inferential statistics and their significance to be generated and showed the following:

The difference between observed and expected values for frequency of lab-work in large schools was small but increases significantly in medium and small schools. The location of the school had no effect on any other factor.

The effect of organization of the school year showed that in semestered schools the observed number of schools conducting less than one lab per week was much lower than expected values and conversely for linear schools was higher than expected.

Neither Grade 11 nor Grade 12 students carry out research projects.

Teachers indicated that there seemed to be sufficient time for the course in Grade 11 but not in Grade 12 and teachers used labs which were confirmatory rather than investigative in both grades, with similar frequency. More Grade 12 than Grade 11 students understood scientific method. Teachers of Grade 11 who gave labs which were primarily confirmatory, rather than investigative, also thought that these labs fostered critical thinking.

There was a positive correlation between years of teaching and the frequency of qualitative labs in Grade 12. However, in view of the fact that this was only +0.2 at a significance level of 0.05, and the fact that years of teaching did not correlate with any other factors, this result was thought to be an artifact. There was a positive correlation (0.425) between the number of quantitative labs conducted in Grade 11 and Grade 12. Few quantitative labs were conducted by either group. The correlation between the number of qualitative labs conducted in a year was also positive (0.4). More qualitative labs were used than quantitative in a year, in both grades, but fewer labs were used overall in Grade 12.

The Provincial Examination

The analysis of the provincial and scholarship examinations for differences in scores between lab-based and non lab-based questions, for multiple choice and written questions, revealed that there was no significant difference in mean scores for any of the question types. Further examination of the lab questions revealed that they were primarily recall type questions requiring little, or at best, a superficial knowledge of the scientific process. Whether students have carried out lab-work or not, whether confirmatory or investigative, would have little effect on their scores on this examination.

Examination of the Biology 11 and 12 Curriculum Guide and IRP

On examining the Grade 11/ 12 Curriculum Guide it is apparent that for Grade 11, 98% of the laboratory exercises listed are qualitative, leaving only 2% quantitative labs. Analysis reveals also that in the options section, 40% of the labs are confined to two topic areas, viz. Invertebrate Zoology and Freshwater Biology. If teachers choose not to cover these options then the mean number of labs per optional topic is reduced from 3.238 to 1.7. It is also interesting to note that the percentage of qualitative labs is the same (98%) for the core, optional labs and labs overall.

In Grade 12, as for Grade 11, the number of qualitative labs far exceeds the number of quantitative labs, with 81% qualitative and 11% quantitative.

Qualitative labs represent 84% of the core curriculum. There are no quantitative labs listed for the options section, which is surprising when one considers such topics as 'senses' and 'biotechnology' in which there would seem to be plenty of scope for quantitative exercises. In the new Integrated Resource Package, to be implemented in September, 1996 for Grade 11 and September 1997 for grade 12, the situation has been simplified by the removal of all options from the course. The number of quantitative labs increases between Grade 11 and Grade 12 from 15% to 24% and as a fraction of the total number of labs by 31%. Differences between Grade 11

and Grade 12 for other resources, i.e. software, video, laser disc and multimedia are not significant.

A comparison of the Biology 11/12 Curriculum Guide with the Integrated Resource package shows that the number of quantitative labs remains the same for Grade 11 at 3 labs, and increases to seven from six for Grade 12. The number of qualitative labs in Grade 11 is reduced dramatically from 127 to 20, while in Grade 12 the number has decreased from 45 to 22. These reductions are caused by the removal of the options from the courses. There is however, a 71% decrease in qualitative labs for Grade 11 on the core alone and an overall 43% decrease in labs recommended for Grade 12. It is difficult to rationalize this action with the statement of philosophy in the IRP which states that:

"..... laboratory skills are essential to students of Biology 12. These skills are developed in lab activities that focus on the hypothetical as well as the practical. An emphasis on the processes of science is integral to the complete study of Biology 12. Also discussed under Methods of Inquiry the importance of providing opportunities for students to have direct physical experience with biological materials and living organisms is emphasized. "Students require both laboratory and field experiences to fully develop their science skills and understanding of science processes".

The effect of removal of the options sections from the syllabuses for Grade 11 and Grade 12 and the reduction in the number of lab exercises provides no choice for the teachers and students and limits the opportunity for teachers to tailor the course to local facilities or expertise.

Conclusions.

There is little laboratory work being conducted in Biology Grade 11 and 12 classes in British Columbia High Schools. Of the labs that are conducted, the large majority are qualitative, and confirmatory, rather than investigative.

The typical pedagogical pattern of instruction reflects an authoritarian, didactic approach to classroom management. The reason may be that many teachers in their education and training have never encountered a learning experience in which they themselves constructed meaning from the experience of conducting laboratory work.

Instruction has become increasingly textbook-centered. Even though laboratory experiences or demonstrations usually are included, students are rarely encouraged to use scientific methods to solve problems. The laboratory exercises are primarily descriptive in nature and require little analysis or synthesis on the part of the student. Almost all reports on the conditions of teaching and learning in schools calls for, more active learning

for students and less passivity; more hands-on, direct opportunities to ‘make meaning’.

It is apparent from this research that the philosophies and the goals listed in various Ministry documents, while admirable in concept, are not being accomplished in the practice of teaching biology at the senior high school level in British Columbia. At the beginning of the Grade 11 course outline there are 12 laboratory exercises recommended which deal with such topics as: formulating hypotheses, making data tables, control and experimental treatments, devising experiments, reporting results, using models to explain ideas, drawing inferences from data and the Chi-Square test of significance. I suspect that few, if any of these fundamental lab exercises, are undertaken on a regular basis. The IRP makes no mention of the ‘scientific method’ “per se”, in the prescribed learning outcomes, but it is covered in the introduction, in a philosophical statement to teachers. A thorough examination of the ‘Suggested Instructional Strategies’ has not been conducted but a superficial survey indicates that the concept of scientific method is not emphasized.

The quantity and quality of lab work undertaken by Grade 12 students appears to have no effect on the scores overall, on either the Provincial or Scholarship examinations, in that there was no difference in mean scores

between lab and non-lab questions, However, results on Provincials show that 62.3% are at a satisfactory or fail level.

Lack of time is a frequently mentioned obstacle to teaching an inquiry-based course and this is compounded by a tendency for teachers to feel that there is a requirement to 'cover the course', particularly at the Grade 12 level, because of the pressure of an external examination.

Very little technology is being used in the teaching of Biology 11 and 12. It would appear that videotapes are the primary supporting technology. There is no convincing evidence of the use of other technologies at significant levels. No schools reported using computer-based data collection.

Assessment techniques are very limited and confined almost exclusively to paper and pencil, recall type tests. The assessment strategy may end up being the key to the degree to which an activity-based or constructivist approach is implemented at the senior level. In particular, the provincial examination, in its present form, would appear to very limited in the variety of assessment strategies utilized.

In summary, the solution involves a complex of changes. A simple change to a constructivist /activity-oriented approach will not effect any real change. It requires a simultaneous change in assessment strategy, hands-on professional development and equally important, a change in expected

outcomes for the course. In addition, curriculum reformers of the 90's seem united on the necessity of reducing basic coverage in textbooks and curriculum guides, (Culotta, 1990) - the 'less is more' belief. However, difficulties seem to arise in deciding what should be included and what should be omitted , and for what levels of education, (Yager, 1992).

Recommendations

- More research on high school level laboratory experiences should be encouraged.
- Increased use of technology in the science curriculum. This includes all aspects of technology but in particular, the techniques for direct computer-based telemetry need to be developed and integrated into science programs.
- The provincial examination does not test scientific process and needs to be re-examined. Greater emphasis should be placed on questions requiring more critical thinking and data analysis.
- Resources need to be developed which allow students the opportunity to engage in scientific thinking and participate in scientific inquiry by learning to pose questions, formulate hypotheses, identify variables, identify experimental controls, and design experiments.

- A full examination of assessment techniques, especially performance based assessment, needs to be undertaken. This was outside the scope of this study, but it is encouraging to see the range of recommended assessment strategies in the IRP for Biology and a move closer to authentic assessment, in addition to paper and pencil tests.
- teachers need much more assistance, professional development, and direct instruction by example, in constructivist-oriented pedagogy rather than the transmission oriented pedagogy prevalent in many professional programs.

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APPENDIX 1
THE PILOT SURVEY

**A SURVEY OF THE QUANTITY AND QUALITY OF
LABORATORY WORK IN GRADE 11 AND 12 BIOLOGY
CLASSES IN BRITISH COLUMBIA**

This survey forms part of a larger piece of research on the laboratory work in Biology being conducted in Grades 11 and 12 in British Columbia schools.

The purpose of this particular survey is to gain some knowledge of the quality and quantity of laboratory work being conducted by teachers. A secondary purpose is to gain information on the number of teachers using an investigative method or traditional method of teaching and the reasons for their choice of instruction method.

Your individual responses to the survey will remain confidential.

Thank you to those teachers willing to take the time to complete this survey. I hope that I will be able to share the results of this and some other research with you in the summer marking session.

Please return your completed surveys to **Peter Gardiner** before the end of the marking session. If you **forget** I would still be happy to receive it either by mail at:

526, Linden Avenue
Victoria, B.C.
V8V - 4G5

or by Fax: 592 2812

or by email: pgardine@cln.etc.bc.ca

If you have any comments on the survey or modifications to improve it I would be very happy to receive them.

Please circle one of the answers or answer on the line

Demographics

1. What is the the size of your school?

Large	>800 students
Medium	800 - 500
Small	<500
2. How would you describe the location of your school?

Urban
Rural
Remote
3. How many students take Biology 11? _____
 Biology 12? _____
4. How is your school year organized?

Quarter system
Semester
Linear (Full Year)
Other

The Teacher

5. How many years have you been teaching? _____ years
6. Was your specialist training in Biology? Yes No
7. Qualifications: BEd Bsc MEd MA MSc PhD

Laboratory work

5. On average how frequently do you use labs?

Less than one per week/cycle	One a week/cycle
Two a week/cycle	More than two per week/cycle
6. How many quantitative labs do you use in a year?
 (ie. measurement rather than observation)

Grade 11	_____
Grade 12	_____
7. How many qualitative labs do you use in a year?
 (ie. observation rather than measurement)

Grade 11	_____
Grade 12	_____
8. Are the labs that you use mainly confirmatory
 rather than investigative? eg eye dissection

Grade 11	Yes	No
Grade 12	Yes	No
9. Do you feel that overall the labs that you use
 require the students to think 'scientifically'?

Yes	No
-----	----

- | | | | |
|--|--------------|------------|----|
| 10. Do you think that students entering your classes understand scientific method? | Grade 11 | Yes | No |
| | Grade 12 | Yes | No |
| 11. Do you require students to formulate hypotheses before beginning a lab? | Always | Frequently | |
| | Rarely | Never | |
| 11. Do the students entering your classes have good practical skills ? | Grade 11 | Yes | No |
| | Grade 12 | Yes | No |
| 12. Do you feel that the lab exercises that you are required to use support the intended learning outcomes in the course outline? | Grade 11 | Yes | No |
| | Grade 12 | Yes | No |
| 13. Do you have sufficient time to teach a lab based course.(ie inquiry approach, constructivist approach) | Grade 11 | Yes | No |
| | Grade 12 | Yes | No |
| 14. Are your labs equipped well enough for students to pursue an inquiry based course? | Grade 11 | Yes | No |
| | Grade 12 | Yes | No |
| 15. Do you feel that the Provincial course outline limits your scope for individual student research | Grade 11 | Yes | No |
| | Grade 12 | Yes | No |
| 16. Do you feel that the Provincial examination limits your opportunities to provide a good, investigative lab-based course? | | Yes | No |
| 17. Do your students carry out any lab-based individual reasearch? | Grade 11 | Yes | No |
| | Grade 12 | Yes | No |
| Why? | | | |
| Why not? | | | |
| 18. If the answer to Question 17 is yes, how often and how much time are they allowed for this activity? | | | |
| Grade 11 Frequency | Time allowed | | |
| Grade 12 Frequency | Time allowed | | |
| 19. Do you think that conducting an in-depth, individual piece of research would be an excercise valuable to students' scientific development? | | Yes | No |

Why?/Why not?

20. Do you give a lab exam?

Grade 11

Yes

No

Grade 12

Yes

No

21. Do you incorporate lab - based questions into your tests?

Never

Rarely

Regularly

Frequently

Always

22. Would you describe yourself as a teacher who : (circle one)

Uses primarily a lecture approach with some lab work

Uses primarily an investigative approach with theory as a backup

Uses primarily a lecture approach but would like to try an investigative approach

Uses primarily a lecture approach and would not use an investigative approach

23. List the main factors that would cause you not to use an investigative approach

Follow up

Would you be willing to be interviewed in a follow up study?

ANONYMITY IS GUARANTEED!!!

Yes

No

If yes please complete the following:

Name:

Contact address:

Tel:

Fax:

email address

Would you be willing to allow your students to participate in a student survey about lab work?

Yes No

If yes, please complete the above contact address.

APPENDIX 2

THE SURVEY

A SURVEY OF THE QUANTITY AND QUALITY OF LABORATORY WORK IN GRADE 11 AND 12 BIOLOGY CLASSES IN BRITISH COLUMBIA

Dear Colleague,

This survey forms part of a larger piece of research on the laboratory work in Biology being conducted in Grades 11 and 12 in British Columbia schools. It takes approximately 10 minutes to complete.

The purpose of this particular survey is to gain some knowledge of the quality and quantity of laboratory work being conducted by students. A secondary purpose is to gain information on the number of teachers using an investigative method or traditional method of teaching and the reasons for their choice of instruction method.

Schools being surveyed have been carefully selected on the basis of their size and location and it is therefore important to the validity of the study to receive as many returns as possible. A number of teachers previously participated in the pilot version of this survey - I would be very grateful if you would once again take the time to complete this final version.

Thank you to those teachers willing to take the time to complete this survey. I hope that I will be able to share the results of this and some other aspects of the research with you at some future date.

Please return your completed survey in the enclosed stamped addressed envelope.

If you prefer to Fax your survey: 604 - 592 - 2812

If you have any questions, comments on the survey or modifications to improve it, I would be very happy to receive them.

Telephone 604 370 6178
Fax: 604 592 2812
email: pgardine@cln.etc.bc.ca

Thank you again for your time and cooperation,

P. G. Gardiner

Peter Gardiner

Please circle one of the answers or answer on the line

Demographics

1. What is the size of your school?

Large >800 students
 Medium 300 - 500
 Small <300
2. How would you describe the location of your school?

Urban
 Rural
 Remote
3. How many students take Biology 11? _____
 Biology 12? _____
4. How is your school year organized?

Quarter system
 Semester
 Linear (Full year)
 Other (explain)
5. Approximate number of hours of instruction per Biology course?

Grade 11 _____
 Grade 12 _____

The Teacher

6. How many years have you been teaching? _____ years
7. Was your specialist training in biology? Yes No
8. Qualifications: BEd; BSc; MEd; MA; MSc; PhD (Circle as many as appropriate)

Laboratory Work

9. On average, how frequently do you use labs?

a) less than one per week or cycle
 b) Two a week or cycle

b) One a week or cycle
 d) More than two a week or cycle
10. How many quantitative labs do you use in a year?
 (i.e. measurement rather than solely observation)

Grade 11 _____ Grade 12 _____
11. How many qualitative labs do you use in a year?
 (observation rather than measurement)

Grade 11 _____ Grade 12 _____

12. Are the labs that you use usually confirmatory rather than investigative?	Grade 11	Always Rarely	Frequently Never	
	Grade 12	Always Rarely	Frequently Never	
13. Do you feel that overall the labs which you assign foster critical thinking in the students?	Grade 11	Always Rarely	Frequently Never	
	Grade 12	Always Rarely	Frequently Never	
14. Do you require students to formulate hypotheses before beginning a lab?		Always Rarely	Frequently Never	
15. Do you think that overall students entering your class understand scientific method?	Grade 11	Always Rarely	Frequently Never	
	Grade 12	Always Rarely	Frequently Never	
16. Do you feel that the labs that you use support the intended learning outcomes in the course outline?	Grade 11	Always Rarely	Frequently Never	
	Grade 12	Always Rarely	Frequently Never	
17. Do you use lab simulations? e.g. video, CD computer.	Grade 11	Frequently	Rarely	Never
	Grade 12	Frequently	Rarely	Never
18. Do you use computer based data collection? e.g. measurement of temperature/pH over time	Grade 11	Frequently	Rarely	Never
	Grade 12	Frequently	Rarely	Never
19. If you answered rarely or never to questions 17 and 18 the primary reason is:	No equipment No experience No interest Other (circle as many as are appropriate) If other please elaborate:			
20. Do you have sufficient time to teach a lab based course? (i.e. inquiry based, constructivist approach)	Grade 11	Yes	No	
	Grade 12	Yes	No	
21. Are your labs equipped well enough for students to pursue a lab based course?	Grade 11	Yes	No	
	Grade 12	Yes	No	

22. Do you feel that the provincial course outline limits the scope for individual student research?	Grade 11	Yes	No
	Grade 12	Yes	No
23. Do you feel that the provincial examination limits your opportunities to provide a good, investigative lab-based course?		Yes	No
24. Do your students carry out any individual, lab-based research?	Grade 11	Frequently	Rarely
	Grade 12	Frequently	Rarely
Why / Why not?			
25. If the answer to question 24 is yes, approximately how often and how much time are students allowed for this activity?	Grade 11		
	Grade 12		
26. Do you think that conducting an in - depth , individual research project would be an exercise valuable to students' scientific development?		Yes	No
Why/why not?			
27. Assuming that you had a well equipped lab and given sufficient time, would you teach an inquiry based course rather than a traditional course?	Grade 11	Yes	No
	Grade 12	Yes	No
28. Do you give a lab exam?	Grade 11	Yes	No
	Grade 12	Yes	No
29. Do you incorporate lab-based questions into your class tests?	Grade 11	Never Regularly Always	Rarely Frequently
	Grade 12	Never Regularly Always	Rarely Frequently

30. Would you describe yourself as a teacher who: (circle one answer below)

- a) Uses primarily a lecture approach with some lab work
- b) Uses primarily an investigative approach with theory as a backup
- c) Uses primarily a lecture approach and would not use an investigative approach
- d) Uses primarily a lecture approach but would like to try an investigative approach

31. List briefly the main factors that would cause you NOT to use an investigative approach.

Follow up

Thank you for completing the survey. Would you like to receive a summary of the results?

Yes

No

If Yes please complete the following:

Name:

Contact Address:

Tel:

Fax:

email:

Would you be willing to be interviewed in a follow up study?

Yes

No

Would you be willing to allow your students to participate in a student survey about attitudes to biology and lab work?

Yes

No

If yes, please be certain to complete the contact address above.

VITA

Surname: Gardiner
Given Names: Peter Grace
Place of Birth Cardiff, Wales
Date of Birth 18/2/44

Educational Institutions Attended:

St. Paul's College, Bristol University 1963-1966
University of Victoria 1974-1976
University of Victoria 1992-1996

Degrees Awarded:

Cert. In Ed.(Distinction)	Bristol University	1996
B.Sc.(Honours)	University of Victoria	1976

Honours and Awards:

Province of British Columbia, Ministry of Education. 1990
Certificate of Recognition for Service and
Outstanding Contribution

National Association of Biology Teachers 1995
The Outstanding Biology Teacher Award for Canada

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Title of Thesis:

A Survey of the Quantity and Quality of Laboratory Work in British Columbia High Schools, Effects on Provincial Examination Scores, and Analysis of Recommended Resources.

Author:



Peter G. Gardiner

September 30, 1996