



uOttawa

L'Université canadienne  
Canada's university

**FACULTÉ DES ÉTUDES SUPÉRIEURES  
ET POSTDOCTORALES**



**uOttawa**  
L'Université canadienne  
Canada's university

**FACULTY OF GRADUATE AND  
POSTDOCTORAL STUDIES**

**Morag S. Gundy**

-----  
AUTEUR DE LA THÈSE / AUTHOR OF THESIS

**Ph.D. (Education)**

-----  
GRADE / DEGREE

**Faculty of Education**

-----  
FACULTÉ, ÉCOLE, DÉPARTEMENT / FACULTY, SCHOOL, DEPARTMENT

**Teacher Perceptions of the Integration of Laptop Computers in Their High School Biology  
Classrooms**

-----  
TITRE DE LA THÈSE / TITLE OF THESIS

**Marie-Josée Berger**

-----  
DIRECTEUR (DIRECTRICE) DE LA THÈSE / THESIS SUPERVISOR

-----  
CO-DIRECTEUR (CO-DIRECTRICE) DE LA THÈSE / THESIS CO-SUPERVISOR

**Liliane Dionne**

**Renée Forgette-Giroux**

**Herman Duchesne**

**Coll. Univ. De Saint-Boniface**

**Awad Ibrahim**

**Gary W. Slater**

-----  
Le Doyen de la Faculté des études supérieures et postdoctorales / Dean of the Faculty of Graduate and Postdoctoral Studies

Teacher Perceptions of the Integration of Laptop Computers in Their High School  
Biology Classrooms

by

Morag S. Gundy

A thesis submitted to the School of Graduate and Postdoctoral Studies  
of the University of Ottawa in partial fulfillment of the requirements for the degree  
of

Doctor of Philosophy in Education



Library and Archives  
Canada

Bibliothèque et  
Archives Canada

Published Heritage  
Branch

Direction du  
Patrimoine de l'édition

395 Wellington Street  
Ottawa ON K1A 0N4  
Canada

395, rue Wellington  
Ottawa ON K1A 0N4  
Canada

*Your file* *Votre référence*  
ISBN: 978-0-494-79725-9  
*Our file* *Notre référence*  
ISBN: 978-0-494-79725-9

**NOTICE:**

The author has granted a non-exclusive license allowing Library and Archives Canada to reproduce, publish, archive, preserve, conserve, communicate to the public by telecommunication or on the Internet, loan, distribute and sell theses worldwide, for commercial or non-commercial purposes, in microform, paper, electronic and/or any other formats.

The author retains copyright ownership and moral rights in this thesis. Neither the thesis nor substantial extracts from it may be printed or otherwise reproduced without the author's permission.

**AVIS:**

L'auteur a accordé une licence non exclusive permettant à la Bibliothèque et Archives Canada de reproduire, publier, archiver, sauvegarder, conserver, transmettre au public par télécommunication ou par l'Internet, prêter, distribuer et vendre des thèses partout dans le monde, à des fins commerciales ou autres, sur support microforme, papier, électronique et/ou autres formats.

L'auteur conserve la propriété du droit d'auteur et des droits moraux qui protègent cette thèse. Ni la thèse ni des extraits substantiels de celle-ci ne doivent être imprimés ou autrement reproduits sans son autorisation.

---

In compliance with the Canadian Privacy Act some supporting forms may have been removed from this thesis.

Conformément à la loi canadienne sur la protection de la vie privée, quelques formulaires secondaires ont été enlevés de cette thèse.

While these forms may be included in the document page count, their removal does not represent any loss of content from the thesis.

Bien que ces formulaires aient inclus dans la pagination, il n'y aura aucun contenu manquant.

  
**Canada**

## **ACKNOWLEDGEMENTS**

A research study such as this is always a collaborative project and I acknowledge with appreciation those who have assisted in the many phases of the thesis.

Thanks must go to those who read and reread early versions of the thesis for clarity, misrepresentations, and misconceptions: Amélie Crosson, Julie Boyd, and to Annette Rossiter who also read a penultimate copy of the thesis.

I would also like to thank the teachers and the schools who agreed to participate in this research study. Although these people must remain anonymous, all contributed to the study and its educational significance.

Particular thanks to my thesis supervisor Dr. Marie-Josée Berger for her continuing support, encouragement, and important suggestions. Thanks also go to the members of my thesis committee: Dr. Renée Forgette-Giroux, Dr. Liliane Dionne, Dr. Awad Ibrahim, and Dr. Hermann Duchesne.

I also recognize the support of my husband, John, son, Stephen, and daughter, Juliette, who have given me their unqualified support through this process.

As this thesis nears completion, my family and I would like to remember K'leigh Cundall, a fourth year science student at the University of Ottawa, whose untimely death on December 5, 2005, added such sadness to this thesis journey.

## **ABSTRACT**

Studies indicate that teachers, and in particular science teachers in the senior high school grades, do not integrate laptop computers into their instruction to the extent anticipated by researchers. This technology has not spread easily to other teachers even with improved access to hardware and software, increased support, and a paradigm shift from teacher-centred to student-centred education. Although a number of studies have focused on the issues and problems related to the integration of laptops in classroom instruction, these studies, largely quantitative in nature, have tended to bypass the role teachers play in integrating laptop computers into their instruction.

*This thesis documents and describes the role of Ontario high school science teachers in the integration of laptop computers in the classroom. Ten teachers who have successfully integrated laptop computers into their biology courses participated in this descriptive study. Their perceptions of implementing laptops into their biology courses, key factors about the implementation process, and how the implementation was accomplished are examined. The study also identifies the conditions which they feel would allow this innovation to be implemented by other teachers.*

*Key findings of the study indicate that teachers must initiate, implement and sustain an emergent and still evolving innovation; teacher perceptions change and continue to change with increased experience using laptops in the science classroom; changes in teaching approaches are significant as a result of the introduction of laptop technology; and, the teachers considered the acquisition*

and use of new teaching materials to be an important aspect of integrating laptop computers into instruction. Ongoing challenges for appropriate professional development, sharing of knowledge, skills and teaching materials are identified.

The study provides a body of practical knowledge for biology teachers who are considering the integration of laptops into their instruction. The results are of interest to science teachers, those whose decisions affect the meaningful integration of technology in science education, those researching the teaching of science in secondary schools and those who prepare science graduates to teach at this level.

**Key Words:** *innovation, laptop, computer, biology, science, secondary, implementation, perceptions, instruction, professional development, qualitative, descriptive.*

## TABLE OF CONTENTS

Title Page	i
Acknowledgements	ii
Abstract	iii
Table of Contents	v
List of Tables	x
List of Figures	xi
List of Acronyms	xii
CHAPTER ONE: INTRODUCTION TO THE STUDY	1
Background of the Problem	2
Statement of Research Problem	4
Research Purpose and Questions	6
Definition of Terms	8
Organization of the Thesis	11
Chapter Summary	12
CHAPTER TWO: LITERATURE REVIEW	13
Implementing Innovations in Science Instruction	13
Implementing Laptops in Science Instruction	14
Implementing Desktop Computers in Science Instruction	22
Teachers Experience of Innovation in Science Education	34
Chapter Summary	43
CHAPTER THREE: CONCEPTUAL FRAMEWORK	47
Change, Implementation, and Diffusion: Theory and Models	48
Change Models	49
Implementation Models	50
Fidelity Perspective	51
Mutual Adaptation Perspective	51
Enactment Perspective	52
Diffusion Models	53
The Concerns-Based Adoption Model (CBAM)	57
CBAM Amended	65

CBAM Amended: The Conceptual Framework for the Study	69
Chapter Summary	70
Research Questions	71
CHAPTER FOUR: METHODOLOGY	73
Design of the Study	73
Qualitative Research	73
Descriptive Study	74
Data Collection	75
Site Selection	78
Background of the Participating Teachers	81
Adele	82
Keith	83
Xandra	85
Darby	86
Audrey	87
Zoe	89
Ross	90
Samantha	92
Richard	94
Kenneth	96
Data Analysis	97
Provision for Trustworthiness	101
Internal Validity and Reliability	102
External Validity	103
Significance of the Research	104
Chapter Summary	105
CHAPTER FIVE: ANALYSIS OF THE FINDINGS	106
A General Analysis of the Participants	107
Analyzing the Data	110
Question One: How do senior grade biology teachers perceive the integration of laptop	

computers into high school biology programs?	111
Type of Innovation	111
Supports during Innovation	112
Challenges to Innovation	113
Diffusion of the Innovation	115
CBAM: Contribution to the Analysis	117
Question Two: How do senior grade biology teachers perceive and introduce new teaching approaches integrating laptop computers into high school biology programs?	118
CBAM: Contribution to the Analysis	120
Question Three: What new teaching materials do senior biology teachers use when integrating laptop computers into high school biology programs? 121	
CBAM: Contribution to the Analysis	124
Chapter Summary	125
CHAPTER SIX: DISCUSSION OF THE FINDINGS	134
The Participating Teachers	134
Summary of the Findings	135
Enumerated Findings	137
Question One: How do senior grade biology teachers perceive the integration of laptop computers into high school biology programs?	138
Findings 1-10 and Discussion	138
Summary: Question One	150
Question Two: How do senior grade biology teachers perceive and introduce new teaching approaches integrating laptop computers into high school biology programs?	151

Finding 11 and Discussion	151
Summary Question Two	154
Question Three: What new teaching materials do senior biology teachers use when integrating laptop computers into high school biology programs?	155
Finding 12 and Discussion	156
Summary: Question Three	159
Design of the Study	160
Concerns-Based Adoption Model	163
Chapter Summary	167
CHAPTER SEVEN: CONCLUSIONS	171
Major Findings of the Study	171
Question One: How do senior grade biology teachers perceive the integration of laptop computers into high school biology programs?	171
Question Two: How do senior grade biology teachers perceive and introduce new teaching approaches integrating laptop computers into high school biology programs?	172
Question Three: What new teaching materials do senior biology teachers use when integrating laptop computers into high school biology programs?	173
Ongoing Challenges	173
Strengths and Limitations the Study	174
Implications of the Study	179
Practical Contributions on Educational Innovations	179
Contributions on the Implementation of Educational Innovations	182
Recommendations for Future Research	185

Concluding Remarks	187
REFERENCES	190
APPENDICES	
A	Detailed Description of the Findings 214
B	Detailed Description of the Analysis 305
C1	Percentage Frequencies by Decade of 12 Emerging Patterns in: Science Education Literature 332 Instructional Methods Teaching Strategy
C2	Percentage Frequencies of Top-Ranked Instructional Methodologies 333 by Decade 1955-1964 1965-1974 1975-1984 1985-
D	Ethics Review 334 Certification of Ethical Approval  Formulaire de consentement à l' intention du conseil scolaire 335 Board Consent Form 337  Formulaire de consentement à l' intention de la direction 339 Principal Consent Form 341  Lettre d'invitation et formulaire de consentement de l'enseignant(e) 343 Teacher Letter of Information and Informed Consent Form 347
E	Interview Questions 350
F	Summaries: Teaching Materials 354

## List of Tables

Table 2.1	Curriculum Documents: Orientation Continuum	35
Table 3.1	Perspectives: Implementation Models	50
Table 3.2	Models for Studying Diffusion	54
Table 3.3	Summary	55
Table 3.4	CBAM: Seven Stages of Concern	59
Table 3.5	CBAM: Six Levels of Use	61
Table 5.1	Type of Innovation	112
Table 5.2	Supports to Innovation	113
Table 5.3	Challenges to innovation	114
Table 5.4	Diffusion of the Innovation	117
Table 5.5	Teaching Approaches	120
Table 5.6	Previous Teaching Materials	122
Table 5.7	New Teaching Materials	123

## List of Figures

Figure 2.1	Changes in Curricular Orientations in Action	38
Figure 3.2	The Concerns-Based Adoption Model	64
Figure 3.3	Conceptual Framework for the Study	70

## List of Acronyms

AP	Advanced Placement
CBAM	Concerns-Based Adoption Model
SoC	Stages of Concern
LoU	Levels of Use
IC	Innovation Configuration
CBC	Canadian Broadcasting Corporation
CMC	Computer Mediated Conferencing
IB	International Baccalaureate
IT	Information Technology
LCD	Liquid Crystal Display
NGO	Non-Governmental Organization
PD	Professional Development
UOIT	University of Ontario Institute of Technology
NABT	National Association of Biology Teachers

## CHAPTER ONE: INTRODUCTION TO THE STUDY

Throughout my career in education, as a teacher and administrator, and through my graduate studies, I have become increasingly aware of disappointment and some frustration about the lack of change in science education, especially in the senior grades of high school. Originally, resistance to change was noted when new curriculum guidelines were issued or new teaching practices introduced. During my career, and the careers of many of the teachers who participated in this study, researchers such as Cuban (1995, 1983), and Postman (1996, 1993) documented and discussed education's "stubborn continuity" (Cuban, 1983, p160). Despite calls for change, I have personally witnessed the lack of long term impact on science education from innovations as diverse as: the use of film projectors, television, film strips, and VCRs; small group instruction and individual projects; provincial exams, no external exams, and the reintroduction of external exams; restrictive and controlling curriculum, laissez-faire curriculum, and the reintroduction of restrictive and controlling curriculum; and, the introduction of overhead projectors and desktop computers in elementary and secondary school settings.

Since then, and until the present time, research studies continue to indicate a pervasive lack of change in how senior science courses are taught, despite the contribution that desktop computers, and subsequently laptop computers, were expected to make to instruction. These research studies tended not to focus on the role of teachers during change, seeking instead to measure gains in student achievement and improvement in student attitudes.

Therefore, for this study, I have focused on ten teachers who introduced laptop computers into their biology classes. The study examines their role as teachers as they strive to integrate laptop computers into their instruction.

This first chapter provides the background, a genealogy if you like, to the lack of change in science education. It introduces the research problem, states the purpose of the research and presents the research questions. The terms used in the research questions are defined and a description is provided of how my thesis has been organized.

### **Background of the Problem**

Research studies have consistently indicated that teachers, especially teachers in the senior high school grades and teachers of science, have not integrated computers, even laptop computers, into their instruction to the extent the researchers anticipated (Bain & Weston, 2009; Coffland & Strickland, 2004; Dickson & Irving, 2002; Mara, 2006; Sclater et al., 2006). Existing studies on the integration of laptops have tended not to focus on the role of the teachers, focusing instead on student attitudes and measuring possible gains in student achievement (Chang & Tsai, 2005; Klopfer et al., 2005; Mouza, 2008; Trimmel, 2004; Webb, 2005). In addition, researchers have noted that the use of computers for instruction does not diffuse easily within groups of teachers, although this research was not designed to ascertain why this is the case (Chamblee & Slough, 2002; Coffland & Strickland, 2004; Newhouse & Rennie, 2001; Norton et al., 2000).

Laptop computers were first introduced into Australian schools in the late 1980s (Bain & Weston, 2009; Stolarchuk, 2001a), but integrating laptop computers into instruction remains a more recent innovation in Canadian schools and elsewhere around the world. While early research appears to support the premise that the use of laptops may improve instruction by decreasing teacher-centred instruction and increasing student-centred learning (Dunleavy & Heinecke, 2008; Higgins & Spitunik, 2008; Newhouse, 1999a; Windschitl & Sahl, 2001), the introduction of laptops does not automatically entail a change in modes of instruction. Some teachers in France and the United States, for example, were found to be using laptops as an add-on, with little change in their teacher-centred instructional practices. (Amankwatia, 2009, Donovan et al., 2007; Jaillet, 2004; Windschitl, 2002).

Despite a lack of studies focusing on the role of the teachers, a number of researchers have concluded that whether desktop computers or laptop computers are integrated into instruction, and how they are integrated, depends on decisions made by individual classroom teachers (Becker, 2000; Chamblee & Slough, 2002; Feldman, 2004; Higgins & Spitunik, 2008; Windschitl & Sahl, 2002). During the years 1990 to 2002, researchers cited the lack of hardware, the lack of appropriate software, and the lack of technical and professional assistance in schools as conditions that discourage teachers from effectively integrating computers into their instruction (Chamblee & Slough, 2002). In contradistinction to desktop computing, laptop computers have inherent advantages that would enhance their introduction as a teaching tool. These

advantages include: high access to hardware; universal access to readily available software; and on-site technical assistance. In spite of these inherent advantages, researchers in Australia, the United Kingdom and the United States still found few teachers who implemented substantial use of laptops in their classroom teaching (Bain & Weston, 2009; Higgins & Spitunik, 2008).

It was anticipated by these researchers that laptop programs, providing universal and ready access to hardware and software for both teachers and students, might address these obstacles. However, researchers continued to identify a similar pattern of under-use of laptops in the classroom and under-use of laptops for instruction. (Donovan et al., 2007; Jaillet, 2004; Stager, 2002 ). This study, investigating which factors influence teachers to introduce and integrate laptop computers into the teaching of science in the senior grades of high school is among the first of such studies that explore this issue from the perspective of teachers.

### **Statement of Research Problem**

Further study is needed to develop a body of knowledge about how laptops have been implemented into teachers' instructional practices (Dunleavy & Heinecke, 2008; Mara, 2006; Newhouse, 2001a; Siegle & Foster, 2001). It is important to identify the most effective and useful means of implementation.

Researchers have found that the degree to which laptops and desktops are integrated into classroom instruction is based largely on decisions made at the classroom level by individual teachers (Hakverdi, 2005; Windschitl & Sahl,

2002). As Bain & Weston (2009) observe the problem was analyzed a decade ago. The early research suggests that a relatively low number of teachers have integrated this technology into their instruction (Parr, 1999; Tebbutt, 1999), and the pedagogy and instructional practices of successful and early innovators are not widely known (Dunleavy & Heinecke, 2008; Siegle and Foster, 2001). This enhances the rationale for this study. All of the above facts and factors underscore the pertinence, timeliness, and importance of the study reported herein.

Not only is the number of successful innovators of computer technology for instruction low, the population of teachers using such technology has not grown to the extent that researchers had expected (Bain & Weston, 2009; Higgins & Spitulik, 2008; Parr, 1999; Tebbutt, 1999;). The factors retarding diffusion of this innovation appear to be complex, involving fixed and largely unexamined opinions about what constitutes effective teaching and a lack of subject specific expertise in integrating computers into classroom instruction (Higgins & Spitulik, 2008; Windschitl & Sahl, 2002). For these reasons, among others, diffusion of laptops and computer technology in the senior high school grades was identified as particularly slow.

To determine the obstacles to integration and ways of overcoming the reluctance to integrate, there is a need to describe and interpret teachers' perceptions about the process they undertook, the problems they faced, and how they accomplished the integration. Perceptions are defined in this study as teachers' intuitive insights based on their experiences in classrooms, schools,

and their years of studying and teaching science. Such an examination of their perceptions would allow us to develop a model for successful implementation and diffusion and to better understand which factors aid and which retard the effective integration of laptop computers in teaching and learning. This present study, therefore, has two objectives. It proposes to examine perceptions of the ten teachers included in the study sample concerning the implementation of laptop technology in high school biology courses and how this innovation affected their instructional practices, and offers an opportunity to learn from these early implementers in order to identify what would make this technology more attractive to teachers and advance how its integration in the classroom.

Admittedly, a number of related issues may influence whether laptop computers are integrated into instruction in senior science classes. It remains an open question, for example, if the integration of laptop and desktop computers into classroom instruction is determined by individual teachers, by the curriculum or by the availability of resources such as hardware and software. This constraint is more pressing for the sciences given the lack of a body of knowledge, pedagogy, and theory on integrating laptops in the context of science instruction and in the setting of science classrooms especially in courses in the senior grades of high school.

### **Research Purpose and Questions**

The literature on implementing laptop programs indicates that teachers must have access to information about how laptop instruction could be integrated

into their specific subject areas and to the support needed to effect this integration (Galanouli et al., 2005; Sasseville, 2004; Siegle & Foster, 2001). Studies by these researchers and by Clark (2006), recommend further research into teacher perceptions about high access computing such as laptop programs that provide universal and ready availability of computer resources, and further research on the pedagogical needs of individual teachers, the range of laptop applications to the curriculum, and the strategies for implementing laptop programs in specific content areas.

Despite the general assumption that how laptops would be used in curricular instruction is obvious (Donovan et al. (2007), teachers who undertake this innovation generally have little assistance and can experience stressful intellectual, pedagogical, and time demands. Dunleavy & Heinecke (2008 and Tebbutt (1999) call for studies focusing on teacher insights into integrating laptop computers in science education because such studies, despite their relevance to practising teachers, have not been published in academic journals and are not in the public domain.

The descriptive study reported herein is designed to obtain qualitative data on teacher perceptions of instructional changes in high school biology programs that integrate laptop computers. Based on their experiences in classrooms, schools and their years of teaching, teacher perceptions provide intuitive insights into what constitutes effective integration and diffusion of laptop computers into science instruction and how to deliver laptop courses specifically in this subject area. Although previous studies have had only limited contact with high school

biology teachers, this study examines the integration and diffusion process from the perspective of these teachers.

In order to fulfil the objectives outlined on page seven, to examine the perceptions of biology teachers who have successfully integrated laptop technology into their instruction and learn from their experiences, this descriptive study is based on the following research questions:

Question One: How do senior grade biology teachers perceive the integration of laptop computers into high school biology programs?

Question Two: How do senior grade biology teachers perceive and introduce new teaching approaches when integrating laptop computers into high school biology programs?

Question Three: What new teaching materials do senior grade biology teachers use when integrating laptop computers into high school biology programs?

### **Definition of Terms**

Change results from the substitution of one thing for another (Webster, 1997).

Sasseville found teachers believe they can control change using their accumulated knowledge and professional experience. "They perceive professional knowledge as a way to steer technological change in a direction they can understand and which they feel is beneficial for their students."

(Sasseville, 2004, p 12)

Diffusion is the process by which an innovation is communicated through certain channels over time among members of a social group (Kirschner et al., 2004), or is defined as the spread of information and ideas that were previously unfamiliar and that may result in the adoption of an innovation (Marsh & Willis, 1995, p 132). Rogers defines diffusion as the process by which an innovation is

communicated through certain channels over time among members of a social system, but adds that it is a special type of communication, in that messages are concerned with new ideas (Rogers, 1995, p 5).

Dissemination is defined as to scatter or spread widely: to promulgate extensively (Webster, 1997), to disperse throughout (Merriam-Webster Online Dictionary, 2009), or an intentional effort to inform individuals or groups about an innovation and to gain their interest in it (Marsh & Willis, 1995, p 132). In this study dissemination refers to the planned spread of an innovation to teachers, often involving a change agent responsible for having the teachers initiate new practices in their classrooms.

Implementation is the process of putting into effect according to a definite plan or procedure (Webster, 1997), or to give practical effect to and ensure of actual fulfilment by concrete measures (Merriam-Webster Online Dictionary, 2009). Fullan & Park state that implementation is a multi-dimensional process and three types of change are necessary: the use of new materials, the introduction of new teaching approaches, and the incorporation of new perceptions about teaching (Fullan & Park, 1981).

Innovation is a process or product that is new to a potential user (Hall et al, 1979), the introduction of something new, or a new idea, method, or device (Merriam-Webster Online Dictionary, 2009).

Integration is the act of combining parts into a whole (Oxford Dictionary, 2003), or the process of altering practices, and is considered to have been achieved in this

research study when “the course could no longer be taught without computers” (Anderson, 1995, p3).

Laptop program is a program where teachers and learners have individual laptop computers and share the same software and where the laptops have been integrated into the instructional process (Stolarchuk & Fisher, 2001a).

Perception is the act or faculty of apprehending by means of the senses or the mind. An immediate or intuitive recognition or appreciation: an insight (Webster, 1997), or a quick, acute, and intuitive cognition (Merriam-Webster Online Dictionary, 2009). The perceptions voiced by the teachers in this study are an important part of the data collected and included, but were not restricted to, perceptions about and their experiences with types of change, as well as supports and challenges to the change they undertook.

Teaching materials: Materials refer to the articles or apparatus needed to make or do something (Webster, 1997), or something used for or made the object of study such as teaching material for the next semester (Merriam-Webster Online Dictionary, 2009). Teaching materials in this study refer to objects that are created by the teachers and/or used for instruction in their classrooms.

Teaching approaches: Approach refers to the method used or steps taken in setting about a task (Webster, 1997), or the taking of preliminary steps toward a particular purpose, such as *experimenting with new lines of approach in the classroom* (Merriam-Webster Online Dictionary, 2009). In this study, teaching approaches include, but are not restricted to, lab activities or exercises, lectures, discussions, teacher demonstrations, and use of audio-visual aids.

## **Organization of the Thesis**

The thesis is organized into seven chapters. This first chapter introduces the background to the research, the research problem, and the research questions. The terms used in the research questions are defined and a description is provided of how the thesis has been organized. In the second chapter I review the literature relevant to change in high school science classrooms when laptops are integrated into instruction, change in science classrooms when desktop computers were made available in schools, and literature on the history of change, or its absence, in high school science classrooms. The third chapter provides a review of the literature on change theory and develops a conceptual framework for the study. In the fourth chapter, I focus on the methodology that guided the study. This chapter includes a discussion on the design of the study and ways of achieving reliability and validity in qualitative research. It also provides information central to this study, including: details of the site selection; a profile of the teacher participants; an outline of the instruments used to obtain data; the modes of analysis; and, criteria for interpreting the findings. For the purpose of clarity, the research questions were used to organize the results and discussion in chapters five, six and seven. In chapter five I provide my analyses of the steps taken by the teachers in order to implement the integration of laptop computers in their instruction. In chapter six I discuss how the research literature illuminates the teachers' perceptions of how their practices changed when implementing the integration of laptops into their teaching practices. In chapter seven, I discuss the practical and theoretical

contributions of the study to knowledge of instructional and instructor change, the implications and limitations of the study, and offer suggestions for future research in the area.

### **Chapter Summary**

This chapter has outlined the background of the study, stated the research problem, the need for the study, and the research questions. It explains the organization of the study and provides the definitions used in the study. The literature review in Chapter Two explores innovation and implementation of laptop computers and desktop computers, and the lived experience of innovation in science education at the high school level of the teachers in my sample.

## **CHAPTER TWO: LITERATURE REVIEW**

During the careers of the science teachers who participated in this study, a number of technological and curricular innovations have been introduced in science education with varying degrees of success. This literature review examines how the nature of selected initiatives, combined with the context of teaching science in schools has influenced the implementation of these innovations in classrooms. Articles and studies on integrating laptop computers, integrating desktop computers, and integrating curriculum innovations in science instruction are reviewed in this chapter.

### **Implementing Innovations in Science Instruction**

Innovation is defined as any process or product that is new to a potential user (Hall et al., 1979). Integration is defined as the process of altering practices so that the innovation can be accommodated. A laptop program is defined as one in which teachers and learners have individual laptop computers and share the same software, and where the laptops have been fully integrated into the instructional process (Stolarchuk & Fisher, 2001a).

A number of teachers are currently implementing laptop technology in their senior biology courses. In searching the literature for studies on integrating laptop technology into high school courses, I found that the studies I located dealt mainly with middle and elementary school grades, tertiary institutions such as colleges and universities, and with subjects other than science. Therefore, in

order to broaden the base of the literature review, I sought studies on integrating earlier forms of computer technology, that is, desktops, and research on how science teachers, such as the teachers who participated in this study, have integrated curriculum innovations into their classroom teaching. I then examined the research I selected for the perspective it could provide on the effective integration of laptop computers into instruction in senior biology courses.

### **Implementing Laptops in Science Instruction**

The literature review focuses first on research studies that provide background information on the integration of laptop computers in classrooms, then considers studies on the integration of laptop computers in science instruction in senior high school grades, followed by an examination of studies that focused on how the laptops were actually used by science teachers in their classrooms.

Existing research on the use of laptops in classrooms concludes that there is a general pattern of under-utilisation (Bain & Weston, 2009; Jaillet, 2004; Mara, 2006; Sclater et al., 2006; Stager, 2002). Few teachers have implemented substantial and substantive use of laptops (Bain & Weston, 2009; Newhouse, 2001a). In the research cited above, some have used laptops to augment their teaching practices, but this has not resulted in effective or complete integration of laptop computers into their classrooms (Higgins & Spitulik, 2008; Jaillet, 2004; Siegle & Foster, 2001). Teachers have perceived that changing established teaching practices is a risk to delivering the curriculum and a risk to maintaining

the good opinion of their peers (Breslow, 2007). More recently, changing practices to integrate laptop computers into instruction has been viewed more favourably, as a collegial undertaking with the prospect of adding value to teaching (Harvey & Kamvounias, 2008; Kane, 2003) and to the students' learning (McMahon, 2007). Nevertheless, it has been argued, even with academic and technical support, the proportion of teachers using laptops for instruction in classrooms remains low and despite increased technical support in the school, peer support in each curriculum area in the school, and a coordinator to facilitate the work of peer coaches, teachers have remained reluctant to adopt this technological tool (Bain & Weston, 2009; Varma et al. 2008).

Researchers, including Bell & Bell (2005) and Newhouse & Rennie (2001) identified factors that influenced the use of laptops for instruction. Factors advancing the integration of laptop computers included the expectations of school administrators and parents that the laptops would be used for instruction. The more recent research has also identified the following elements as advancing the integration of computers in classroom instruction: a collaborative management style at the school (Bell & Bell, 2005), especially when combined with formal and informal opportunities for teacher learning; a culture of high expectations; and, a sufficient financial investment by the school in the innovation (Fullan, 2007; 2006; 2005). Factors that hinder this integration include: the perception that others (colleagues, parents, students) might not support a change in teaching approaches; a concentration on external standardized testing that diverts resources from other projects; a lack of time to manage innovation;

and, the lack of expert assistance. The allocation of support staff in schools is often not considered for science teachers, or for students learning in science laboratories, but rather is typically focused on special education (Levin & Fullan, 2008). Earlier researchers in the field, including Newhouse (2001a) found that teachers who initially maintained a neutral response about integrating laptops became increasingly negative, based on their perceptions of existing attitudes, beliefs, preferred instructional practices, early obstacles they experienced implementing laptops, and obstacles experienced by other teachers.

Laptops were first introduced into Australian schools in the late 1980s with considerable care, expertise and enthusiasm (Klieger et al., 2010; Bain & Wilson, 2009; Stolarchuk & Fisher, 2001a). In a series of papers dealing with education in elementary and secondary schools, Stager reports that in the fifth year of a laptop program, Methodist Ladies College in Melbourne, Australia, had 2,000 students and teachers with personal laptop computers. By 1998, Stager reported that 50,000 Australian students had their own laptops. Yet, he quotes Australian government figures indicating that in 2002, less than half of these students spent 40 minutes a week using the laptop computers at school and two-thirds of the students spent less than an hour doing so (Stager, 2002). This low level of use was evident despite, as he had said, wide-spread awareness in the schools and school systems of the importance of best practices to overcome obstacles to laptop use and to facilitate the use of the laptops in and beyond the classroom.

Other studies report similar patterns and confirm a low utilization of laptop computers in Australian schools at that time (Newhouse & Rennie, 2001). In

France, Jaillet (2004) observed a similar pattern, but in his research he was able to ascertain that where students were using laptops more frequently, the students were accessing inappropriate (i.e. non-academic) sites and games. Thus, the introduction and the use of laptops for genuinely educational purposes remain as challenges to those who would integrate time in their classroom teaching.

Researchers note that the presence of laptops alone did not necessarily initiate change in instructional practices sufficient to ensure integration (Donovan et al., 2007; Dunleavy & Heinecke, 2008; Jaillet, 2004; Newhouse, 1998 a,b; Ward & Parr, 2010; Windschitl, 2002). The researchers noted that teacher beliefs about what constitutes good teaching was a powerful influence on whether laptops were used effectively and that the amount of time students used their laptops, and what they used them for, depended to a great degree on the teachers' perceptions. All in all, few teachers implemented substantial computer use, and many teachers who did perceived a very limited role for the laptops. Factors that impeded the implementation of instruction with laptops included a perceived lack of time and encouragement. In addition, changing established teaching practices was perceived by teachers as a risk to both the curriculum and the good opinion of their peers. It was noted that the research that was available provided little direction for teachers about how to use laptops in their teaching, and most importantly did not provide specific examples for usage in their subject area. Researchers, in seeking to improve the integration of new

technologies called for training, and time for teachers to reflect on their practices and pedagogy.

Early researchers, including Siegle and Foster, 2001, noted evidence of a general pattern of underuse of the laptop computers, especially in senior high school grades and in science courses in those grades. Researchers still conclude that teachers need more subject-specific knowledge and assistance on how to teach science with laptop computers (Dunleavy & Heinecke, 2008; Higgins & Spitulik, 2008; Klopfer et al. 2005). As was stated earlier, have largely avoided a focus on teacher concerns about integrating laptops into instruction, what influenced them to try, or how they sought to accomplish this integration. Invariably, there is little to no indication that the researchers asked the teachers about their concerns about integrating laptops into their instruction. The research on integrating laptops into instruction in science has continued to by-pass the role of the teacher and has clustered around student achievement, attitudes and class environment (Chang & Tsai, 2005; Klopfer et al., 2005; Mouza, 2008; Owusu et al., 2010; Webb, 2005). As Loucks-Horsley (1998), one of the developers of a model used to study educational change observed, our understanding of integration is jeopardized because researchers tend to focus on student learning before teachers are comfortable with new teaching approaches and new teaching materials.

One case study however, did deal with the use of laptops in the teaching of biology at the senior high school level (Siegle & Foster, 2001). The researchers concluded that the laptop computers had been used as a

supplementary add-on to the course and that the teacher had not made any effort during the year of observation to integrate the laptops more fully into instruction. They concluded that additional research was required into different approaches to teaching with laptop computers. In other case studies that attended to the views of teachers, it should have been possible to hear the voices of science teachers in grades 11 and 12 involved in laptop programs (Newhouse & Rennie, 2001). In fact however, it is quite difficult to differentiate what the science teachers are saying from what the teachers of other subjects report. What is clear in these studies is that a large percentage of senior students reported that the laptops were never used in science class, even though most of these students reported using laptops in the earlier grades of high school. These students also reported that the laptops were often used in English, mathematics, computing and art classes. In a more recent study, Zucker and Hug (2008) report a quite different pattern of usage in high school physics, where a majority of the students in their sample reported using the laptops every day and many of the remaining students reported using the laptops once a week. Much of the laptop usage data reported by Zucker and Hug is attributed to frequent use of electronic textbooks, whole-class presentations projected from the teachers' laptops, word processing, student presentations and the use of probes for lab experiments—materials and resources which would not have been available to teachers in the earlier studies.

There are a number of studies that speak to the issue of teaching science with laptop computers, but the specific grades in high school in these studies are

not identified (Varma et al., 2008; Phillips et al., 1999; Tebbutt, 1999). Tebbutt (1999) found little use of the laptop technology in science, even in schools which had made substantial provisions for their use. Phillips designed a study to measure the change in the use of laptop computers by teachers. This research was not as useful as it might have been because the design did not differentiate between teachers' personal use and their instructional use of laptops. This being said, it did differentiate between science teachers and teachers in other subject areas. It was reported in this study that science teachers had increased their personal and instructional use of laptops less than had teachers in music, art and health education, or deputy heads of school, but were as active, or more active, in their personal and instructional use of laptops than were most other teachers. In the same study, the researchers tried to take into account the fact that some teachers had greater expertise than did others at the beginning of the study by establishing another indicator to reflect only new activities teachers had undertaken with laptop computers. Again, science teachers introduced significantly fewer new activities using the laptop computers than had teachers of English, music, art, health education, or deputy heads of schools, but were more active in the combined personal and instructional use of laptops than most of the other teachers.

As Bain & Weston (2009) observe, the problem was analyzed a decade ago. Early researchers, including Tebbutt (1999), Lowther (2003) and Owen and Lambert (1998) concluded that poorly understood factors, such as the amount of time, effort, and organization required of the teachers to use the laptops

effectively were pivotal factors, and that by itself, the technical ability to use laptop technology was not sufficient to insure that teachers would integrate the laptops into instruction. Few differences in teaching methods between laptop classrooms and control classrooms were reported and there was a lack of empirical evidence to document the difference laptops make to instruction, but the burden on teachers seeking to integrate laptop computers into their teaching was noted. Researchers, including Higgins & Spitulik (2008) describe what they call a double innovation which they say includes: first, learning about the technology, peripherals, the software appropriate for their students, and the management of computers in the classroom; and then, implementing an appropriate curriculum for the technology, which means dealing with content, teacher roles, assessment and student achievement. While acknowledging the importance of the teachers in this double innovation process, none of the studies dealt with the decisions teachers make about adopting and integrating laptop computers into their curriculum or about how they accomplish or seek to accomplish this integration (Dunleavy & Heinecke, 2008; Higgins & Spitulik, 2008). There remains a need, therefore, for studies focused on teachers as they strive to integrate laptop computers, and on the diffusion of instructional practices using laptops in biology courses at the senior high school level. If relevant pedagogy and theory are to be developed in this area, there is a pressing need for description on the decisions teachers make as they work to integrate laptop computers into their instructional practices (Higgins & Spitulik, 2008; Mara, 2006; Varma et al., 2008).

Having reviewed the general picture of how teachers use laptops in biology and senior science courses, it is worthwhile to focus on how teachers use the laptops in their classrooms. Researchers, such as Higgins & Spitulik (2008) and Tebbut (1998), established that science teachers use the laptops differently than teachers in other subjects. Data logging, word processing, Internet use, databases for cataloguing samples, simulations and mind-mapping software were used by individual science teachers; however, these practices remained isolated to their classrooms; they did not diffuse readily to science teachers working in other classrooms. Researchers note that there remains a perceived lack of subject-specific professional development (Klieger et al.2010; Simmie, 2007) as teachers continue to require academic support in their specific subject areas, as well as technical support with a similar specific-subject focus Higgins & Spitulik, 2008; Klieger et al.2010; Varma et al., 2008). Other researchers note that teachers prefer to receive the professional development sufficient to support laptop integration from those who teach the courses they teach (Bell & Bell, 2005).

### **Implementing Desktop Computers in Science Education**

As indicated in the introduction to this chapter, the studies I located for this literature review dealt mainly with middle and elementary grades, tertiary institutions such as colleges and universities, and with subjects other than science. For these reasons, I broadened the base of this literature review by seeking studies on the integration of earlier forms of computer technology, that is

to say. During this process of broadening my search to the integration of desktop computers into instruction, I located only one study on the advantages and disadvantages of laptops compared with other computer technologies such as desktop computers (Smith et al., 1999). This study, carried out at the post-secondary level in the United States focuses on such disadvantages of laptops as expense, fragility, and security issues, and offsetting advantages of laptops, such as portability and flexibility which allows them to be used in lecture rooms and labs. In this study, mention is made of the computers being used as an add-on to courses, their use for student presentations, and the increased opportunities for the active learning that laptops can provide, but these aspects of the integration of laptops into instruction are not developed in this research. In an Australian study carried out at the same time, it was noted that few of the benefits claimed for laptop programs are specific to laptop technology (Albion, 1999), and for these reasons, and in order to provide an additional perspective on the integration of laptops, I will now review information from research studies on teachers who seek to integrate desktop computers into classroom instruction.

The teachers in this study dealt with desktop computers, for personal use if not for instruction in their respective classrooms, and then made the transition to laptop computers sometime in the late 1990's or early 2000's. Since desktops were introduced into schools before laptops and since they remain the dominant form of computers in most schools, there is a thicker body of research available on the use of desktops for instruction which gives context to the perceptions of the teachers who participated in this study. This more extensive body of research

was examined in order to explore instructional uses of computers and to glean concepts that may aid us in better understanding the integration of laptop computers in classroom teaching. This segment of the literature review examines the following: the background of teachers using desktop computers; the factors affecting the integration of desktop computers into biology and senior grade science courses; and, how the desktops were used in these courses.

Becker (1994) examined teacher backgrounds in order to document which science teachers were most successful at mastering the challenges of using desktop computers effectively in the classroom. He found substantial personal differences between exemplary computer-using science teachers and other science teachers. The most important factors he identified included: the exemplary science teachers spent twice as many hours working on computers at school; they had significantly more advanced degrees and credits; and, they tended to be males, and spent over twice as much time on computers at home. Minor factors that he identified included: the exemplary teachers had formal instruction about computers and about teaching with computers; they had undergraduate majors in science (not education); if they were secondary science teachers, they had more years of experience teaching and teaching with computers; and, they had learned about computers and about teaching with computers on their own. Becker acknowledges the difficulty in isolating the effects of years of experience in the classroom, years of experience with computers, and the opportunity to collect more credits and degrees, since, as he notes, additional degrees, credits, and opportunities using computers, tend to be

accumulated by teachers with more teaching experience. Both Becker (1994) and later, Davis (2006) have observed that teachers with strong subject matter knowledge and strong interest in the subject matter they teach tend to employ, or at least consider, more effective or innovative teaching strategies and these factors may differentiate those teachers who integrate computers effectively in their classroom instruction from those who do not. Simmie (2007) in a more general study on innovations in biology classrooms in Ireland, confirms the creativity and commitment of biology teachers who undertake curricular innovations.

A large quantitative study (n=516) in the United States reported that very few teachers were exemplary users of desktop computer technology (Becker, 1994). Exemplary users were defined as teachers who used a wide range of software, including software for: writing, electronic communications and accessing the World Wide Web (WWW); and, spreadsheets and software for graphing, analyzing data, accessing databases, problem solving and simulations. When the results were adjusted to account for the teachers who were not using computer technology at all, the percentage of teachers whose use of computers was exemplary fell to only 3 percent! Five years later, in another large quantitative study, Becker and his colleagues reported that only one third of teachers assigned work which required the use of computers on a regular basis (Becker et al., 1999). In this same study the researchers found that, except for word processing and information gathering functions, relatively few senior high

school teachers in academic subjects experimented with computer simulations software, graphics software, presentation software, spreadsheets or databases.

The reasons behind this data prove important in giving context to the data elicited in the present study. In the studies reviewed, teachers expressed concerns that integrating computers would increase an already heavy workload, not only in the short term, but for years to come (Becker, 1994; Bybee, 1996a; Gershner & Snider, 1999). In a qualitative study conducted in Canada, Reid (2002a) found that teachers required time—time to learn to use the technology and time to customize their teaching materials or to create new teaching materials if they were to integrate desktop computer use in a meaningful manner or take advantage of the instructional capabilities of computers. Researchers estimate that it would take teachers at least five years of additional work to integrate computer technology fully and effectively into their teaching (Becker, 1994; Snyder et al., 1992).

Becker hypothesized that the integration and diffusion of computer technology among teachers might depend on three primary factors. First, integration and diffusion might be dependent on the degree of use by other teachers and ready access to software and hardware. Second, integration and diffusion might be dependent on the technical, professional and individual support teachers received. Third, researchers might find that diffusion was dependent on changes in teacher beliefs and on the instructional practices they selected. In this last case, Becker predicted that the diffusion of the classroom integration of computing technology would be slow and difficult. The diffusion of

the integration of desktop computers into instruction has, in fact, been slow and the teaching practices that might encourage teachers to persevere with integrating computers have not been ascertained, nor has the argument that the integration of computers into classroom teaching requires the adoption of new teaching practices (Dexter et al., 1998; McRobbie & Thomas, 1998).

An examination of research on desktop use by biology and senior science teachers reveals, as was noted in the research on laptop computers, that many studies researching the integration of desktop computers into biology courses tended to focus on student achievement and/or attitudes (Alonso, 1998; Carmack, 2000; Kim, 1997; Lu, 1993; Parker, 1998; Parker 1995; and Zeitz, 1992). Four other studies were located that investigated the use of desktop computers in science courses. One of these four studies focused on media literacy in high school students (Bajkiewicz, 2002), while another focused on student and teacher attitudes in high schools (Paul, 2005). The third study researched changes in pedagogical beliefs and teacher attitudes as science teachers integrated desktop computers into their classroom instruction (Hendren, 2000). In the fourth study, Hakverdi (2005) researched desktop computer use by high school and middle school science teachers. A brief review of these studies proves enlightening and pertinent to my research.

Hendren (2000) found that teachers who provided student-centred active learning opportunities were more likely to use desktop computers and he identified a gap between most teachers' actual and ideal use of desktops, which he attributed to lack of time, lack of technical support, and lack of readily

available computer hardware and software. Hakverdi (2005), in a large quantitative study, determined that it was the teachers who were pivotal in determining if computers would be used in science classes. He found that individual teachers needed help in learning how to integrate the desktop computers into their teaching and that such help was generally not available. Further, he found that teachers were left to develop the necessary teaching materials and lesson plans requiring desktop computer use independently. He also noted that the challenges of integrating computers into laboratory instruction posed unique difficulties for science teaching compared to teaching in other subject areas. As well as information on appropriate pedagogical approaches, teachers needed practical assistance, including: a database of exemplary desktop-integrated activities; and, access to scientific websites for teaching science concepts. Hakverdi recommended that future research include follow-up interviews with science teachers in order to get a deeper understanding of their beliefs and practices as well as in-depth information on the factors influencing their ability to integrate desktop computers and their interest in accomplishing this integration.

The research on the use of desktops also provides general information on how the desktops were and are being used in science classrooms. Compared to a general population of teachers, less than half as many science teachers reported assigning work that required desktop computers on a regular basis. Not only were science teachers less likely to assign tasks requiring the desktop

computers, they were also less likely to assign independent student work requiring the use of a computer (Becker et al., 1999).

A number of quantitative studies such as Becker (1994) and Hakverdi (2005), and a few qualitative studies such as Windschitl & Sahl (2002) indicate that science teachers may be slower to integrate desktop computers into their courses than are teachers in other subject areas. These studies identify concerns that may be influencing the decisions teachers make when they consider adopting and implementing this innovation. Some, but not all of these concerns are specific to science teachers and include: available peer support; a perceived lack of time to implement innovations; the teaching approaches science teachers selected for lessons; equality of student access to desktop computers and computer resources; and a perceived lack of resources if desktops are to be used for science instruction.

Becker (1994) found that peer support is particularly important to science teachers, yet teachers integrating desktop computers into their instruction face unique and personal challenges for which little support is available. For example, teachers who are ahead of them in the implementation process, or who are behind them, may be dealing with very different concerns about the integration process thus limiting pedagogical sharing. Further, other science teachers have limited time to provide technical or professional assistance to their peers.

Bybee (1996a) anticipates that it would take science teachers three years to deal with their initial concerns about integrating desktop computers into their programs and noted that even after that time the teachers would continue to

become aware of problems with the technology that they had not anticipated. Dealing with the unexpected, in the daily context of managing different classes and courses while meeting the needs of large numbers of students through the implementation of such a complex technological innovation, adds substantially to teacher workloads and so may influence if and how desktops are integrated into classroom instruction.

Studies indicate that science teachers begin to integrate desktop computers only when they are satisfied that all students have equal access to hardware and software. The equal access must be during class, in the school, and outside the school (Becker, 1994). Operationally, science teachers begin integrating desktop computers when there is a ratio of four students to each computer, and, unlike teachers of other subjects in the school, science teachers begin integrating desktops only when they have software sufficient in capacity and availability to plan whole-class activities (Becker & Ravitz, 1999).

Some of the concerns outlined above allow us to understand that science teachers, perhaps more than teachers of other subjects in the school, report having to deal with situations where there was a limited range of software available for instruction. In addition, science teachers reported that software they intended to use had often gone missing, that software was unexpectedly not available, or that software was more difficult to use than expected (Becker, 1994; Becker & Ravitz, 1999). They noted that they must use the hardware and software provided at the school and must cope with the consequences of any consequent unreliability (Reid, 2002a). This unreliability makes classroom

teaching very time-consuming and adds a stress factor that can impede integration.

In summary, more than other teachers, science teachers reported having to deal with a limited range of software and with software that was not available or was difficult to use (Becker, 1994; Becker & Ravitz, 1999). They expressed a need for sufficient hardware, one computer for every four students, and software sufficient to support whole-class activities (Becker & Ravitz, 1999), as well as equality of access to hardware and software for all students, both in class and outside of the classroom (Becker, 1994). Given these concerns, science teachers said the conditions in which they had to use desktops in schools, typically fell below the critical level of knowledge, support, and availability that would encourage them to integrate computers in their courses.

The science teachers' expressed interest in teaching in a whole-class context may reflect the adaptation requirements they face in changing from teacher-centred to student-centred teaching practices (Becker, 2000; McRobbie & Thomas, 2000). As was stated earlier, computers can be used to sustain a teacher-centred perspective in the classroom with little change in instructional practices (Ruthven et al., 2004; Rutherford, 2005). On the other hand, some researchers (Becker & Ravitz, 1999; Dexter et al., 1999; McRobbie & Thomas, 1998) have noted that integrating desktop computers into instruction may correlate with a transition to student-centred instructional practices.

Perhaps oddly, the conditions which inhibit the use of desktops for instruction do not appear to affect science teachers' personal use of desktops to

facilitate their own work. Notwithstanding a low level of experience in integrating desktop computer technology into instruction, science teachers report their personal use of desktop computers facilitates other aspects of their work. Science teachers use desktop computers quite differently depending upon the frequency of their computer use. Science teachers who use desktops personally on a weekly basis or more often, reported using them most frequently as a medium for preparing handouts, for recording student grades, for composing lesson plans or notes, and, least frequently, for getting information from the Internet (Becker et al., 1999). Science teachers who personally use desktops only occasionally reported using them for: corresponding with parents; exchanging files with other teachers; in conjunction with the use of camcorders, digital cameras or scanners; and, least frequently, for posting materials on the Web. In their personal use of computers, a different pattern of lower-level and higher-level use by different populations of science teachers is evident.

Overall, the research provides what will, for some, be a disheartening picture of low use of desktop computer technology by science teachers for instruction, who assign few tasks to students that require the use of desktop computers. The research reveals that senior high school teachers use desktops mainly for word processing and information gathering functions, rather than for higher level computer functions, such as the use of simulations, spreadsheets, graphing and data logging software. Even so, it is worthwhile to examine in more detail how desktops were used by biology and senior science teachers. Becker et al. (1999) observed that science teachers in their sample who did assign tasks

involving desktop computers at least ten times a year, reported that their objectives included student use of desktops for: word processing; accessing the WWW; CD-ROMS; spreadsheets; databases; graphics, simulations and exploratory environments; email; skill/practice games; and multimedia. These science teachers, teachers assigned work requiring desktops to students, differed most from other science teachers in their use of a wide range of: spreadsheets; presentation software; Netscape, and CD-ROM reference software (Becker et al., 1999).

Becker found that the small percentage of science teachers in his sample using desktop computers as teaching and learning tools were more likely than teachers of other subjects in the schools to assign only word processing tasks. Senior high school teachers were less likely to use computer simulations, graphics, spreadsheets, databases, or presentation software than teachers in the earlier years of high school. Eventually, other researchers began to observe the occasional use in classrooms of new teaching materials, including: Internet browsers; laboratory sensors; data logging; graphing software; mathematical models for predicting and testing theories; software for publishing, record keeping, and authoring web pages; and PowerPoint presentations. These uses of desktop technology, however, were neither widespread (Reid, 2002a; Rogers & Finlayson, 2003), nor fully integrated in classroom teaching.

Other researchers report that teachers need expert assistance in their subject area and that the teachers' personal computer expertise is not a good predictor of whether the computers are used for instructional purposes (Phillips et

al., 1999). Integrating desktop computers to the degree that courses cannot be taught without them requires skills in dealing with multiple and complex changes in the classroom (Anderson, 1995). Germann and Sasse (1997) confirmed that integrating desktop computers into science instruction involves successfully implementing multiple innovations over many years.

### **Teachers' Experience of Innovation in Science Education**

The first two sections of this literature review have highlighted what research reported was happening in schools while the science teachers who participated in this sample were using desktop computers, and later laptop computers. This research on desktop computers conducted largely in the 1990s, and the research on laptop computers, conducted largely in the 1990's and 2000's, gives context to the lived experiences of the science teachers who contributed their perceptions for this study.

Currently, there is substantial evidence (Marbach-Ad and McGinnis. 2007) that teachers' perceptions of the teaching and learning they have experienced influence the decisions they make in the classroom. To paraphrase Marbach-Ad and McGinnis, teachers' past events create personal images that act as a filter for new information and may be resilient enough to become the standard to which new information is compared. Other researchers, such as Cuban (1983) have established that how science teachers were taught science in high school and in science faculties at universities is instrumental in influencing how they teach science in their classrooms. In proposing this research I thought it likely

there would be teachers in the sample who had studied science in high school and university during the 1970's and started teaching high school science in the eighties. In fact, four of the participating teachers are close to that description.

I thought it important that readers, who would be reading the teachers' perceptions of implementing an innovation, have a background on the lived experiences of senior grade science teachers who might participate in the study. We have explored the context in which it was expected that desktop computers and laptop computers would be implemented in classrooms, but during their years of studying and teaching science, a range of science curriculum documents were produced by education officials and were distributed for implementation with varying degrees of success. The nature of these curriculum innovations required different orientations, if they were to be implemented in schools by teachers. The chronologically sequential orientations range from fidelity, to adaptation, to enactment orientations and will be explored in this section of the Literature Review.

**Table 2.1: Curriculum Documents: Orientation Continuum**

	<b>Prior to 1970</b>	<b>After 1970</b>	<b>After the late 1980s</b>
<b>Orientation</b>	Fidelity	Adaptation	Enactment
<b>Curriculum-making design</b>	Experts top-down	Experts make design: teachers adapt middle-up	Guidelines: teachers make curriculum bottom-up
<b>Modes of teaching</b>	Teacher-centred/ traditional	Teacher-centred	Student-centred

Adapted from: Leithwood et al., 1999; White & Tischer, 1986

Prior to 1970, teams dominated by scientists developed curricula that were consistent with one end of the curriculum continuum, presented in Table 2.1, the fidelity orientation (White & Tischer, 1986). Teachers were expected to

faithfully implement innovations presented by curriculum developers (Leithwood et al., 1999). Senior high school science was divided into separate disciplines. Course structure and content were emphasised, as was the preparation of students for more advanced study in the discipline (Miller, 1983). At the time, it was thought that top-down, control-oriented strategies directed by ministry and board officials would ensure that teachers implemented curricula effectively (Rowan, 1990), but little research was carried out to ascertain how teachers used curricula in their classrooms (White & Tischer, 1986) or whether they were effectively transmitting the curricula to learners (Welch, 1979).

Science curricula after 1970 moved towards the middle of the curriculum continuum, to the adaptation orientation. These curricula were developed by teams dominated by educational psychologists and experts in curriculum theory (White & Tischer, 1986). The emphasis shifted from the structure and content of science courses to the process of learning science. Teachers were expected to have, and were actually allowed to have, personal input into adapting the curriculum for their classrooms. It was at this time that the extent and complexity of teachers' decisions concerning the learning experiences of their students became more evident to researchers (White & Tischer, 1986). Researchers, such as Leithwood and Montgomery (1980), observed that the provision of subject content or materials did not insure the successful implementations of curricular changes and that it was classroom teachers who determined the innovations that would be integrated in classrooms (Ivany et al., 1987; Klopfer et al., 2005; White & Tischer, 1986). Yet, despite the shift to the adaptation

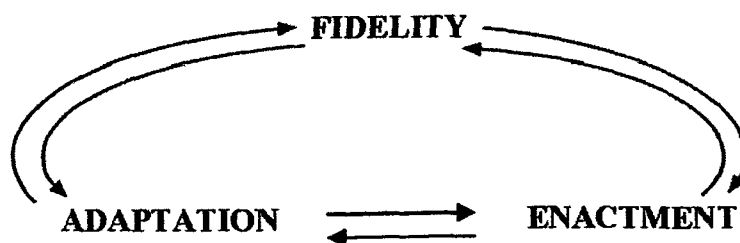
orientation, researchers consistently observed little change in content or instruction in science classrooms (Cuban, 1983; Kumar & Crippen, 2005; Rutherford, 2005).

Having moved from a fidelity orientation to an adaptation orientation, the nature of curriculum continued to evolve toward the enactment orientation (See Table 2.1). In most subject areas and grade levels, the majority of teachers were finding that the implementation of curriculum became more complex during the late 1980s and early 1990s. They were increasingly finding themselves at the enactment end of the curriculum continuum, where multiple simultaneously implemented innovations were requiring strong teacher commitment to insure the successful implementation of new curricula (Leithwood et al., 1999). Teachers were expected to develop the necessary instructional practices and materials needed to insure a successful implementation of the curriculum which required an enhanced level of process and knowledge skills, very similar to those skills and capacities required for integrating laptop or desktop computers into instruction.

For these reasons, it is worthwhile to examine the orientations of the curricula that biology teachers and senior grade science teachers have implemented over the decades and the impact these curricula have had on their teaching approaches starting with the fidelity orientation, and moving through the adaptation orientation to the enactment orientation. The Biological Sciences Curriculum Study Project (BSCS), arguably the most successful of the national curriculum projects undertaken in the United States in the 1960s and 1970s

(Bybee, 1996b; Ellis, 1993, Marsh & Willis, 1995), is an example of a curriculum which required fidelity of implementation by the teachers and was considered to be “teacher-proof” by educational authorities, that is to say, given the curriculum, appropriate resources and the required materials, the characteristics and values of individual teachers would and should not affect implementation. Fidelity of implementation and a teacher-proof curriculum seem appropriate to courses where the content is unusually complex and difficult to master; courses where the knowledge the students are learning requires definite sequencing, and/or, courses where student understanding depends on a sequential matching of curricular strands from previous courses. However, in order to implement BSCS courses, teachers needed the appropriate resources and training if they were to present the courses as envisioned by the developers. In reality, faithful implementation was quickly abandoned or modified to fit specific classroom realities such as the resources and facilities available to the teachers, factors which the experts had been unable to foresee (Marsh & Willis, 1995). As a result, a fidelity orientation to curriculum implementation quickly transitioned into an adaptation orientation. However, other factors also encouraged an adaptation orientation in some educational jurisdictions.

**FIGURE 2.1 CHANGES IN CURRICULAR ORIENTATIONS IN ACTION**



Following the reorganization of Ontario school boards into larger administrative units in the late 1960s, school boards had more resources and more staff, including: their own area superintendents, and the opportunity to have an area superintendent in charge of curriculum; and, science consultants and/or science coordinators. There followed a period of time when the Ministry was inactive in the revision of science curricula, and a policy of shared responsibility for curriculum emerged. It was estimated 80 percent of Ontario school boards intervened between the Ministry document and teacher planning at this time to fill the resulting curricular gaps. Larger and wealthier school boards developed complete curriculum packages that could be shared, or sold, to those who did not have the resources or staff to develop comparable materials in every subject. Many teachers used these documents prepared by the larger school boards, or the Science Teachers' Association of Ontario, as guidelines for planning their courses (Connelly et al., 1985).

Boards used the curriculum documents that were available from the Ministry to provide context as local course outlines were developed. Some boards held implementation workshops for principals and teachers to familiarize them with curriculum documents available from the Ministry. The principals and teachers then developed their own courses of study and lesson plans. Other boards used what documents were available from the Ministry to produce a general course outline of the program to be followed by the schools, and the schools produced specific courses of study which the teachers translated into

lesson plans. In a related pattern of curriculum development during this phase, the boards produced detailed guidelines and specific course outlines and provided implementation workshops for board personnel. It was expected these documents would be used by schools and teachers (Connelly et al., 1985).

In addition to the policy of shared responsibility for curriculum, the Ministry issued a number of new science guidelines consistent with an enactment orientation and requiring teachers to make multiple simultaneous changes in classrooms to implement the curriculum (e.g. Ontario's Environmental Science Guidelines, 1973). Perhaps ironically, practicing teachers at that time, concerned with what they considered to be the abstract or philosophical nature of the guidelines, by which they meant the lack of specific content, lobbied to have these guidelines replaced with documents which resembled earlier science curricula (Connelly et al., 1985), were consistent with the fidelity end of the curriculum continuum, and required a fidelity orientation to implementation (see Figure 2.1).

The current pedagogical context for teachers in Ontario is that science curricula are mandated by the Ministry for implementation in schools (Bencze et al., 2003; Hodson, 2001). Researchers, such as Perkins (1999) and Russell (2006) describes such curricula as content heavy and among the most conceptually challenging that students encounter in the senior grades of high school. These content-heavy and conceptually challenging curricula are taught under such conditions as are normally found in high schools including rotary timetables and students taking six to

eight different subjects. Since the knowledge required by the curriculum is abstract and the immediate applicability of the knowledge being learned is low, the curriculum may or may not be appropriate for the students. In my experience, this remains the pedagogical context of school science at this time and it is variously described in the literature with words such as traditional, positivist, and didactic, and as transmission-oriented utilizing direct teaching methods. The most discretion left to these science teachers is to choose the teaching approaches they select (Hodson, 2001).

When teaching approaches are examined, it is found that students continue to learn science in teacher-controlled environments. The teachers determine what is learned, how it is learned, when it is learned, and they control the safety and the physical environment of the laboratory (Hodson, 1999). For these students, most of the knowledge they acquire is still from the teacher or the textbook (Cuban, 1983) via direct or teacher-centred transmission.

Miller (1983) identified characteristics of science teaching in Ontario as including: behavioural goals and objectives for students; stress on content; content sequenced throughout a course and in consecutive courses; teachers who organize and transmit learning to the students; and a passive role for the students who are expected to adapt to the content and pace of the courses. Other researchers confirm the domination of this teaching approach, that it remains the dominant teaching approach, and

that it has persistently reasserted itself after other teaching approaches have passed through the schools (Cuban, 1983; Gardiner & Farragher, 1999; Ponder, 1997; Welch, 1979). Reasons for the persistence of this teaching approach are identified as stemming from a number of teacher concerns, including: the heavy content demands of the courses they teach; the norms they experienced in the science courses they studied at high school and university; the personal view of science they have developed; and their beliefs about how science should be taught (Hewson et al., 1999; Lorsbach, 1991). Although dependent on the expertise of the teachers to be successful, this dominant teaching approach is deemed an efficient way for large numbers of students to learn and a good match for teachers who are subject specialists, who repeat every lesson to different classes and who have limited preparation time (Cuban, 1995). The majority of the teachers in senior science courses do teach large numbers of students, they do repeat lessons to multiple classes and they do have little time, or assistance, to prepare for laboratory courses and so the dominant teaching pattern persists or reasserts itself.

The teaching approaches science teachers have selected have invariably been teacher-centred, directed to developing content, and focused on whole-group instruction characterized by lectures, note taking, and a question and answer dialogue with students (Cuban, 1995; Hiller, 1995; Weiss, 1997). The teachers have little time to develop their instruction beyond structured and pre-scripted problem solving and

laboratory experiences (Gardiner & Farragher, 1999; Hodson, 1999). Criticism continues in the educational community that even minor innovations, characteristic of recent science curricula, have resulted in less change in instruction than might have been anticipated by researchers. Whether the preferred implementation pattern for science teachers in senior grades is of a fidelity, adaptation or enactment orientation, a body of scholarly research on the pattern of implementation that can be readily or routinely used by practitioners is simply not available.

This research will be among the first studies in this area, collecting and analyzing data on how teachers in the sample group implemented laptops into biology curriculum. The review of the research literature available on implementing laptops, desktops and science curricula over the time the teachers in this sample were learning science and teaching science, provides a perspective from which to view what these teachers attempted to do in their classrooms and how they accomplished their objectives.

## **Chapter Summary**

Researchers have observed that teachers with strong subject matter knowledge tend to employ, or at least consider, more effective or innovative teaching strategies (Becker, 1994; Davis, 2006) and confirmed that biology teachers bring creativity and commitment to the implementation of innovations in their classrooms (Simmie, 2007). In the

enactment orientation requiring multiple simultaneous change for an innovation to be successfully implemented, it is the individual teachers who determine what innovations will be implemented and how they will be implemented in the classroom.

Given the nature of science curricula, science teachers may have more experience implementing curricula with fidelity and adaptation orientations than implementing curricula with an enactment orientation. Science teachers in the senior high school grades may have even less experience with curricula requiring multiple simultaneous change in the classroom and may have had less opportunity to develop the necessary skills which insure a successful implementation in the enactment orientation.

Certainly, researchers have identified senior science teachers as less likely to integrate laptop computers and less likely to change their instructional practices. Knowing why they are less likely to integrate innovations and less likely to change their instructional strategies is the challenge, since in most studies the voices of senior science teachers cannot be differentiated from their colleagues in the junior and intermediate panels and from teachers in other subject areas (Newhouse, 2001a; Newhouse & Rennie, 2001). It appears the science teachers have many concerns which discourage them from integrating computers into classroom instruction. Integrating computers into instruction requires skills in dealing with multiple, complex changes and senior high school

teachers are less likely than teachers in other subjects and other grades levels to have had curricula that required them to develop these skills (Becker, 2000).

Gregoire Gill (2006) has raised the difficulties inherent in ascertaining how teachers make decisions about teaching and learning despite the importance of these curriculum and pedagogical decisions on their classrooms. This is an important consideration since existing research indicates classroom teachers largely determine if and how laptops will be integrated into instruction.

Researchers anticipated that laptop programs would have addressed many of the concerns science teachers cite as discouraging them from integrating previous forms of computer technology. They consistently anticipated that the introduction of computers and then, laptops, would encourage teachers to alter their teaching practices, leading to less teacher-centred instruction and more student-centred instruction (Amankwatia, 2008; Inan et al., 2010; Mayer-Smith et al., 1998). Nevertheless, under-utilisation of laptop technology and little change in science instruction characterize teaching and learning in the senior grades of high school.

This literature review has argued that science teachers are a special population in the schools and that senior science teachers are a special population among science teachers. Specifically, they have different patterns of implementing laptop, and desktop computers into instruction and different experience, and different skills from implementing science curricula than teachers in other subject areas in the school. We might conclude that this lack of experience with implementing curricula with an enactment orientation may

account for the lower implementation of laptop computers since both require the ability to manage multiple complex changes in the classroom. If so, there is something we can examine during the interpretation of the results.

In reviewing the literature, quantitative research (Dunleavy, 2008; Inan & Lowther, 2010b; Hakverdi, 2005) has identified the need for a body of knowledge, pedagogy and theory on integrating computers in the context of science instruction and science classrooms. Qualitative research (Erixon, 2010; Varma et al., 2008; Windshittl & Sahi, 2002) has clearly identified that these needs and the need to understand how science teachers make decisions about integrating innovations have not been met and are ongoing. If this study is to collect information, describe and interpret the perceptions and knowledge of biology teachers with respect to the implementation process, it is not evident from the research literature reviewed thus far how the study should be organized to accomplish those goals. More detailed information on how the implementation of innovations in classrooms has been carried out is required to provide a framework for this study. Chapter Three outlines the development of the Conceptual Framework for the study.

## CHAPTER THREE: CONCEPTUAL FRAMEWORK

The perceived lack of change in science education in the senior grades, even with the introduction of laptop computers, raises the question as to how this proposed study should proceed. The objectives of this study were to examine the teachers' perceptions of integrating laptop computers into high school biology courses and to learn from the lived experiences of these early implementers. I sought to build a conceptual structure, sufficiently robust and vigorous to organize a study of teachers' perceptions based on their lived experience while integrating laptop computers in the complex setting of the senior science classroom (Dottin, 2001; 1999), by examining a number of frameworks for understanding the implementation of innovations.

Fullan & Park state that implementation is a multi-dimensional process. Different types of change are necessary in order to ensure the integration of innovation, including: the use of *materials*; and, the introduction of new *teaching approaches*. They predicted that teachers who changed in only one or two dimensions would achieve only minor changes in their classrooms (Fullan & Park, 1981; Fullan, 1982). Connelly and Clandinin (1990) further reinforced the importance of the teachers' role, arguing that teachers were central figures in change, and that changes in teacher perceptions must take place if change was to occur. Researchers (Hakverdi, 2005; Mara, 2006; Newhouse, 2001a; Siegle &

Foster, 2001) have thus realised the need for studies that would focus on teachers' understandings or perceptions of integrating innovations.

In searching for a conceptual framework for this study, a number of models for educational change were examined in order to ascertain if they focused on the parameters identified Chapter Two. I sought models that would address or be capable of addressing the following: change initiated and implemented by individual classroom teachers in their subject area with little or no external assistance; the importance of the role of the individual teacher in the integration of innovation during change; how teachers actually use innovations in their classrooms; and, how the teachers would implement a poorly structured innovation requiring multiple, simultaneous changes.

The following section examines the theoretical discourse that surrounds change, implementation, the diffusion of innovations and a comprehensive list of models that I considered as candidates for a conceptual framework for this study. As well as establishing a background on the literature dealing with educational change, increasingly I will focus on one model, the Concerns-Based Adoption Model (CBAM) including: how it becomes pertinent to a study of teacher perceptions; and how, in an amended form, it contributes to the development of the conceptual framework of this study.

### **Change, Implementation and the Diffusion of Change: Theory and Models**

It has been estimated that researchers developed at least 50 models for studying change (Nitti, 2000), yet no pattern of systematic development of

knowledge about change, and the implementation and diffusion of innovation emerged from the 1950s to the 1990s. There was a recurring pattern of new models developed for different policy initiatives and the use of these models for research in schools and school systems, but these models resulted in little actual change in classrooms (Anderson, 1997). From these 50 models, ten models were selected because they have been identified in the literature as significant models in the research on change (see Anderson, 1997; Cho, 1998; Marsh & Willis, 1995; Miller & Seller, 1990; and, Pinar et al., 1995). The ten models selected for consideration as a conceptual framework for this study were:

The Research, Development and Diffusion Model (RD&D); the Center-Periphery Model (CP); the Organizational Development Model (OD); the Concerns-Based Adoption Model (CBAM); the Problem Solving Model; the Linkage Model; the Rand Change Agent Model; the Innovation Profile Model (IP); the Denver Curriculum Revision Model; and, the Eight-Year Study Model.

### **Change Models**

Since I was interested in models that dealt with change, implementation and the diffusion of an innovation, I began by examining a number of models developed between 1958 and 1980 that have been identified in the literature as models for studying these aspects of educational change. From the models listed as externally motivated, top-down models, I selected four models which might be used as a conceptual framework of the study: the Research Development & Diffusion Model (Clark & Guba (1972); the Center-Periphery

Model (Schon, 1971); the Organization Development Model (Schmuck & Runkel, 1972); and, the Concerns-Based Adoption Model (Hall & Loucks, 1978). As explained above, in these models it is assumed that the motivation for change is external to the teacher. I also chose to retain an interactive, middle-up model, the Problem Solving Model (Marsh & Willis, 1995). The assumption of an interactive middle-up model is that there will be some input by teacher practitioners after the innovation is developed by experts.

### Implementation Models

After selecting five change models for further study, I then examined a number of models identified in the literature as implementation models. According to Cho (1998), perspectives on the implementation of innovations can be arranged on a continuum depending on amount of teacher input and the complexity of the decisions teachers are required to make.

**Table 3.1: Perspectives: Implementation Models**

Fidelity	Mutual Adaptation	Enactment
Research Development & Diffusion	Rand Change Agent	Denver Curriculum Revision
Linkage	Innovation Profile	Eight Year Study
Concerns-Based Adoption	Organizational Development	
>>	>>	>>
Increasing teacher input		

Adapted from Cho, 1998

### **Implementation Models: Fidelity Perspective**

First, I examined models with a fidelity perspective, characterized by externally motivated and externally imposed, top-down implementations (Cho, 1998) and involving little or no teacher input. Prior to 1970, teams dominated by scientists developed science curricula for the schools and it was assumed that teachers would implement the curriculum provided to them in their classrooms (White & Tischer, 1986). Teachers would use a simple pattern of decision-making focused only on effective implementation of the innovations provided by educational authorities, usually the Ministry and the school board (Pinar et al., 1995). Three implementation models developed between 1965 and 1975 typify this perspective: the Research Development & Diffusion Model, the Linkage Model, and the Concerns-Based Adoption Model (Cho, 1998).

### **Implementation Models: Mutual Adaptation Perspective**

I then examined models with a mutual adaptation perspective, characterized by an externally imposed middle-up dynamic (Cho, 1998). This perspective requires that the external authorities allow modifications to the innovation that has been designed by external experts for the classroom and also requires more complex decision-making by teachers as they reshape or adapt the innovation for their respective classrooms (Pinar et al., 1995). Science curricula developed after 1970 were produced by teams which included science educators, but were dominated by educational psychologists and experts in

curriculum theory (White & Tischer, 1986). It was expected that officials at the systems level, such as subject co-ordinators, would have additional input to adapt the prescribed curricula for the schools and that teachers would have personal input in the adaption of new curricula for their classrooms. This perspective recognized the complexity of the classroom settings for which the curriculum was intended. Three middle-up models developed between 1972 and 1980, typify this type of implementation and were used to ascertain the extent to which teachers had implemented a new curriculum: the Rand Change Agent Model (Berman & McLaughlin, 1975), the Innovations Profile Model (IP) (Leithwood & Montgomery, 1980), and the Organizational Development Model (OD) (Cho, 1998), for a total of eight models.

### **Implementation Models: Enactment Perspective**

I then examined models in the third implementation perspective, the enactment perspective. This perspective is driven by an internally imposed, bottom-up dynamic (Cho, 1998). Teacher decision-making is regarded as being complex, focused on what will or will not be implemented, and how innovation will be implemented in their classrooms. Implementation of innovations in most subject areas and grade levels became more complex in the enactment perspective. Unlike many models which focused on school systems or schools, models in the enactment perspective focused on involving teachers in implementing innovations in their classrooms (Pinar et al., 1995). The literature (Cho, 1998; Snyder et al., 1992), and curriculum textbooks (Marsh & Willis, 1995;

Miller & Seller, 1990; Pinar et al., 1995) point to the relatively old Denver Plan (1920s) and the Eight-Year Study (1930s) for models to illustrate bottom-up implementation by teachers in their classrooms. This brought the list of models I considered to ten. However, there is some question as to whether contemporary science curricula introduced into high schools would have required an enactment style of implementation of the teachers and whether contemporary science teachers in the senior grades have implemented innovations characteristic of this perspective.

In summary, my selection of the ten models re-introduced the concepts of externally driven top-down dynamics, mutual adaptation middle-up dynamics, and bottom-up enactment dynamics, concepts originally introduced in Chapter Two, the literature review. My examination of models introduced the concepts of models used to study educational change and models used to study implementation of innovations. It should be noted that these concepts are not mutually exclusive and models do appear in more than one classification. For example, CBAM appears as both a model for studying change and a model for studying implementation. In fact, the body of research in North America, Europe and Australia based on this model indicates that it performs beyond the original parameters of its developers (Anderson, 1997).

### **Diffusion Models**

I then turned to an examination of the models researchers have used to study the diffusion of innovations, innovations such as the integration of laptop

computers in senior science courses which is the focus of this study. No new models were introduced. All the models for studying diffusion were among the ten models selected for studying change and/or implementation of innovations. Here the models have been sorted according to how they have been used to study sources of the motivation for diffusion, external or internal to the teacher, and whether the target for the diffusion studied is a school system, a school, or an individual teacher. These relationships are spelled out in the following table.

**Table 3.2: Models for Studying Diffusion**

Externally Motivated Models	Internal Motivation	
Within School Systems	Within schools	Within teachers
RD&D Model	OD Model	CBAM
CP Model	Problem Solving Model	

CBAM is the only model that has been used to study change where the motivation to change is internal to the teacher and the focus during change is the individual teacher.

In summary, after a review of the literature on models used to study educational change, implementation and diffusion, ten models frequently cited in the literature were of interest: the Research, Development and Diffusion Model (RD&D); the Center-Periphery Model (CP); the Organizational Development Model (OD); the Concerns- Based Adoption Model (CBAM); the Problem Solving Model; the Linkage Model; the Rand Change Agent Model; the Innovation Profile

Model (IP); the Denver Curriculum Revision Model; and, the Eight-Year Study Model.

Since I was looking for a robust model capable of studying change, Implementation and the diffusion of an innovation, the models were examined using that criterion. The Linkage Model, the Rand Agent Model, the Innovations Profile Model, the Denver Curriculum Revision Model and the Eight-Year Study Model were described only as implementation models (Cho, 1998) so they were not of interest as a conceptual framework for this study, leaving five models. The Center-Periphery Model (CP) and the Problem Solving Model were described as models used for studying change and diffusion (Cho, 1998; Marsh & Willis, 1995) but not implementation, so they were not of interest as a conceptual framework for this study, leaving three models: the Research, Development and Diffusion Model (RD&D), the Organizational Development Model (OD) and CBAM.

**Table 3.3: Summary**

<b>Models</b>	<b>Change</b>	<b>Implementation</b>	<b>Diffusion</b>
RD&D	✓	✓	✓
CP	✓		✓
OD	✓	✓	✓
CBAM	✓	✓	✓
Problem Solving	✓		✓
Linkage		✓	
Rand		✓	
IP		✓	
Denver		✓	
Eight-Year		✓	

<b>Models</b>	<b>Focus, Large-Scale Studies</b>	<b>Individual Teachers</b>
RD&D	✓	
OD	✓	
CBAM		✓

Since I was searching for a model capable of studying teacher-initiated change, implemented and sustained by classroom teachers, the remaining three models were examined against these criteria. First I examined the RD&D Model which, while widely used for educational research on change, is not credited with producing change at the classroom level. It is identified as a change model (Marsh & Willis, 1995), an implementation model in the fidelity perspective (Cho, 1998) and, it is also identified as a model for studying the diffusion within school systems of an externally motivated innovation (Schumacher, 1972). The model, in fact, describes an active and widely spread dispersal of an innovation that is better defined as dissemination (Kelly, 1982). Since diffusion implies the natural movement of an innovation from areas where it has become highly used to areas where it is not being used, this model might be more accurately described as the Research, Development and Dissemination Model and, as such, is not a useful model for studying the diffusion of an innovation. As the RD&D model assumes an externally imposed innovation, designed by expert researchers and an active, pre-planned dissemination process in school systems, the Research, Development and Diffusion Model is not a helpful conceptual framework for studying individual teachers as they initiate and implement a poorly structured innovation in their classrooms which is the focus of the present study.

The second model I investigated was the Organizational Development Model (OD) (Schmuck & Runkel, 1972), identified by Marsh & Willis (1995) as an externally motivated, top-down change model. The OD Model is also identified

as an implementation model with a mutual adaptation orientation (Cho, 1998). Diffusion models where the motivation for innovation originates from internal influences within schools, include models that focus on schools and models that focus on individual teachers. The Organizational Development Model is identified as a model for studying the diffusion of an innovation in schools and is used for large-scale studies. It was not developed to focus on the perspective of individual teachers (Anderson, 1997) and, therefore is not a suitable model for this study.

Having eliminated two of the three remaining models, the model that remained was CBAM, and I will now focus in more detail on this model which has particular applicability to the data captured and addressed by the present study.

### **The Concerns-Based Adoption Model (CBAM)**

The last model, the Concerns-Based Adoption Model (CBAM), is identified as a model to study externally motivated, top-down change (Marsh & Willis, 1995) facilitated by an agent who understands the innovation being implemented from the point of view of the teachers (Surry, 1997). CBAM was developed by Hall & Loucks (1978) and is associated with the University of Texas at Austin. The model originally had three diagnostic tools and I will deal with them in order: Stages of Concern (SoC); Levels of Use (LoU) and Innovation Configuration (IC).

This model identifies various levels of teacher concerns about an innovation (Stages of Concern), examines how the teacher is using the innovation in the classroom, and describes teacher behaviour during the

implementation process (Levels of Use). A third component of CBAM, Innovation Configuration, recognizes how different an innovation may appear to researchers when implemented by individual teachers in their own classroom. Organized as a rubric with ideal, acceptable, and unacceptable categories, an Innovation Configuration might include a number of factors such as: the necessary resources and conditions to implement the innovation, six to eight characteristics of the innovation; and, descriptions of how the characteristics have been implemented (Horsley & Loucks-Horsley, 1998). CBAM is considered primarily a descriptive and predictive model (Anderson, 1997) which can help teachers, and those who assist teachers, in implementing innovations by helping teachers develop effective strategies for their classrooms.

Horsley and Loucks-Horsley (1998) state that CBAM is based on a number of assumptions: 1) change is a process, rather than an event, that occurs when teachers are given an innovation to implement; 2) the process is a personal experience, and teachers experience the change in their own unique way; 3) the result of a successful implementation of an innovation requires a change in the classroom practices of individual teachers; 4) individual teachers must change before schools or school systems can change; 5) teacher change is a developmental process that occurs in stages and which involves not only growth in knowledge and use of skills, but also the development of a set of personal feelings towards the innovation (Horsley & Loucks-Horsley, 1998). For the successful integration and diffusion of an innovation to take place, initial activities should thus be directed toward meeting the concerns of the individual teachers.

The originators of this model have noted that it is difficult for researchers to ascertain teachers' perceptions about the integration and diffusion of an innovation and designed CBAM to assist in identifying the nature of teachers' concerns.

Hall et al. (1997) maintained that the individual teachers make decisions about degrees of acceptance or rejections of a specific innovation, and they do so, not because of the public reasons usually given, but because of the specific concerns that they develop as they become involved with the innovation.  
 (Marsh & Willis, 1995 p154)

The CBAM model conceptualizes teachers' concerns as having seven major focuses, which constitute a developmental sequence (Bagby, 2007) that can be metaphorically represented as climbing a set of stairs while exploring the teachers perceptions of their experiences:

**Table 3.4: CBAM: Seven Stages of Concern**

7	<u>Refocusing</u> : Is there anything else that's better?
6	<u>Collaboration</u> : It's working fine, but how do others do it?
5	<u>Consequence</u> : Is this working? Is it worth it?
4	<u>Management</u> : How can I master the skills and fit it in?
3	<u>Personal</u> : How does this impact me? What's my plan to do it?
2	<u>Information</u> : How does it work?
1	<u>Awareness</u> : What is it?
0	<u>Unrelated concerns</u>

Adapted from Sweeney, 2003

Information for the Stages of Concern portion of CBAM is collected by having teachers complete a 35-item questionnaire. If researchers decide to use the Stages of Concern Questionnaire to collect data, for copyright reasons, they must obtain permission to adapt the questionnaire for their study. First, there are Unrelated Concerns, where teachers may be aware of the innovation but are not concerned about how the innovation would affect their own classrooms. This stage is followed by Personal Concerns (Awareness, Information, Personal), where the teachers are aware of the impact of the innovation on their personal situation and are concerned about how the innovation compares to their present practices. These concerns are followed by Task-related Concerns (Management, Consequence), where the introduction and application of the innovation in the classroom is the basis of their concerns. Finally, there are Impact-Related Concerns (Collaboration, Refocusing) where teachers' concerns regarding the innovation extend beyond their personal concerns or their classroom, to how other teachers are implementing the innovation. Teachers' concerns at this final level might include the following questions: What are the consequences for the students? How are other teachers implementing the program? What is the future impact of this innovation? (Hall & Hord, 2001; Hord et al., 1987).

The Concerns-Based Adoption Model (CBAM) (Hall et al., 1975) is also identified as an implementation model with a fidelity orientation (Cho, 1998). As

an implementation model, the Levels of Use of the innovation (LoU) portion of CBAM can be used to study the performance of the teachers while using the innovation. To study the fidelity of the implementation, Levels of Use also collects information from teachers on how they are using the innovation in their specific classrooms and the descriptions they provide of their behaviour during the implementation. This information is collected through a questionnaire which is administered to individual teachers by the researcher. For copyright reasons, if a researcher wishes to use the Levels of Use Questionnaire to collect data, permission must be sought to adapt the questionnaire to the research study.

Levels of Use describe the teachers' developmental progression in acquiring new skills as they attempt to use the innovation. The model acknowledges the possibility of non-utilization and identifies six observably different types of behaviour and patterns of use.

**Table 3.5: CBAM: Six Levels of Use**

- 6 **Renewal:** where the teachers are re-evaluating the quality of their use of the innovation. They are examining modifications of the present innovation, new developments in the field, and exploring new goals for themselves and the system.
- 5 **Integration:** where the teachers are combining their personal efforts to use the innovation with the related activities of their colleagues to achieve a collective impact on students within their sphere of influence.
- 4 **Routine and Refinement:**  
4A **Routine:** the teachers' use of the innovation has stabilized. Few changes are being made on an ongoing basis, but little preparation or thought is being given to improving the use of the innovation or the consequences of using the innovation.

4B Refinement: the teachers are varying the use of the innovation to increase the impact on the students in the classroom. Variations are based on the teachers' knowledge of short and long-term consequences for the students' learning.

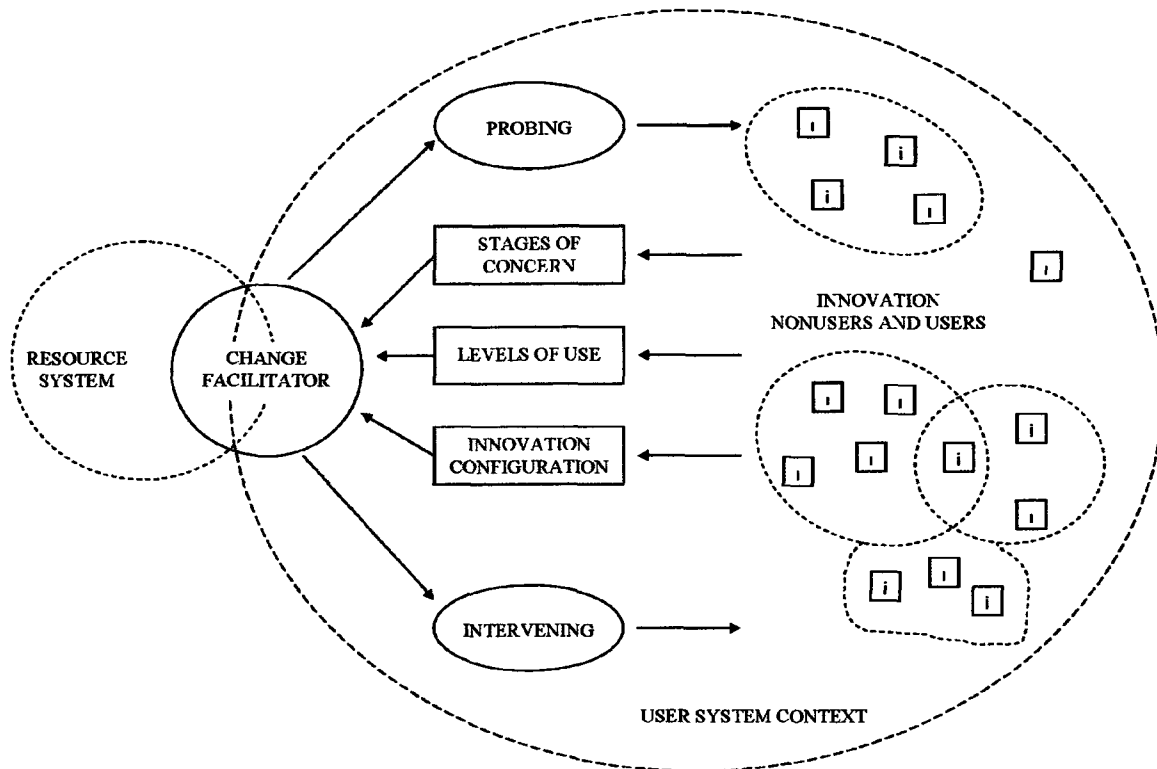
- 3 Mechanical use: The teachers are focusing most of their efforts on the short term, day-to-day use of the innovation and have little time for reflection. Changes are made more to meet the needs of the teachers than for the benefit of the students. Teachers are attempting to master the tasks required as they teach, often resulting in disjointed and superficial use of the innovation.
  - 2 Preparation: where the teachers are preparing for the first use of the innovation.
  - 1 Orientation: where teachers are acquiring knowledge of the innovation and are exploring its values and its demands upon them and their classrooms.
  - 0 Non-use: where the teachers have little or no knowledge of the innovation, no involvement with the innovation and are doing nothing toward becoming involved in it.
- Adapted from: Hall, et al., 1975; Hall & Hord, 1987

CBAM is also identified as a model for studying diffusion where the motivation for the innovation originates from internal influences within teachers, and where the focus is on the individual teachers (Hall et al., 1975). Awareness of the diffusion of the innovation is evident in the Stages of Concern (SoC), the Levels of Use (LoU), and the Innovation Configuration (IC) concerns about how the innovation looks in other teachers' classrooms. Of the seven Stages of Concern, the highest stages, Collaboration and Consolidation, deal with the effect of the innovation on others. These are impact-related concerns in which teachers' perceptions of the innovation extend beyond their personal or management concerns to how other teachers are managing the innovation.

Teachers' concerns at this level might be expected to include questions such as the following: How are other teachers implementing the innovation? What is the future impact of this innovation? (Hall & Hord, 2001; Hord et al., 1987).

Of the six Levels of Use, researchers can use to observe different types of behaviour and patterns of use, the highest two levels, Five and Six, deal with the innovation and other teachers. At the Integration Level, Level Five, the model anticipates teachers are combining their personal efforts to use the innovation with the related activities of their colleagues to achieve a collective impact on the students. At the Renewal Level, Level Six, the model anticipates that teachers are re-evaluating the quality of their use of the innovation. At this final level the teachers are examining possible modifications of the present innovation, new developments in the field and exploring new goals for themselves, the school and the system.

**FIGURE 3.2 THE CONCERNS BASED ADOPTION MODEL**



Source Hall & Hord, 1987

As I view it, CBAM focuses on the perceptions and lived experiences of individual teachers as they encounter innovation and operates as a change model (SoC), an implementation model (LoU), and at its highest levels (SoC and LoU) provides information about the diffusion of an innovation to other teachers. As well, CBAM can be used to describe how the innovation looks to researchers when implemented by individual teachers in their classrooms. For all these reasons, I consider CBAM a helpful conceptual framework for this study, a model that I amend in the following pages.

From the original count of 50 models used to study educational change referenced at the beginning of this chapter, we have focused on CBAM,

recognizing that this is model that has been used extensively to study educational change and which has performed beyond the parameters of its original developers. As we go forward with this dissertation CBAM will be used, not as originally envisioned as a quantitative predictive model, but as a descriptive model (Anderson, 1997): a descriptive model robust enough to explore individual teacher perceptions, their lived experiences, and form the basis of rubrics to guide the qualitative analysis of change as teachers integrate an innovation, in this case laptop computers, into their biology classrooms.

### **CBAM Amended**

Although CBAM was originally designed to measure, describe and explain externally motivated, top-down change, with facilitators to assist the teachers during the change process, as well as a fidelity approach to implementation of the innovation, the body of research in North America, Europe and Australia based on this model indicates that it performs beyond the original parameters of its developers (Anderson, 1997). Even so, I am not recommending that CBAM be used as originally designed by its developers, but that it be amended for the following reasons.

Despite the volume of research based on this model, a number of criticisms of CBAM's functioning have not been resolved. Researchers have found integrating data provided by the first three diagnostic tools, Stages of Concern, Levels of Use, and Innovation Configuration, has proven difficult (Anderson, 1997). In addition to this concern, Anderson describes the general

pattern of use of this model as follows: most CBAM research uses only the first diagnostic tool, Stages of Concern about a change; a few research studies use the second diagnostic tool, Levels of Use; even fewer research studies use both the first and second diagnostic tools: and, almost none of the research uses the third diagnostic tool, Innovation Configuration. Slough and Chamblee (2007) also note very few research studies actually use the entire CBAM model to study the integration of technology.

Slough and Chamblee (2007) also make two other relevant critiques of CBAM research: almost all studies are short in duration; and the research studies document successful modification of lower-level concerns using CBAM, but do not document successful modification of higher-level concerns. Bermel (2008) also notes the lack of empirical studies on the higher levels of use in CBAM. These higher levels, particularly refining and refocusing, were an important part of her study, and I anticipate will be a concern for this study as well.

Academics have criticized a number of other aspects of CBAM, including: the predictive qualities of the model; the reliability of the results obtained; and, the type of change CBAM can be used to study. CBAM assumes facilitators can assist teachers through the implementation process, yet the Levels of Use represent a possible, not a definitive progression in teachers' use and behaviours. As a result, the predictive aspect of the model is weak since it does not predict what interventions a facilitator should make to successfully maintain the teachers' progress toward the fidelity of use required for a successful implementation of an innovation (Anderson, 1997). Anderson also addresses

concerns that CBAM might best be used for investigating well-structured innovations rather than poorly structured innovations. Technology, as an example, is not a well-structured innovation but a poorly structured innovation, a constantly changing innovation that presents teachers with a continuous series of problems concerning implementation and diffusion (Slough & Chamblee, 2007). In addition, academics have criticized the reliability and validity of quantitative results obtained using CBAM when, as the quantitative data collected often indicates that large numbers of teachers decide not to integrate the innovation. In response to such criticism, in the 1980s Hall & Loucks (1978) added a fourth, and last dimension, qualitative interviews, to the original CBAM model to augment the quantitative data the model provided (Anderson, 1997).

In summary, in most CBAM research only part of the model is used, or CBAM is used and an amended model is presented at the end of the study (Bermel, 2008; Newhouse, 1997), or CBAM is modified prior to the study (Christou, et al., 2004; Davis & Roblyer, 2005; King, 2003; Shotsberger & Crawford, 1996; Slough, 1997), or CBAM is augmented by another model (Osborne, 1993; Slough & Chamblee, 2007; Surry, 1997) in order to study different types of educational change. Although CBAM functions beyond the original perspective of its developers (Anderson, 1997) and has particular applicability to the data captured and addressed by the present study, CBAM as it was originally designed was not chosen as the conceptual framework of this study. Instead, I chose the fourth dimension added to CBAM, interviews with teachers, but I also used aspects of the original CBAM as a useful guide: to

maintain the focus on the perceptions of individual teachers undertaking change; and, to emphasize the importance of listening to, and hearing what the teachers are saying about their experiences (Donovan, 2007). So, although CBAM was not used for its original quantitative or diagnostic purposes, I developed rubrics for a qualitative analysis of teacher perceptions (SoC), their experiences with the complex changes they undertook (LoU), and what the integration of laptops looked like when new teaching materials were implemented in their individual classrooms (IC).

The importance of teachers' perceptions about what is encountered during the implementation of an innovation and the interpretations the teachers ascribe to what they experienced has been recognized for some time (Snyder et al., 1992), and leads to my first research question:

**Question One: How do senior grade biology teachers perceive the integration of laptop computers into high school biology programs?**

Quantitative researchers, including Hakverdi (2005) and Dunleavy & Heinecke (2008), and qualitative researchers, including Siegle & Foster (2001), Tebbutt (1999) and Windshittl & Sahl (2002) have recommended that teachers' perceptions about changing instructional practices, their role during changes, and how they actually use the innovation in their classrooms should be documented. The remaining research questions address these recommendations as this research has yet to be carried out for science teachers in the senior grades of high school. .

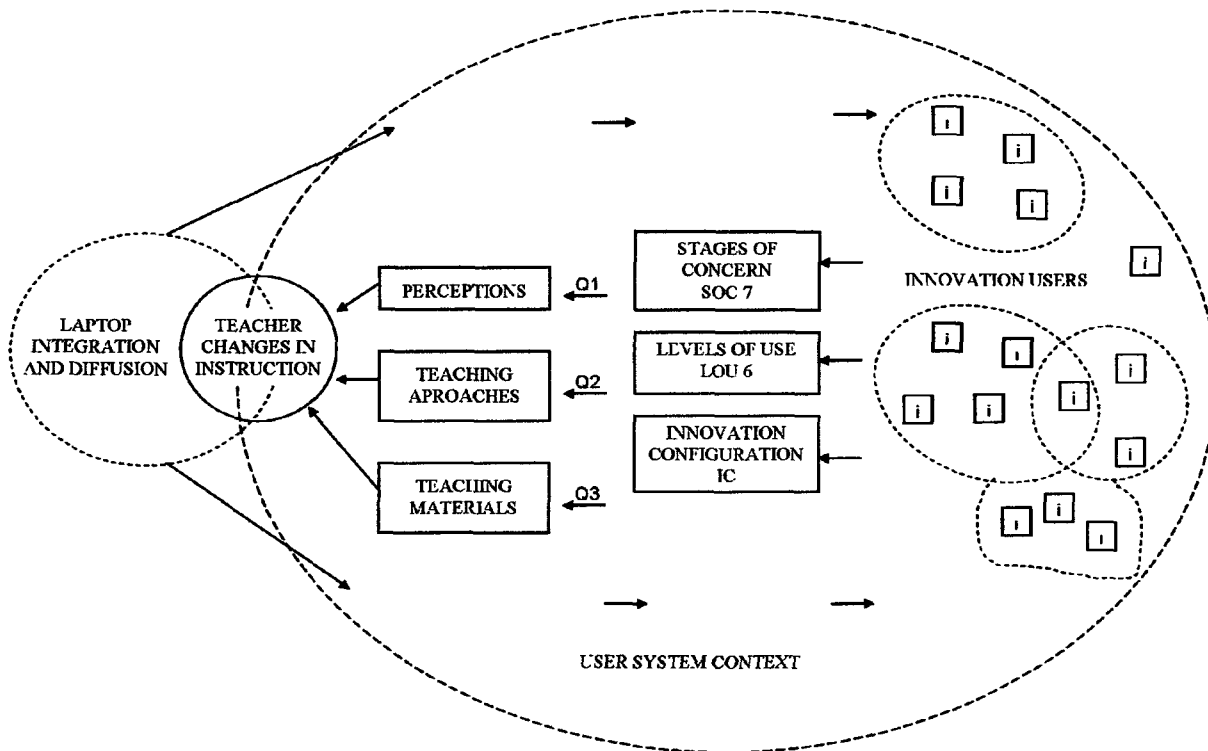
**Question Two: how do senior grade biology teachers perceive and introduce new teaching approaches integrating laptop computers into high school biology programs?**

**Question Three: What new teaching materials do senior grade biology teachers use when integrating laptop computers into high school biology programs?**

### **CBAM Amended: The Conceptual Framework for the Study**

The conceptual framework for the study, developed from the research questions and using aspects of CBAM is presented in Figure 3.3.

**FIGURE 3.3 CONCEPTUAL FRAMEWORK OF THE STUDY**



ADAPTED FROM : HALL & HORD, 1987

## Chapter Summary

From the second chapter, the Literature Review, I determined that this study examines a bottom-up, teacher-initiated change requiring a complex pattern of decision making on the part of the teachers if they are to integrate laptop computers successfully into instruction. The implementation of laptop computers into instruction is not a well-structured change but one that continues to evolve with the introduction of new hardware, software, curricula, and teaching assignments. Diffusion of this innovation between teachers appears to be slow, and while it has been hypothesized that teachers might need time, opportunity, and/or a change in pedagogy, the factors that influence diffusion of the integration of laptop computers between teachers is not well understood.

In this chapter, the Conceptual Framework, I examined the literature on change for a model that would be sufficiently robust and vigorous to organize a study of teachers' perceptions and experience of integrating laptop computers into the complex setting of the senior science classroom. After examining ten models identified as significant models in the literature and the research on change, I eliminated seven models which did not deal with change, implementation and diffusion of an innovation. After a detailed examination of the three remaining models, which did deal with change, implementation and diffusion of an innovation, two were eliminated because they dealt with well-structured innovations, designed for the teachers by experts. Innovations which were then dispersed through a pre-planned dissemination process to school systems and schools. These were not suitable models for a study of a poorly

structured teacher-initiated change, requiring a multiple, simultaneous pattern of decision making by individual teachers to integrate laptop computers into instruction in their classrooms. The fourth model, CBAM, described as the most robust, empirically grounded model developed by researchers in the area of educational change (Anderson, 1997), was the only model which met most of these criteria (Hall et al., 1975).

CBAM does focus on individual teachers' perceptions about change, whether the innovation was being used in the classroom, and provides information on the diffusion of an innovation among teachers. CBAM has three diagnostic dimensions to its structure: Stages of Concern; Levels of Use; and, Innovation Configuration. Criticisms about the functioning of CBAM resulted in the later addition of a fourth tool, qualitative interviews, to augment the quantitative data the model provided (Anderson, 1997). I decided the original CBAM as designed by its developers was not a suitable conceptual framework for this study. Since qualitative data acknowledges that teachers construct much of what they learn and understand as a result of their professional experience (Hewson et al., 1999), I decided to amend the original CBAM by adding research questions to the model, and to conduct a qualitative descriptive study based on the research questions.

**Question One: How do senior grade biology teachers perceive the integration of laptop computers into high school biology programs?**

**Question Two: How do senior grade biology teachers perceive and introduce new teaching approaches when integrating laptop computers into high school biology programs?**

**Question Three: What new teaching materials do senior grade biology teachers use when integrating laptop computers into high school biology programs?**

Further information on the rationale for this decision and an explanation on how the study was organized and put into practice are developed in the next chapter, Chapter Four, Methodology.

## **CHAPTER FOUR: METHODOLOGY**

In Chapter Two, the Literature Review, the objectives of the study were identified as examining the perceptions of teachers concerning the implementation of laptop technology in high school biology courses and providing an opportunity to learn from their experiences. Three research questions were developed to meet these objectives.

Question One: How do senior grade biology teachers perceive the integration of laptop computers into senior biology programs?

Question Two: How do senior grade biology teachers perceive and introduce new teaching approaches when integrating laptop computers into high school biology programs?

Question Three: What new teaching materials do senior grade biology teachers use when integrating laptop computers into high school biology programs?

In Chapter Three, the Conceptual Framework, these research questions were incorporated into a model, the Concerns-Based Adoption Model (CBAM), a model capable of focusing the research on the perceptions of the teachers and their lived experiences (Donovan, 2007). A qualitative descriptive research design was chosen for the reasons outlined in the next section.

### **Design of the Study**

#### **Qualitative Research**

Qualitative research can be used to collect data on “how” and “what” questions as listed above and where the researcher has no control over the actual event being studied (Yin, 1994). As Stake observes, qualitative research can be used to study phenomena that take a long time to happen and which

evolve along the way. He also notes that it often takes a long time to understand what is going on. (Stake, 1995, p. 45, 46). Within qualitative research there are many strategies for inquiry, from case studies to grounded theory. For this research I chose a descriptive study.

### **Descriptive Study**

A descriptive study was appropriate for research designed to describe teachers' perceptions concerning the implementation of laptop technology in high school biology courses and provided the opportunity for participants to learn from their experiences. Descriptive studies have greatly increased knowledge of what goes on in schools (Gall et al., 1996), since they explore actions, events, frames of reference, and processes in natural settings such as classrooms. This descriptive study stresses the importance of the context in which biology teachers teach, their perceptions, and seeks to hear their voices and understand their lived experiences as they integrate laptop computers into their high school biology programs (Marshall & Rossman, 2006).

Although I have identified strengths and limitations to the design of the study later in this chapter, a qualitative descriptive study was chosen despite the limitations, since it allowed for a study focused on teachers' perceptions and experiences of integrating laptop computers into their biology courses. The descriptive approach ensured that the research was conducted in a manner that captured the perceptions and experiences of the teachers. Multiple sources of information were sought at each site: three semi-structured interviews, informal

interviews; follow-up questions; and, the collection of new teaching materials the teachers had prepared. An intense analysis of the data followed the data collection (Seidamn, 2006)

### **Data Collection**

Having chosen to conduct a descriptive study, appropriate strategies for collecting data were selected. Three semi-structured one hour interviews were conducted with each teacher (see Appendix C). The first interview was used to review teacher background, to gather teachers' perceptions and information on changes in teaching approaches and the use of new instructional materials. The second interview was used to gather the teachers' perceptions about integrating laptops into instruction and new teaching material prepared by the teachers was requested. The third interview was used to explore the teachers' perceptions of their future plans to integrate laptops into their teaching, and their opinion of the possibility that other biology teachers would integrate laptops into instruction. Follow-up questions and additional informal interviews were used to investigate any remaining issues. The data were collected at the sites over a period of seven months during 2007.

Interviews were scheduled to accommodate the teachers' individual schedules and responsibilities. In most cases a teacher's interviews were about a week apart which required three trips to the school. The teachers chose the location for their interviews. In most cases they chose science labs or science

offices attached to labs. In other cases they chose another office, or a conference room, or some other location. An electronic recorder, a tape recorder, and voice recognition software were used to prepare transcripts of the data collected.

Gregoire Gill (2006) acknowledges the importance of perceptions on curricular and pedagogical decisions affecting classrooms, but discusses the difficulty researchers face in ascertaining the effect of these perceptions and experiences on instruction and learning. According to Gregoire Gill, interviews, a common method of collecting such information can be viewed as problematical. However, Marshall and Rossman (2006) state that in-depth interviews can be used as a method of collecting information about perceptions and experiences, and as the sole source of collecting data, if the subjective view of events is what is important, and if the purpose of the study is to uncover and describe the teachers' perspectives. Seidman (2006) supports this view, stating that interviewing not only provides the context of teachers' behaviour, but also provides the researcher with a means of understanding that behaviour.

Every research method has its limits and strengths. In-depth interviewing's strength is that through it we can come to understand the details of people's experience from their point of view. We can see how their individual experience interacts with powerful social and organizational forces that pervade the context in which they live and work, and we can discover the interconnections among people who live and work in a shared

context (Seidman, 2006, p.130).

Pertinent to this study, Marshall & Ross (2006) list the strengths of interviews, such as: fostering face-to-face interactions with participants; useful for uncovering participants' perspectives; facilitating immediate follow-up for clarification; useful for describing complex interactions; facilitating discovery of nuances in culture; facilitating analysis, validity checks and triangulation; and for obtaining a large amount of data quickly.

This study relies on previous research, largely quantitative in nature, which identified science teachers as a special population within schools, slow to integrate laptop computers into instruction especially in the senior grades, and which recommended further qualitative research to explore teacher's perspectives of what was happening in their classroom (Becker, 1994; Hakverdi, 2005. As Bain and Weston (2009) observe, the problem was analyzed a decade ago. This study relies on previous research, largely qualitative in nature, which identified that teachers need information about integrating laptops into instruction and a better understanding of the processes if they are to succeed, and that a decade later, these needs are not being met ( Dunleavy & Heinecke, 2007; Tebbutt, 1999).

Building on this previous research, I chose a qualitative, descriptive design for this study and a purposeful sample of ten senior grade biology teachers, instead of identifying the nature of the research problem and the nature of the a sample by quantitative means. Mindful of Anderson's 1997 critique of CBAM,

that it identifies many teachers who are not implementing the innovation being studied, that the existence of these teacher further erodes the quantitative and predictive functions of the model, and, that CBAM is probably best suited for well-structured innovations, I did not consider using the original three quantitative, diagnostic, dimensions of the model. Scott (2008) discusses in considerable detail the difficulties of using the quantitative, diagnostics aspects of CBAM in a study of an unstructured innovation which continues to evolve as it is implemented, where how the innovation should be used and what it will look like when implemented has not been established for the teachers. The study might have been stronger if it had included a quantitative aspect instead of relying on previous research to establish a problem, the context, and the sample that should be studied.

I chose instead to use the fourth dimension added to CBAM, interviews, and to focus on the needs of the teachers previous researchers had identified and were indicating had not yet been met. I developed a qualitative, descriptive design for the study, and used in-depth interviews to collect data from the teachers, in order to explore the perceptions and meaning the teachers ascribe to their experience (Marshall & Ross. 2006; Seidman, 2006).

### **Site Selection**

A purposeful sample (Merriam, 1988) was sought of ten Ontario teachers who were teaching biology in the final two years of high school, in laptop environments where teachers and students have access to personal laptops and

the same software. Sites were sought where laptops were being used with a range of software including probes and data-bases, with a view to enhancing the learning of science, rather than simply being used as word processing and presentation tools (Stolarchuk, 2001a). A group of biology teachers was sought because this is the subject in which I have the most academic (B. Sc.), professional (Honours Specialist Certificate), and teaching experience (grade 13 biology, OAC/12 biology, grade 11 biology, IB higher level biology, IB subsidiary biology). Since we shared similar academic and professional backgrounds, the teachers could discuss their perception of change in a context where we might share a similar level of understanding.

Five school boards were considered for this study, with a total of nine schools believed to have laptop programs. Further investigation revealed that for three of the boards, biology, as a subject in grade 11 and 12, had not been included in their laptop programs. Correspondence and a total of six visits to the other two school board offices did not result in permission to approach any of their teachers within the seven months that data were being collected, even though one of the boards allowed me to visit two high schools with laptop programs and meet with administrators.

First, letters of permission were issued to directors of education with copies of sample letters of consent for principals, and teachers (Appendix D). Where permission was granted by the director of education, principals of high schools with laptop programs were issued with letters of permission and sample letters of consent for teachers (Appendix D). As stated, this process did not

result in any teachers for the sample during the seven months that data were being collected.

In addition to the school boards, independent schools, believed to have laptop programs were approached with an invitation to have their biology teachers participate in the study. Letters of permission were issued to the heads of the independent schools with sample letters of consent for teachers (Appendix D). Three of these schools determined that their laptop program did not meet the definition to be used in this study and two schools did not reply within the seven months that data were being collected. The independent schools which did participate were in Ontario.

Consent was obtained from all persons who contributed to this research. Written permission to approach teachers was issued by the heads of the seven schools that agreed to participate. In some cases, the heads identified the biology teachers who had agreed to participate. In most cases I was directed to a department head or another administrator at the secondary school level and I met and worked through that person. Whatever the system the school used to disseminate the information I provided about the study, ten teachers volunteered to participate. Sometimes the sample letter of consent for teachers (Appendix D) had been passed on to the teacher, but in all cases the letter was discussed with the teacher, and signed by the teacher and the researcher, prior to the first interview.

This chapter recounts how the teachers who participated in the research described themselves. These descriptions allow readers to determine the

usefulness of the teachers' perceptions and experiences as they changed their instruction as they integrated laptop computers in their classrooms. The teachers are presented in random order and have been given pseudonyms to protect their identity: Adele, Keith, Xandra, Darby, Audrey, Zoe, Ross, Samantha, Richard and Kenneth.

The teachers represented by these pseudonyms, Adele, Keith, Xandra and the others, in a sense do not exist. Describing the teachers' perceptions and actions, no matter how carefully executed, must reflect the ongoing decisions required of the researcher while analyzing and presenting the data. Darby, Audrey, Zoe, and the others, are necessarily a blend of the teachers interviewed and the role of the researcher in a descriptive case study.

### **Background of the Participating Teachers**

I sought a purposeful sample of ten Ontario teachers who were teaching biology in the final two years of high school in laptop environments where teachers and students both had access to laptops and the same software. I sought teachers who were using laptops with a wide range of software with the objective of enhancing science instruction, not just using laptops for word processing and presentation tools. The teachers in this purposeful sample were successful early innovators (Clark, 2006; Feldman, 2004). It is important to note in the following descriptions that none of the teachers taught the same course in the same school as one another.

## **Adele: Background**

Adele is in her fourteenth year of teaching at her school and has taught five science courses at the intermediate and senior levels, including Biology 11 and Biology 12. The laptop program started with the grade 9 classes, eight years ago. Although she did not teach grade 9 Science that year, her first contact with the laptop program was to help redesign biology units for the grade 9 Science course. In the third year of the laptop program the laptops had been introduced in grade 11 and she was teaching Biology 11 that year. In the fourth year of the program, the laptops were introduced into grade 12 and she was teaching Biology 11 and Biology 12 that year. She has participated in the laptop program every year since, and this year, as well as teaching Biology 12 she, with another colleague, has students who are preparing to write Advanced Placement (AP) papers in Biology.

She had not had a lot of experience with computer technology prior to teaching and was not actively involved with using the desktop computers or the computer science labs which predated the laptop computer program at the school. She described her background as:

Very basic, and it was fourteen years ago so there wasn't, didn't seem to be, a lot out there at the time. Just word processing, pretty much (Adele, I-43).

After the initial experience helping to redesign grade 9 Science units for use with the laptops, she was able to observe other teachers implementing the laptop program in grades 9 and 10 before she began implementing the laptops in

Biology 11. By that time the students in grade 11 had completed two years in the laptop program.

Adele has an undergraduate degree in science from an Ontario University and has completed additional undergraduate courses in physics, radiation biology, physiology and neural anatomy. She completed her teacher education at a Canadian university and did her practice teaching in Ontario and the United States. Since graduation she has completed an additional qualifications course in teaching English as a Second Language and an Honours Specialist Certificate in Science.

She has had the opportunity to attend workshops to assist her with the integration of laptops. One workshop in the United States, while not specifically on laptop computers, was deemed useful as it dealt with technology associated with the use of laptops.

I went (to the USA) to a science and math conference ...

Fabulous conference, a week long ... Didn't actually get a lot from it for the laptop program but for technology in other ways. We got a lot of information about that, not necessarily laptops. At that time we had just been developing units of study using laptops as a tool (Adele, I - 71).

### **Keith: Background**

Keith is in his twenty-sixth year of teaching at the school and has taught five science courses at the intermediate and senior levels, including Biology 11

and Biology 12, as well as courses in computer science. He has taught in the laptop program since its inception eight years ago. At the time of this study he was teaching Biology 12, a grade 11 computer science course, and one of the units in grade 10 Science. He has Grade 12 students who are preparing to write AP Biology.

Prior to teaching at this school he had experience with computer technology while writing his master's thesis and had taught a first year computer science course at a local community college. He was actively involved with the planning and wiring of the school which sustained the computer technology, the desktop computers and the computer science labs, which predated the laptop computer program.

Keith has an undergraduate degree in zoology and a master's degree in biology from an Ontario university. He has completed five additional courses in computer science at the undergraduate level as well as a professional development course at another Ontario university in the late 1980s which included: an examination of how schools might become laptop communities; the role of laptops in schools; and, the costs associated with laptop programs. He was also selected to attend a biotechnology course at a third Ontario University.

There was a call for educators to take this special biotechnology course which had been created by the university, fully funded.

They brought in educators from across Canada, I think 18 were chosen. Essentially what we did was listen to cutting edge university professors in the morning and then did labs in the

afternoon. We visited research facilities in Ottawa and Montreal, looked at their facilities and got to talk to their people.

Essentially it got us up to speed with the science at the time.

(Keith, II – 387).

In the late 1990s, Keith enjoyed an opportunity to help plan and teach a series of summer professional development courses for Ontario teachers in laptop programs. At that time, the focus was on teaching computer skills rather than how to teach science with laptop computers.

### **Xandra: Background**

Xandra has been teaching for fourteen years. In addition to her ten years of experience in Ontario schools, she has taught at international schools in Europe and Asia. She has taught seven different Ontario high school science courses and has prepared students for Standard and Higher Level biology papers in the International Baccalaureate (IB) program. She is currently teaching Biology 11 and 12 and one section of grade 10 Science. She has been teaching in this school's laptop program since her arrival back in Canada five years ago.

She learned to type and signed up for a course in WordPerfect at university which helped her as she started working with desktop computers. She had some experience teaching science with desktop computers at her previous school in Ontario and at both international schools. In her last year at the international school in Asia, a subsidy program was introduced which encouraged her to purchase a personal laptop computer.

Xandra has an undergraduate degree in science from an Ontario University. She completed her teacher education at an Ontario university and did her practice teaching in the province of Ontario. Since graduation she has completed additional qualifications courses, including: English as a Second Language; Mathematics; and, an Honours Specialist Certificate in Science. She has also completed Additional Basic Qualifications for the Junior and Intermediate panels. She has had the opportunity to attend a course in biotechnology sponsored by the labs of an Ontario hospital, and three or four International Baccalaureate (IB) Biology workshops. Presently, Xandra has students preparing to write IB Biology papers at both Standard and Higher Levels and she is an IB Biology marker which means examination papers are sent to her from other IB schools around the world for her to mark. She is currently completing a leadership diploma at an educational institute in Ontario.

### **Darby: Background**

Darby is in her sixth year of teaching, all at her present school. Her undergraduate degree, from a Faculty of Engineering at an Ontario university, is in biotechnology. After some initial co-op placements in engineering, she decided on a career in teaching and completed a degree in the Faculty of Education at the same university. She has taught fourteen different courses from grade 8 to grade 12/OAC over her six years at the school: six of these courses were science courses. She has taught in the laptop program since coming to the school and is currently teaching Biology 11 and 12. She has students who are

preparing to write IB Biology at the higher and standard levels. Like Xandra, she is an IB marker in Biology and marks examination papers from IB schools around the world.

As an undergraduate she completed a course in computer programming and felt she had gained a general understanding of computers by that time. Between her undergraduate degree and attending the Faculty of Education, she was employed temporarily in a government department dealing with health. She used computers for word processing, producing PowerPoint presentations, and accessing data-bases. She does not recall any professional development being provided, but notes that she has always been comfortable dealing with computers.

I am from one of the first generations where it is intuitive. I can figure it out (Darby, I - 65).

There was no laptop program when she was completing her teaching degree, although some students owned laptops and desktop computers were available. Darby completed her practice teaching in Ontario, and at one of the schools there was technology available which could have been used with computers, but the associate teacher did not use it.

### **Audrey: Background**

Audrey is in her eighth year of teaching at the high school level. She also has experience in an early childhood education environment and experience as a

teaching assistant for science undergraduates and medical students in university environments. She has taught science courses from grades 9-12 over the years, including Biology 11 and Biology 12. When she joined the school in 2000-2001 the grade 11s had already used laptops in grades 9 and 10, and Biology 11, which she was teaching that year, was included in the laptop program. In retrospect, she feels the laptops were used mainly for attendance and posting homework sheets. She did not perceive an expectation that they would be used for instruction and commented that it took her two years to realize what involvement in a laptop program meant for student learning. It was at that point she began to initiate changes. She has participated in the laptop program since 2000-2001 and was teaching Biology 11 at the time of the study.

She had no experience with computers during her own high school years, but used them for mapping as part of her studies in geography as an undergraduate. As a graduate student at the master's and doctoral levels, computers were used for data management, computer modeling, and word processing. Few students were using laptops at the university level at that time. None of the teaching assistants used laptops, and desktop computers were not made available for the teaching assistants to use except at work stations in the labs. By then she was using a desktop computer at home to prepare lessons and handouts.

Audrey has had the opportunity to attend workshops to assist her with the integration of the laptops. One workshop in the United States, while not

specifically with laptop computers, was deemed useful as it dealt with technology used with laptops.

### **Zoe: Background**

Zoe has been teaching for seven years, all at her present school. She has taught six different science courses at the intermediate and senior levels including Biology 11 and Biology 12. This year she is teaching Biology 12 and grade 9 Science. The school had a laptop program for a number of years before she was hired and she has taught in the laptop program since joining the school.

Prior to teaching, Zoe worked for five years in scientific and medical research in university and hospital settings, as well as in the educational department of a software company where she received training in database software tracking tools. As an undergraduate she completed an introductory course in computers and the university issued e-mail accounts to undergraduates at that time. As a graduate student she had the opportunity to complete advanced courses in the use of a number of computer functions including: the Internet: and, a word processing program.

Zoe has an undergraduate and a master's degree in science from an Ontario University. She completed her pre-service teacher education at another Ontario University and since graduating has completed Additional Basic Qualifications courses at the Junior and Primary levels, and Additional Qualifications in Guidance.

The fact that I had the science background and the technology background, I was a perfect fit for the school (Zoe, 187).

She remembers one assignment during her pre-service program where she prepared a town hall presentation on the use of computers in the classroom. She was to discuss the positives associated with computers in the classroom, which she did, relying on her general knowledge of computers, her research and business experience, plus a reading of the educational theory.

I actually researched it and basically based it purely on theory.

I ended up proving the point to be pro-technology, and talked about being a facilitator. At the time I had no practical knowledge of what that meant. The irony is, my personal experience now is totally what my stance was then (Zoe, 11 – 51).

All her professional development on laptop computers has been provided by the IT department at the school where she teaches. She has focused on incorporating the strategies outlined by the IT staff about the programs used by all the teachers at the school.

### **Ross: Background**

Ross is in his twenty-second year of teaching. He began his career with a year of supply teaching with boards in a large urban area in Ontario. He then spent three years at an international school in Europe teaching middle school

general science. Since that time he has taught at his present school. In Ontario, he has taught five different science courses, including Biology 11.

Ross has taught in the laptop program since its inception at the school seven years ago. Prior to that, they were teaching in what he described as a robust network system and he had three desktop computers at his disposal: one at home; one in the science office; and, a third desktop computer, with a projector, in his classroom. The school had computer labs with twenty-five networked computers for students. Teachers could sign up and take students to the computer lab for a science lesson. This was rarely done. Despite the robustness of their desktop system, and despite some early technical difficulties with the laptops, he was quickly impressed with the possibilities of introducing a laptop computer program at the school. These possibilities became a reality three years into the laptop program with a fully functioning wireless system and World Wide Web (www) capability.

Ross has an undergraduate degree in science from an Ontario university. He worked for a year as a teaching assistant at the university level before deciding to enter a faculty of education rather than graduate school. He completed his pre-service teaching degree at another Ontario university, and since graduation has completed two Honour Specialist Certificates, in Environmental Science and Biology.

Before the introduction of the laptop program, the school encouraged the teachers over a twelve year period to gradually acquire computer skills. Although he considers himself self taught, he recognizes the benefit of the professional

development opportunities provided by the school over the years. Most of the opportunities were provided by the IT department, by collegial sharing of experiences with other teachers in the science department, or with teachers in other subject areas in the school. In the late 1990s he also had the opportunity to attend a summer institute for teachers in laptop programs in Ontario. He began using a website for his teaching at that time, but recalls that not all teachers were enthusiastic about this teaching approach, not even the computer science teachers.

### **Samantha: Background**

Samantha was within days of completing her second year of teaching at the time of the interviews and had taught three science courses at the high school level, including Biology 11. She was hired to teach at a school with an established laptop program, although she had not taught using laptops prior to accepting her present teaching position.

Samantha has an undergraduate degree from an Ontario university with a double major in biology and cognitive science. She completed her pre-service teaching degree at a university overseas, and did her practice teaching in that country and in a large urban centre in Ontario. Since graduation she has completed an additional course in psychology.

Neither of the overseas high schools where she completed her practice teaching had laptop programs. In the urban high school in Ontario, the teachers had desktop computers in their offices, but there were no desktop computers in

the biology labs. The overseas campus where she did her pre-service teaching degree was laptop friendly and many of the students from that country used their laptops. International students such as her did not use laptops, because of compatibility problems. Students who did not use laptops used computers at home or in the campus' computer labs to prepare presentations for their courses. She was generally impressed by the computer skills of the other pre-service teachers. Certainly some had attended private high schools with laptop programs, but others had come from public high schools in that country where they had little exposure to computers. During her pre-service education, how to use laptops in schools was demonstrated in a science course. The university she attended in Ontario as an undergraduate was not a laptop university, but she was required to complete a half credit course in computer programming, and she went to the computer labs to prepare her lab reports. During her high school years in Ontario she had very little contact with computers. Students went to a computer lab to do word processing or information gathering, but this was rare.

As a newly hired teacher in a laptop school, Samantha received orientation at the school by the IT staff on programs used by all the teachers. The head of the science department provided orientation on the resources available to teach science and was able to advise her on what other staff members had been able to do with laptops in the past. One of the school administrators was also available to her as a resource person. In addition, she was provided with course binders for grade 10 Science and Biology 11 which she

found to be an enormous help. Although the binders didn't reflect courses taught entirely with laptops, she could see how the laptops had been used in every unit.

If I flipped through the course of study, I could see the laptops were being integrated in every unit in some way (Samantha 1-2). It would show you're going to be using virtual fly lab simulations, or you're going to be using the Internet (Samantha, 1-2).

Yes, they are great. They are my Bible. If you don't have those, there is no direction for you if you are a beginning teacher. You don't know what to do (Samantha, 1-2).

For the grade 11 Biology, I was given the resources from the teacher who taught it the year before. I went solely on those resources, so it wasn't too bad (Samantha, 1-2).

### **Richard: Background**

Richard is in his twentieth year of teaching at his school. In addition to the variety of other positions of responsibility he has assumed over the years, he has taught six different secondary science courses including Biology 11 and Biology 12. This year he is teaching two sections of Biology 12 and has students who are preparing to write AP papers in biology. He has participated in the laptop program every year since its inception seven years ago.

As an undergraduate he took one course in computer programming. Other than that, he learned his computer skills through professional development activities at this school and by teaching in the networked desktop environment they had in the science laboratories prior to the introduction of the laptop computer program. The school assisted the teachers in buying their first computers and he describes a fairly seamless interface for the teachers between the networked desktop program and the laptop computer program which replaced the desktop program.

Richard has undergraduate degree in science and a degree in education from an Ontario university. Since graduation he has completed two Honour Specialist certificates, one in Biology and one in Environmental Sciences. He has also completed a Master's degree in Education (Curriculum Studies) at another Ontario university.

He feels that he and the other teachers at the school have enjoyed tremendous support from the school while they gained the skills and expertise required to teach in the laptop program.

It's part of my job. I love it. I'm learning. I mean I want to be a good teacher. I mean that's my goal (Richard, II – 183).

The professional development he refers to has been made available at school: some provided by experts but much provided by colleagues.

### **Kenneth: Background**

Kenneth is in his twenty-third year of teaching and has taught five science courses at the intermediate and senior level, including Biology 11 and some units in both grade 9 and 10 Science. He has been teaching in the laptop program since it was introduced at the school some eight years ago.

He describes himself as being a combination of self taught, with the benefit of professional development experiences provided by the school over the years. During his pre-service teacher education program, he remembers one educational media course which provided experience with a Gestetner machine and the preparation of multiple layer transparencies. He also remembers manipulating data using punch cards during his undergraduate studies.

Kenneth has an undergraduate degree in science from an Ontario university and completed his pre-service teaching program at a second Ontario university. Since graduation he has completed an Honours Specialist in Environmental Science at a third Ontario university.

### **Summary: Background of the Teachers**

The teachers in this study are academically and professionally prepared for their teaching assignments in biology. As a group, the combination of their undergraduate degrees, graduate degrees, professional certificates, their experience teaching at the intermediate level, their experience teaching at the post-secondary level, and their years of experience teaching grade 11 and 12 biology courses is impressive. Not all the teachers have every one of these

characteristics, but they are well prepared to respond to the interview questions with insight and knowledge. A detailed account of their voices is found in Appendix A.

### **Data Analysis**

In qualitative research, data are typically collected, organised, and then reorganized in a form that may vary from the initial description. O’Leary describes this process as “uncovering and discovering themes that run through the raw data, and interpreting the implications of those themes” (O’Leary, 2009, p. 204).

The recordings of the interviews were converted to a computerised transcript. The data collected were first analyzed by hand and initial themes and categories were determined. Although there was no prior intent to develop theory from this descriptive study, the themes and categories developed were entered into the software NVivo and the text was coded. The NVivo software’s capability to structure and organize data makes it easier for researchers to rework data analyses as new data are collected and to integrate new themes as they emerge (Richards & Richards, 1994; Willis & Jost, 1999).

Themes for analysis were generated from the research questions and from the literature review (Merriam, 1988), and these initial themes were re-evaluated as the data were analysed. Inductive analysis involves discovering patterns, themes and categories in the data for the teachers. In this research, topics raised with the teachers during the interviews resulted in themes based on

their experiences. These common themes, as well as sub-themes, were grouped and coded as illustrated below:

**Question One: How do senior grade biology teachers perceive the integration of laptop computers into high school biology programs?**

- Type of innovation
- Supports to innovation
- Challenges to innovation

Diffusion

- How they might differ from other biology teachers
- Advice to other biology teachers
- What would encourage other biology teachers

**Question Two: How do senior grade biology teachers perceive and introduce new teaching approaches when integrating laptop computers into high school biology programs?**

- Handouts
- Notebooks
- Lab activities
- Active learning (independent learning, inquiry learning, group learning, collaborative learning, projects)
- Homework
- Assessment
- Back-up plans

**Question Three: What new teaching materials do senior biology teachers use when integrating laptop computers into high school biology programs?**

- Used to Use
  - Hardware
  - Software
  - Peripherals
  - Internet
  - Email
  - Textbooks
- Now Use
  - Hardware
  - Software
  - Peripherals
  - Internet
  - Email
  - Textbooks

The coding and re-coding required during the analysis were used to ascertain relationships identified in the data (Stake, 1995; Yin, 2003) and to develop a report on each teacher found in Appendix A.

Using the Concerns-Based Adoption Model (CBAM) as a guide kept the research and the researcher focused on the classroom teachers in the sample, on their perceptions and experience of the innovation they had undertaken, and on their perceptions of the conditions under which the innovation they had

undertaken would be successfully integrated by new colleagues (Donovan, 1997). I also determined that aspects of CBAM would be helpful for analyzing the data obtained from the teachers in the sample.

The rubric developed from the Stages of Concern was used during the analysis of the teachers' perceptions. Specifically, it evaluated the teachers' perceptions against the levels found in the Stages of Concern.

Level 6—Refocusing—*I have some ideas about something that would work even better.*

Level 5—Collaboration—*How can I relate what I am doing to what others are doing?*

Level 4—Consequence—*How is my use affecting learners? How can I have more impact?*

Level 3—Management—*I seem to be spending all my time getting materials ready. How do I implement this change? What do I need to do to make this change happen with my students?* (Hord et al., 1987; Loucks-Horsley, 1996).

This rubric was helpful as a guide when analyzing the participating teachers' perceptions about integrating the laptops into instruction.

The rubric developed from Levels of Use (LoU) was used by the researcher to determine the degree to which teachers in the sample were using new teaching approaches in their respective classrooms and proved helpful during the process of analysis.

The rubric for Innovation Configuration (IC) was informative in that it indicated that the teachers in the sample were in the highest category for use of the innovation, but it was not appropriate for determining the use of new and modified teaching material in the classrooms of the teachers in this sample. Since it did not deal directly with or describe what the new teaching materials would look like, this rubric was less useful for analysis than I had anticipated.

### **Provisions for Trustworthiness**

Since the researcher is the primary instrument in qualitative research, the principle threats to the validity of qualitative research are researcher errors which can result from researcher attributes and worldview (O'Leary, 2009; Seidman, 2006). I bring no potential bias to this research. Although my experience in teaching high school science has been extensive, including teaching grade 11 and grade 12 biology, it did not include integrating laptops into instruction. It was my expectation that the active listening and interpersonal skills, practised over many years, would help to obtain and to interpret the teachers' descriptions of their experiences.

As an experienced high school science teacher, vice-principal, principal, and with training as a supervisory officer for the Province of Ontario, I brought considerable academic and professional understanding to this research. During decades of professional experience I consistently reflected on my personal and professional practices as a guide for future actions. A consultative leadership

style has proven advantageous in the past when dealing with teachers and schools, and that orientation was maintained during this study.

Comparisons with existing literature provide an additional check on the trustworthiness of the findings. Further threats to trustworthiness were dealt with in the planning of the research and this will be discussed in the next section.

### **Internal Validity and Reliability**

Internal validity confirms that the results of the study reflect the reality of the case being studied, while reliability confirms consistency within the results of the study (Robson, 1994). This study incorporated strategies for internal validity: 1) collecting data from multiple sources; 2) checking interpretations with individuals interviewed; 3) staying on site over a period of time; 4) asking peers to comment on emerging findings; 5) involving participants in all phases of the research; and 6) clarifying researcher biases and assumptions (Patton, 2002; Robson, 1994).

A variety of sources for data collection provided triangulation in the data, including: a series of semi-formal interviews; informal interviews; follow-up questions; and, the collection of new teaching materials. This variety offered different avenues for the teachers to provide information about integrating laptops into instructional practices. The teachers were also given the opportunity to review the information representing their perspectives for accuracy and so they could provide additional information. Peers, including the head of science I

and the head of computer science in a laptop school read early copies of the thesis and were asked to comment on the emerging findings.

Researchers, such as Marshall & Rossman (2006), Robson (1994) and Seidman (2006) observe that semi-structured interviews fare well when compared to other data collection techniques in terms of the validity of the information obtained, especially if follow-up questions can be used to clarify meaning or to explore new questions. Transcribing information further reduces the threat to valid description, while participant checks provide accuracy of transcription and act as a control on researcher bias.

In addition to the strategies for internal validity (Merriam, 1988), Merriam's proposals for reliability were also incorporated in the study, including: explaining the assumptions and theory underlying the study; triangulating the data; and providing sufficient detail to illustrate how findings were derived from the data.

### **External Validity**

External validity, that is the ability to generalize, is recognized as problematic in qualitative research. Qualitative research focuses on process, understanding and interpretation of a unique or innovative situation, rather than on generalising from a sample of a larger population ( Rutherford, 2005). The question arises as to what extent findings from this case study could be generalized to teachers in other schools.

This qualitative case study was not designed to test theory on how instructional strategies are changed to accommodate the requirements of the

integration of laptop computers. It can, nonetheless, provide understanding and insights into the integration of such an innovation in a particular setting, with a particular group, and at a particular time. A rich description of the perceptions and experiences of the participating teachers allows readers to determine whether the findings can be transferred to similar situations and settings (Taber, 2000; Ruthven et al., 2005).

### **Significance of the Research**

Previous research, largely quantitative in nature, has identified senior science teachers to be an understudied dynamic in schools, and identified the need for qualitative research to increase our knowledge about the integration of laptop computers in the science classroom. This qualitative descriptive study has been designed to focus on senior biology teachers who were early innovators in the integration of laptop computers in their instruction. This research uses the opportunity these teachers have had to integrate laptop computers to focus on: a special population of teachers, senior science teachers; a special context in schools, a laboratory subject; and the likelihood that laptop computers will be integrated into instruction. Building on recommendations from previous research, the study collected information, and interpreted the teachers' perceptions of the innovation they undertook and the effect of the changes required on their teaching approaches and their use of new materials. This is among the first research studies in this area.

The study provides a body of practical knowledge for biology teachers in the senior grades of high school who are considering the integration of laptops into their instruction. The results of the study are of interest to biology teachers, science teachers, principals, science co-ordinators, science consultants, and board officials whose decisions will lead to the meaningful integration of technology in science education in the senior grades of high school. The study will also be of interest to those researching the teaching of science in secondary schools and to those who prepare science graduates to teach at this level.

### **Chapter Summary**

This chapter has outlined the methodology used for the study, limitations of that methodology, the teachers who participated in the study, and how the data were collected and analyzed. A rich description of the data the teachers contributed is found in Appendix A. The next chapter, Chapter Five, will present an analysis of the data the teachers provided.

## CHAPTER FIVE: ANALYSIS OF THE FINDINGS

This chapter presents an analysis of the data provided by the teachers who participated in the study. Specifically, this chapter addresses the nature of the sample and what the teacher participants shared with us regarding the themes first identified in Chapter Four. The group of teachers who participated in this study was approximately balanced between male and female teachers. Although beyond the control of the researcher, the four male teachers in the sample were the most experienced teachers and the six female teachers were mid-career or early-career teachers. The four male teachers who volunteered to participate in the research were in boys' or co-educational boarding/day schools, and the women teachers who volunteered were from girls' boarding/day schools, girls' day schools and co-educational schools. Of the two women teaching in co-educational schools, one of those schools was a day school and the other was a boarding/day school.

The nature of this purposive sample obscured the effect of a number of factors on the teachers' perceptions of innovations when laptop computers are integrated into biology programs, including: the gender of the teacher; the gender of the students; the effect of a day or day/boarding environment in schools; and, the effect of a single-gender or coeducational environment. Therefore, the analysis in this chapter focuses on the teachers' experience in the classroom whether experienced, mid-career, or early-career. How these three categories were established will be described in the next section.

## **A General Analysis of the Participants**

The research methodology called for ten teachers who had successfully implemented laptop computers in Biology 11 and Biology 12 programs in Ontario. All the teachers who volunteered to participate had strong backgrounds in science and biology and were academically well-prepared to teach high school biology courses. All had undergraduate degrees in science from Ontario universities. In addition to their original undergraduate degrees, they reported having completed additional undergraduate credits in chemistry, physics, radiation biophysics, neural anatomy, and psychology. Five had graduate degrees; four had a M.Sc. or M.A in science; and one had an M.Ed. in curriculum. Prior to deciding to teach high school science, one of the teachers had started a Ph.D. program and another was about to start one.

As a group, these teachers also had strong backgrounds for teaching biology. For most, this involved certificates and specialist qualifications from the Ontario Ministry of Education. For others, it involved graduate degrees, doctoral work, and experience teaching biology at the post-secondary level. Eight teachers had B. Ed. degrees, almost all from Ontario universities. As a group, these teachers had done the majority of their practice teaching in Ontario high schools. Between the ten teachers, they held seven honour specialist certificates in science subjects: two in biology, two in science, one in environmental biology, one in environmental science, and one in chemistry. They had taken three additional basic qualifications courses: two at the junior level, and one at the

intermediate level. They had completed six additional qualifications courses: three in guidance, two in English as a second language, one in biology and one in mathematics. Two of the teachers reported having completed three short specialized courses: one on implementing computers in schools held at an Ontario university, one in biotechnology held at an Ontario hospital, and one in biotechnology funded by an Ontario university.

The biology teachers who participated in this study could be sorted into three groups according to years of experience. Samantha, Darby, Zoe and Audrey had eight years of experience or less in the classroom. Adele and Xandra had 14 years of experience, while Richard, Ross, Keith and Kenneth had between 20 and 26 years of experience. The majority of this teaching experience was in Ontario schools, although two of the teachers had taught in international schools in Europe. One of the two teachers who had taught in Europe had also taught in an international school in Asia. In total, five of the ten teachers in the sample had taught in another province or country during their careers. Three of the teachers had taught at three or more schools and one had taught at two schools. The remaining six teachers had taught at the one school where they were now teaching. All of the early-career teachers had been hired into existing laptop programs. The mid-career and experienced teachers had made a transition into the laptop program. They made the transition from a variety of backgrounds ranging from never having taught with the available desktop computers, to having taught with sophisticated networked desktop

systems whose main difference from a laptop program was that the students did not necessarily have easy access to personal computers.

All were teaching in Ontario at the time of the study in schools which followed the Ontario Curriculum. All of the teachers taught Biology 11 and/or Biology 12. Five of the ten teachers had students writing biology exams for external programs (International Baccalaureate or Advanced Placement) to which their schools had subscribed. All of the teachers encouraged the students to participate in biology competitions. These teachers were teaching four to five classes during 2006-2007 and almost without exception, these were science courses ranging from grades eight to twelve. The number of different preparations per teacher varied from one to six, with the average number of preparations for 2006-2007 being four science courses.

As described above, the teachers who participated in this study reported a wide background of experience teaching science, from grade eight to entrance courses for post-secondary education, to post-secondary education. Current teaching assignments meant one teacher was teaching five different science courses. One teacher taught four different science courses and one taught three different science courses. Four of the teachers taught two science courses and two of the teachers taught one science course. A part-time teacher in the sample had a teaching assignment of two science courses.

These teachers worked in a variety of types of schools and reported varying types of programming, scheduling and school size. Over the years, their additional positions of responsibility within the schools had also varied. Two had

acted as head of the science department or as acting head of science. All reported heavy involvement with students outside the science classroom: all noted the amount of time required to carry out these responsibilities and the wide range of duties assigned by their schools. Duties varied, but included: home room responsibilities; coaching; clubs; school activities; trips; counselling; residential responsibilities; office hours; and, extra help sessions.

As described, the non-teaching responsibilities of teachers at their schools decreased the time the teachers had available for academic responsibilities, and thus reduced the feasibility of changing instruction in their classrooms as they integrated laptop computers. Despite the time pressures they reported, the teachers in the sample expressed satisfaction with the efforts of their colleagues and the Instructional Technology (IT) departments to assist them in implementing the laptop program. All the teachers expressed satisfaction with the vision of the school administration, and with the support the administration was prepared to provide to the teachers participating in the laptop program.

### **Analyzing the Data**

Inductive analysis involves discovering patterns, categories and themes in the data. This study was designed to collect data describing biology teachers' perceptions and experiences of integrating laptop computers into their courses. It was not designed to test hypotheses, nor was it designed to develop theory (Seidman, 2006). The analysis was guided by the research questions and the themes and categories described in Chapter Four. In this chapter, findings

common to teachers from all level of experience are presented first. Then, the findings from experienced teachers, mid-career teachers and early-career teachers are presented when appropriate. (For further details of the analysis, see Appendix B.)

**Question One: How do senior grade biology teachers perceive the integration of laptop computers into high school biology programs?**

The teachers' perceptions as they integrated the laptop computers into their instruction dealt with three themes: the type of innovation the teachers were introducing in their classroom; what the teachers perceived supported their ability to modify their instruction; and, what challenges the teachers perceived they faced, and still face, in changing their instruction.

**Type of Innovation**

Teachers at all levels of experience perceived that they had modified their instructional practices as a result of integrating laptop computers into their biology courses. It is an implementation they perceived would continue over time and there was no consensus as to how long the implementation would continue. Teachers at all levels of experience indicated the implementation of the laptops would be ongoing for a number of reasons, including: the technology they used will be updated and improved; curriculum will be revised; and, their course assignments will change. As discussed in Chapter Three, integrating laptops into their biology courses is an example of a poorly-structured innovation, in contrast to innovations integrated by all the teachers in the school for administrative

purposes. These innovations are designed and implemented by the school (and teachers comply with the implementation schedule established for the school), which is an example of a well-structured innovation.

**Table 5.1: Type of Innovation**

Type of Innovation	Teachers in Sample		
<b>Commonalities</b>			
	<b>Teachers at all Levels of Experience</b>		
Teacher initiated	√		
Teachers sustained	√		
Teacher use of innovation unique	√		
Some collaboration in academics	√		
Evolutionary approach to implementation	√		
<b>Differences</b>			
	<b>Experienced</b>	<b>Mid-career</b>	<b>Early-career</b>
<b>Time for Initial Implementation</b>			
2-3 years	√		
1-2 years		√	
1-6 years			√
Implementation will be ongoing	√	√	

### **Supports during Integration**

Teachers at all levels of experience felt supported through the process of integrating laptops into instruction by the following: feedback from the students they taught and have taught; the professional development made available to them; the school’s support, whether through the administrators or through the IT department; the improvement they perceived in their teaching performance; and, the improvement they perceived in themselves as professionals.

Experienced teachers spoke most often about the various types of support provided by the school and noted that other schools, comparable to the school they are teaching in, had laptop programs. Mid-career teachers said they were supported through the implementation process by the following: professional development made available to them; feedback from students and alumni/ae;

their personal perception that their teaching has improved; and, by their personal perception that they were better teachers. Early-career teachers said that they were supported as they integrated the laptops into instruction by positive feedback from students and alumni/ae, and by the support of their colleagues.

**Table 5.2: Supports to Innovation**

Supports to Innovation	Teachers in Sample		
Commonalities	Teachers at all Levels of Experience		
The students	√		
The schools	√		
Professional development	√		
• At the school	√		
• In response to their needs	√		
• School funds available	√		
• Their progress to date	√		
Differences	Experienced	Mid-career	Early-career
<b>Students provide support</b>			
Increased student learning	√		
Increased student motivation	√		
More learning experiences		√	
Increased student output			√
Students like the course			√
Students are less stressed			√
<b>The school</b>			
Funds for biology peripherals	√		
Feedback from program evaluation			√
<b>Professional development</b>			
Early integration support important	√		
PD with colleagues		√	
Up to date technology			√
Exposure to new ideas		√	
Appropriate PD			√
<b>Instructional issues</b>			
More efficient teaching		√	
Improvement in instruction			√
Personal control of rate of change	√		
Access to Internet resources			√
Courses are easier to teach		√	
Access to standards for technology		√	
<b>Themselves as teachers</b>			
Their personal approach to change	√	√	
Their positive attitude to change		√	√

## Challenges to Innovation

Teachers at all levels of experience said that instructing in a laptop program remained a challenge as did improving the skills they needed to continue integrating laptop computers into their biology courses. They mentioned that obtaining the professional development they needed was a challenge and expressed doubt that the professional development they needed was available. Teachers at all levels of experience said there were ongoing challenges in obtaining and mastering the hardware and peripherals which would make it easier for them to teach their biology courses.

Experienced teachers noted challenges, including: securing appropriate software for teaching biology; and, the maturity level of adolescents which affect how they can use the laptops in the classroom while ensuring an efficient learning environment. Experienced and mid-career teachers both identified the challenges involved in implementing an innovation which will continue to evolve year after year. Mid-career teachers spoke of the challenge their personal level of laptop expertise presented to their ongoing progress in a laptop program. Early-career teachers noted the challenge of improving their instructional techniques when teaching biology in a laptop program, and their need for professional development which would assist them in meeting that challenge.

**Table 5.3: Challenges to Innovation**

Challenges to Innovation	Teachers in Sample
<b>Commonalities</b>	<b>Teachers at all Levels of Experience</b>
<b>Nature of technological innovations</b>	
Hardware/ software/ peripherals	√
Incompatibility of resources	√
<b>Instructional issues</b>	

Their lack of skills and knowledge		√	
Increased time constraints		√	
Maturity of teenagers		√	
<b>Role as biology teacher</b>			
Teaching a laboratory subject		√	
Providing more effective learning		√	
Accessing appropriate PD		√	
Inadequate feedback		√	
<b>Differences</b>	<b>Experienced</b>	<b>Mid-career</b>	<b>Early-career</b>
<b>Instructional Issues</b>			
Delivery of lessons			√
Individualizing instruction			√
Checking Internet resources		√	
Cumbersome assessment processes		√	

### **Diffusion of the Innovation**

Teachers at all levels of experience were of the opinion that the perceptions of biology teachers new to a laptop program are the most important factor in the diffusion of this innovation. Experienced teachers felt they differed from most biology teachers not already in laptop programs in their perceptions as to how courses and lessons should be organized. Mid-career teachers were of the opinion that they differed from other biology teachers not in laptop programs in their willingness to develop new teaching materials. Early-career teachers thought that they might differ from other biology teachers not in laptop programs in their willingness to develop and adopt new teaching approaches.

When asked what advice they would give to biology teachers new to laptop programs, teachers from all levels of experience mentioned the importance of seeking assistance from more experienced colleagues, and having a supportive administration, as well as the importance of the new colleague having the patience to learn new skills and deal with new experiences.

Teachers at all levels of experience were of the opinion that teachers new to teaching biology in a laptop program will be encouraged to continue implementing the laptops as they realize the benefits of this innovation to their teaching, the benefits to students and to the students' learning, and if they perceive that the school identifies the laptop program as a priority. Experienced teachers believed new colleagues will be encouraged if they understand the nature of the implementation they had undertaken, and if they perceive the support available to them during the implementation process. Mid-career teachers believed these teachers will be encouraged to continue implementing the laptops as they modify their teaching approaches. Early-career teachers said new teachers would be encouraged to continue implementing the laptops as they realize the positive effect of the changes they are making as they develop new teaching materials.

In conclusion, when the data obtained from the questions on the diffusion of the innovation were analyzed, experienced, mid-career and early-career teachers tended to stress different aspects of the themes analyzed in this study. Experienced teachers talked about the control the new teachers had of the rate of change in their classrooms and, the supports available to the new teachers during the implementation process. Mid-career teachers stressed the importance of the teachers modifying their teaching approaches and developing new teaching materials. Early-career teachers stressed the importance of the success with which the teacher, as an individual, dealt with the challenges they would face when implementing laptop computers.

According to the teachers in the sample, the success of the diffusion of a laptop computer program, and whether the implementation of the laptops will be sustained in new classrooms depends on a number of interdependent factors, including: the new colleagues perceptions and understanding of the innovation they are implementing and, personal characteristics. These factors, which the teachers in the sample identified as affecting the successful diffusion of laptop computers for instruction, have been highlighted in the following table.

**Table 5.4: Diffusion of the Innovation**

<b>Factors Affecting the Successful Diffusion Of Laptop Computers for Instruction</b>	<b>Teachers in Sample</b>		
<b>Commonalities</b>	<b>Teachers at all Levels of Experience</b>		
New colleague's perceptions are crucial	√		
Perceive LT program is a school priority	√		
Perceive administration is supportive	√		
Perceive can ask for assistance	√		
Perceive LTs improve their teaching	√		
Perceive LTs benefit student learning	√		
<b>Differences</b>	<b>Experienced</b>	<b>Mid-career</b>	<b>Early-career</b>
Understands nature of innovation	√		
Perceives can control implementation	√		
Perceives support is available	√		
Can deal with new experiences		√	
Can deal with new challenges			√
Can be patient		√	
Will modify teaching approaches			√
Will adopt new teaching approaches	√		√
Will learn new skills		√	
Will develop teaching materials	√		√

### **CBAM: Contribution to the Analysis**

Using the Concerns-based Adoption Model (CBAM) as a guide kept the research and the researcher focused on the classroom teachers in the sample and on their perceptions of the innovation they had undertaken, and on their

perceptions of the conditions under which the innovation they had undertaken would be successfully integrated by new colleagues.

The rubric for the six Stages of Concern (SoC) indicated that all the teachers in the sample were focusing on concerns at the highest three levels:

6-Refocusing

5-Collaboration

4-Consequences

Only one early-career teacher, who was finishing her second year in a laptop program at the time of the interviews, was deemed to be still focusing on concerns at the third level:

3-Management.

None of the teachers in the sample expressed concerns at the lowest three levels:

2-Personal, level

1-Informational

0-Awareness

Other than the one teacher who expressed some Level 3 (management concerns), there were no other differences in the nature of their concerns by years of experience. Interpreting the results for Level 5 (collaboration) proved difficult, since all of the teachers were isolated in the sense that they were either the only teacher in their schools teaching their biology course, or the only teacher in the school teaching biology.

**Question Two: How do senior grade biology teachers perceive and introduce new teaching approaches when integrating laptop computers into high school biology programs?**

The teachers described new teaching approaches resulting from the integration of laptop computers into their instruction, including: lesson preparation and lessons; notebooks; lab activities; active learning opportunities, homework, and, assessment procedures. There was a high degree of congruency in the new teaching approaches introduced by the teachers in my sample and a few differences in the emphasis they placed on these teaching approaches according to their years of experience in the classroom.

Teachers at all levels of experience described modifications in teaching approaches in the laptop program which affected almost every aspect of their instruction, although some differences in emphasis were noted according to the teachers' years of experience in the classroom.

Teachers at all levels of experience spoke about introducing new teaching approaches, including: the addition of PowerPoint presentations; the use of PowerPoint presentations for teaching, for maintaining notes and for assisting students to catch up when classes had been missed; the use of laptops for taking notes during classes; labs, which remained mainly a hands-on experience for the students, now included simulations to broaden the students' experiences; there was more independent learning; students were being taught how to use the laptops to research biology topics; and, homework assignments were designed to be more interesting and meaningful to the students. Teachers at all levels of

experience spoke of lessons that were more truly Socratic since there was less need for students to take notes during class.

Experienced teachers most often emphasized changes in lesson preparation. Mid-career teachers most often noted changes in maintaining science notebooks and students' laboratory experiences, as well as changes in how they prepared lessons. Early-career teachers emphasized increased active learning opportunities for students in the laptop computer program.

Table 5.5: Teaching Approaches

Teaching Approaches	Teachers in Sample		
Commonalities	Teachers at all Levels of Experience		
<b>Lesson preparation and lessons</b>			
PowerPoint presentations	√		
Less whole class instruction	√		
SMART Boards are convenient	√		
<b>Lab activities</b>			
Simulations augment labs	√		
Lab technicians augment labs	√		
<b>Active learning opportunities</b>			
More independent learning	√		
More student research of topics	√		
Easier to make up missed work	√		
<b>Homework</b>			
More meaningful assignments	√		
<b>Assessment procedures</b>			
Few changes in assessment practices	√		
Differences	Experienced	Mid-career	Early-career
Changes in lesson preparations	√	√	
Changes in lab experiences	√		
More active learning opportunities	√		√
Easier to plan for groups			√
More time on homework	√		
Less time on homework		√	

### CBAM: Contribution to the Analysis

Using the Concerns-based Adoption Model (CBAM) as a guide kept the research and the researcher focused on the classroom teachers in the sample

and on their experiences as they integrated laptop computers into their Instruction.

The rubrics developed from the six Levels of Use (LoU) indicate a high level of use of new teaching approaches by all the teachers in the sample. All of the teachers' patterns of use of the laptop computers were focused at the three highest levels:

VI-Renewal

V-Integration

IV B-Refinement,

None of the teachers were focusing on use of the laptop computers at the lower levels:

IV-Routine

III-Mechanical Use

II-Preparation

I-Orientation

0-Non-Use.

As previously noted in Question One, the results for Level V (integration) were difficult to interpret using this rubric since there were experienced, mid-career and early-career teachers who were the only biology teacher in their school, or the only biology teacher teaching their course.

**Question Three: What new teaching materials do senior grade biology teachers use when integrating laptop computers into high school biology programs?**

The teachers' perceptions of new teaching materials as they integrated laptop computers into instruction dealt with four themes: hardware, peripherals, software and the Internet. I will deal first with the teaching materials the teachers described using prior to the introduction of laptop computers into their instruction, and then with the teaching materials they described using with the laptop computers.

Most teachers in the sample had chosen not to use desktop computers for instruction. But whether it was the use of hardware, software, the Internet, or technology associated with teaching biology, it was the experienced teachers in the sample who brought a range of these skills to the laptop program. The mid-career teachers described considerable experience with technology associated with teaching biology and some personal experience using the desktops, available in their schools before the laptop program was introduced. The early-career teachers also had some personal experience with desktops, but most of them had started teaching in a laptop program.

Table 5.6: Previous Teaching Materials

Teaching Materials	Teachers in Sample		
	Prior to Laptop Program	Experienced	Mid-career
<b>Hardware</b>			
Desktops			
Desktop with projector	√		
Multiple desktops	√		
Networked desktops	√		
<b>Peripherals</b>			
Scanners	√	√	
Biotech tools			√
Video microscope	√		
Laser disk player	√		
VHS player		√	√
Camera	√		
Overhead projector	√	√	√
<b>Software</b>			
Marks gathering	√		

Platform: Lotus Notes	√		
Dissection programs	√		
PowerPoint		√	
Spreadsheets	√		
Course website	√		
<b>Internet access</b>			
Email		√	
<b>Textbooks</b>			
Textbooks		√	

In the laptop program, teachers at all levels of experience noted using the laptops for instruction, increased use of peripherals, software, teaching resources accessed on the Internet and email, and decreased use of hardcopy textbooks. The experienced and mid-career teachers talked most frequently about their use of peripherals associated with teaching their biology courses. Mid-career and early-career teachers talked most about their changing use of textbooks. One mid-career teacher obtained and used the multimedia kit associated with the course textbook and one early-career teacher began to use an online text. It is the early-career teachers who talked most about their use of hardware, software, and the teaching materials they accessed on the Internet.

Table 5.7: New Teaching Materials

Teaching Materials	Teachers in Sample		
	Experienced	Mid-career	Early-career
<b>Laptop Program</b>			
<b>Hardware</b>			
Laptops	√	√	√
Tablet laptops			√
<b>Peripherals</b>			
Whiteboards	√	√	√
LCD projectors	√	√	√
SMART Boards	√	√	√
Probes	√	√	√
Biotech tools	√	√	
Micropipettes	√		
Digital microscope	√		
Digital camera	√	√	

Spectrophotometer	√		
<b>Software</b>			
Platform:Blackboard/ Lotus			
Notes/ First Class	√	√	√
PowerPoint	√	√	√
Excel		√	√
Microsoft Office			√
Attendance programs	√	√	√
Marks programs	√	√	√
Report card programs	√	√	√
Desktop publishing	√	√	√
Chime (organic molecules)			√
Cobweb (ecology)			√
<b>Internet resources</b>			
Animations		√	√
Simulations		√	√
Dissections		√	√
Interactive demonstrations		√	
Preparing webquests		√	√
Databases	√	√	√
Scientific journals			
Websites	√	√	√
Interactive websites			√
University websites	√		√
NGO websites	√		
Medical websites	√		
Government websites			√
NABT website	√		
Biology Place	√		
Turnitin.com		√	
Email	√	√	√
<b>Textbooks</b>			
Resource booklets	√		
Textbooks/ CD ROMS	√	√	√
Textbooks/ multimedia packages		√	
Electronic textbooks			√

### Contribution of CBAM to the Analysis

The rubric developed for Innovation Configuration (IC) was only partially successful in contributing to the analysis. The results were valuable in that the rubric indicated teachers in the sample, from all levels of experience, were in the top category in eight of ten characteristics of a laptop program.

- 1 Access to computers
- 2 Student use of computers in subject area

- 3 Classroom organization
- 6 Learning activities
- 7 Nature of task environment
- 8 Technological literacy

The exceptions were Categories 4 and 5:

- 4 Independent learning
- 5 Teacher-student relationship

These two categories differentiated between the classroom of one teacher in the sample, an early-career teacher in a student-centred program, and the other nine teachers who had introduced student-centred activities, but the programs remained more teacher-directed than the student-centred program. The descriptors for Levels 4 and 5 in the IC made it difficult to place these nine teachers on the rubric. However, the rubric developed for Innovation Configuration (IC) did not focus sufficiently on developing new teaching materials to add to the analysis of Question Three already presented in this chapter.

### **Chapter Summary**

In this chapter, through an analysis of the data provided by the ten participating teachers in Appendix A, much more was learned about the teachers' perceptions and knowledge about integrating laptop computers into their biology programs. Because of the nature of the purposive sample assembled for this study, the analysis examined the biology teachers' perceptions about integrating laptop computers into their instruction from the perspectives of experienced, mid-

career and early-career teachers. I became aware of the similarities the teachers expressed about integrating laptop computers into their instruction. The differences the teachers expressed about integrating laptop computers into their instruction were differences of emphasis and should read as such.

The teachers' perceptions as they integrated the laptop program encompassed three themes: the type of implementation they were carrying out; what they perceived supported their ability to integrate laptop computers into their instruction; and, what challenges they perceived they faced implementing the laptop computers and sustaining the integration of the laptops in their respective classrooms. In order to gather the teachers' perceptions of the diffusion of this innovation, biology instruction in a laptop program, the teachers were asked three questions. How might you differ from biology teachers not teaching in a laptop program? What advice would you give biology teachers entering a laptop program? What would encourage biology teachers to integrate laptops into their instruction? As explained in the previous paragraph, in all cases the teachers' perceptions were analyzed from the perspective of experienced, mid-career and early-career teachers.

**Summary Question One: How do senior grade biology teachers perceive the integration of laptop computers into high school biology programs?**

Table 5.1: Type of Innovation: The teachers' perceptions as they integrated the laptop program can be summarized as follows: instructional innovation in their classroom was initiated and implemented by them; integrating the laptops into instruction was a poorly structured innovation carried out in an

evolutionary manner; in contrast, non-pedagogical innovations, that is to say administrative innovations affecting all the teachers in the school, tended to be mandated by the school; these non-pedagogical innovations, required by the school for all teachers, were designed by others, such as the IT department, and implemented by the teachers according to a schedule established by the school.

There does not appear to be a simple pattern of how teaching experience influenced the teachers' perceptions of the type of implementation they had undertaken when integrating laptop computers into instruction. The most experienced teachers and the mid-career teachers were more likely to describe the reasons why the innovations due to the laptops would impact their instruction every year. Early-career teachers were more likely to specify the number of years they expected were necessary to accomplish the initial integration of laptop computers into their instruction.

Figure 5.2: Supports to Integration: The supports the teachers perceived and the ongoing challenges they faced were different for their pedagogical and non-pedagogical roles in the schools. If we examine the supports the teachers perceived and the ongoing challenges they faced when implementing the laptop computers into their instruction, there are variations in these perceptions according to years of teaching experience.

Teachers at all levels of experience felt they had been supported in the laptop program by the school, the students, the professional development available to them, and by their perception of improvement in their teaching in the classroom. Perceptions of what supported the ongoing integration of the laptops

included: experienced teachers considered the support of the school administration and the fact that comparable schools had laptop programs as being important; mid-career teachers valued their perceptions that their instructional practices had improved, they were becoming better teachers, and that professional development would be made available to assist them; and, early-career teachers noted positive feedback from students and alumni/ae, and the support of colleagues as being important in a laptop program.

Table 5.3: Challenges to Innovation: Teachers at all levels of experience described the challenge of instructing in a laptop program, obtaining appropriate professional development and obtaining appropriate resources and equipment to teach biology. Perceptions of challenges to the ongoing integration of laptops included: experienced teachers perceived the necessity of updating hardware, software and locating suitable peripherals for teaching their biology courses, the ongoing acquisition of the knowledge and skills they required as teachers, and the maturity of adolescent learners in a laptop program as being important challenges; mid-career teachers perceived that acquiring the knowledge and skills they required to be better teachers in the laptop program was their main challenge; and, early-career teachers perceived how to vary their instructional approaches in laptop classrooms and the availability of appropriate professional development were important to the ongoing progress of integrating laptops into their biology courses.

Table 5.4: Diffusion of the Innovation: All the teachers in the sample believed the perceptions of new biology teachers affected the diffusion of the

integration of laptops into their instruction and were the teachers' the most important factor affecting what decisions the teachers would make about initiating and implementing this innovation in their classrooms. How the interplay of willingness to modify perceptions, willingness to alter teaching approaches, and willingness to develop new teaching materials affected the diffusion process was perceived differently depending on the years of teaching experience of the teachers in the sample. As noted previously, there does not appear to be a simple pattern of how the years of experience of the teachers in the sample influenced their perceptions of the likelihood that new colleagues would integrate laptops into their biology instruction.

Experienced teachers stressed the importance of the support provided at the school and by the school, and allowing the new colleagues control of how and when the laptops were integrated into their courses. Mid-career teachers perceived that whether new colleagues could manage the new challenges they would face in a laptop classroom, and their willingness to alter their teaching approaches and develop new teaching materials increased the likelihood that the laptops would be integrated into instruction. Early-career teachers perceived that whether new colleagues integrated the laptops depended on how quickly they realized their instruction was more effective in a laptop program and whether they were prepared to deal with the challenges of implementing a self-initiated, poorly structured innovation which would continue to evolve every year.

**Summary Question Two: How do senior grade biology teachers perceive and introduce new teaching approaches when integrating laptop computers into high school biology programs?**

Table 5.5: Teaching Approaches: Teachers at all levels of experience spoke of introducing new teaching approaches, including: the addition of PowerPoint presentations; the use of PowerPoint presentations for teaching, maintaining notebooks and for assisting students to catch up when classes had been missed; laptops were often used for taking notes during classes; labs, which remained mainly a hands-on activity for the students, included simulations to broaden the students' experiences; more independent learning and less teacher-directed learning; students were being taught how to use the laptops to research biology topics; and, homework assignments were designed to be more interesting and more meaningful to the students. Teachers at all levels of experience spoke of lessons that were truly Socratic since there was less need for students to take notes during class and they could participate in the discussion. An exception to the introduction of new teaching approaches was that most of the teachers at all levels of experience did not alter their assessment practices. Most continued to assess student progress using pen-and-paper tests and examinations, and they continue to mark and return paper copies of student assignments.

While teachers at all levels of experience described modifications in teaching approaches in the laptop program affecting almost every aspect of their instruction, I noted some differences in emphasis according to the teachers' years of experience in the classroom. Experienced teachers described changes in how they prepared lessons most often and were of the opinion that high-

achieving students spent more time on homework in the laptop program. Mid-career teachers tended to describe changes in maintaining science notebooks and in students' laboratory experiences, as well as changes in how they prepared lessons. Early-career teachers emphasized increased active learning opportunities for students in the laptop computer program.

**Summary Question Three: What new teaching materials do senior grade biology teachers use when integrating laptop computers into high school biology programs?**

Table 5.6: Previous Teaching Materials: Most teachers in the sample had chosen not to use desktop computers for instruction in their classrooms, although the experienced teachers brought a range of skills to the laptop program, whether it was the use of hardware, software, the Internet, or technology associated with teaching biology. The mid-career teachers described considerable experience with technology associated with teaching biology and some experience using the hardware, that is to say, the desktops, available in their schools before the laptop program was introduced. The early-career teachers also had some personal experience with desktops, but most of them had started teaching in a laptop program.

Table 5.7: New Teaching Materials: In the laptop program, teachers at all levels of experience noted using the laptops for instruction, as well as increased use of peripherals, software, teaching resources accessed on the Internet and email. The experienced and mid-career teachers described their use of peripherals associated with teaching their biology courses. Mid-career and early-career teachers described their use of textbooks. One mid-career teacher

obtained and used the multimedia kit associated with the course text book and one early-career teacher began to use an online text. It is the early-career teachers who commented most about their use of hardware, software, and the teaching materials they access on the Internet.

### **Summary: CBAM's Contribution to the Analysis**

The three rubrics prepared from the Concerns-Based Adoption Model (CBAM) indicated that the teachers in this sample were operating at the highest levels of CBAM, whether Stages of Concern (integrating the laptops into their classrooms), Levels of Use (using the laptops in their respective classrooms), or Innovation Configuration (what the integration of laptop computers looked like in their classrooms). At some levels (5 - SoC and V - LoU) the relative isolation in which the biology teachers taught in their schools made using the rubrics developed from CBAM difficult to interpret. The rubric developed from Innovation Configuration (IC) indicated teachers in the sample were in the top category in eight of ten characteristics of a laptop program, but in retrospect it did not focus sufficiently on teaching materials.

### **Conclusion**

In conclusion, considerable detail of the biology teachers' perceptions on integrating laptop computers was provided in this chapter so that readers could select information that is important from their perspective and use it to judge the relevance of the findings of this study with regard to their personal situation and

other contexts. During the analyses reported in this chapter and when analyzing the results obtained from the CBAM rubrics, I was most aware of the similarities in perceptions of integrating laptop computers described by the teachers in the sample. See Inan & Lowther (2010a) and Ward & Parr (2010). The differences noted, by years of teaching experience, were differences of emphasis of the perceptions the teachers noted, rather than differences in perceptions. The sample used in this study was small and these findings are an indication of variations which should be investigated further in future quantitative and qualitative research, or read in conjunction with complementary research on the significance of years of teaching experience (Inan & Lowther (2010a) ; Hinds, 2007; Ward & Parr (2010). For these reasons, what will be carried forward from Chapter Five to Chapter Six are the perceptions noted by teachers at all levels of experience. Chapter Six will also summarize the major findings of this research with respect to the current literature reviewed for this study.

## **CHAPTER SIX: DISCUSSION OF THE FINDINGS**

This chapter discusses the findings of the study with respect to the research literature reviewed for the study. The findings of the study encompass the following: the teachers who participated, the three research questions, the literature review, the conceptual framework, and the design of the study. As has been discussed in Chapter Two, the objectives this study are to provide description and analysis of the pedagogical integration of laptops into *contemporary senior science classrooms and an opportunity to learn from teachers who are early implementers*. For clarity, these findings will first be presented in a summary. They will then be elaborated upon in detailed enumerated findings.

### **The Participating Teachers**

The relationship between teacher background and the implementation of laptops for instruction in science classrooms is only addressed tangentially in the recent literature I have reviewed. Becker (1994) observes that science teachers with more years of formal schooling, and specialization in their subject matter, are more likely to integrate computers into their instruction. While noting that subject specialization invariably increases with years of experience in the classroom, and acknowledging that it is hard to differentiate between the influence of educational background, years of teaching experience, specialist qualifications and experience using computers, Becker finds that the teachers most proficient in using computers for pedagogical purposes have more

qualifications in their academic subject matter. For this reason, I have provided considerable detail about the backgrounds of the biology teachers who volunteered to participate in this study.

The teachers who volunteered for this study have a combination of undergraduate degrees in science, graduate degrees, professional certificates, specialist certificates, experience teaching science at the intermediate level, experience teaching science at the post-secondary level, and years of experience teaching grade 11 and 12 biology courses. While not all the teachers in my sample possess each of these characteristics, the combination of the characteristics noted above that they do possess as biology teachers is noteworthy. Based on Becker's earlier study, and a study by Davis (2006) which confirms that secondary science teachers with strong subject-matter knowledge tend to employ, or at least consider, more effective or innovative teaching strategies, there is a high likelihood that the teachers in this study's sample would be willing to integrate laptop computers into their instruction and be willing to sustain the innovation after the initial implementation.

### **Summary of the Findings**

My search of the literature, as discussed in Chapter Two, indicates that teacher-initiated, poorly structured learning innovations are multi-dimensional processes, and are successful only if three things take place: the incorporation of new teaching perceptions, the introduction of new teaching approaches, and the use of new teaching materials by the teachers concerned. On this basis, three

research questions were established for this study which resulted in 12 pertinent findings:

**Question One: How do senior grade biology teachers' perceive the integration of laptop computers into high school biology programs?**

1. Teachers indicated that they make the decisions as to how and when laptops are integrated into instruction in their biology courses.
2. Teachers perceived a sense of pedagogical isolation and noted that how they use the laptops for instruction in their classrooms often differed significantly from the implementation efforts of their colleagues.
3. Teachers described a gradual, evolutionary transition as they introduced laptop instruction into their classrooms.
4. Teachers reported that there were no institutional or systems experts designing, planning or supervising how they were to integrate laptops into their instruction.
5. At the same time that teachers were integrating laptops into their instruction, they were also implementing institutional technological innovations, such as computerized systems for reporting attendance, reporting marks and preparing report cards. This required a great deal of time and effort, especially during the first year in a laptop program—time which might otherwise have been used to integrate the laptops into instruction.
6. Teachers perceived wide ranging support as they integrated laptops into their instruction.
7. Teachers noted that they faced, and continue to face, a wide range of challenges with regard to integrating laptops into their instruction. Some of these challenges were previously identified as supports, but are supports which remain inadequately or incompletely implemented.
8. Teachers provided advice which they believe would increase the likelihood that new colleagues would integrate the laptops into their instruction.
9. Teachers listed what they believed would encourage new colleagues to integrate the laptops into their instruction.
10. Assisting new colleagues to organize and obtain subject-specific skills to integrate laptop computers into their instruction appeared to be on an *ad hoc* basis.

**Question Two: How do senior grade biology teachers perceive and introduce new teaching approaches integrating laptop computers into high school biology programs?**

11. The teachers described significant changes in teaching approaches when integrating laptop computers into their instruction.

**Question Three: What new teaching materials do senior grade biology teachers use when integrating laptop computers into high school biology programs?**

12. The teachers described significant changes in teaching materials when integrating laptop computers into their instruction.

The following detailed Enumerated Findings will examine the findings of this study with respect to the research literature I reviewed. For clarity, they will also be organized by the research questions.

**Enumerated Findings**

**Question One: How do senior grade biology teachers perceive the integration of laptop computers into high school biology programs?**

I found little in the research literature I reviewed for this study to validate the data the high school teachers in the sample provided on integrated laptops into their instruction. In fact, Russell (2006) observes that most research about the secondary level is carried out by the tertiary level rather than by the secondary level and, Inan et al. (2010) observe that teaching approaches and materials differ with grade level and subject area. Certainly, most of the studies that I was able to locate tended to have been carried out at other educational levels or in other subjects, including: the post-secondary level (Bell and Bell, 2005; Ferdig, 2006; Landry & Hartman, 2006; Reading et al., 2006; van Oostven & Muirhead, 2007; Windschitl & Sahl, 2002); middle school science (Kiboss et al., 2004; Moore, 2004; Rogan, 2007); or in subjects other than science (Kearny & Schuck, 2007). Therefore, in this section, as in other sections of this chapter,

many of the findings of the study will be discussed with respect to research findings derived from studies at levels of education other than secondary schools. In this section five findings present material new to this study, two findings confirm for high school biology teachers findings that have been described in studies at other levels of education, and three findings confirm that needs identified in previous research are still not being met. Findings 1, 2, 3, 5 and 8 are new to this study. Findings 4 and 6 confirm for high school biology teachers, findings that were previously identified at other levels of education. Findings 7, 9 and 10 confirm that needs identified in previous research are still not being met.

### **Findings 1-10 and Discussion**

1. *While entering a laptop program is a school-based decision, the teachers participating in this study indicated that they made the decisions as to how and when laptops are integrated into instruction in their biology courses.*

I have found no other research on agency in decision making when laptops are being pedagogically integrated into the classroom.

2. *The teachers in my sample often perceived a sense of pedagogical isolation, reporting that how they chose to use laptops for instruction in their classrooms often differed significantly from the implementation efforts of their colleagues.*

I have found no other research which deals directly with the perceptions noted in this finding, although van Oostven and Muirhead (2007) observe that faculty teaching science courses in their study at the post- secondary level use

laptops differently from faculty teaching other subjects. Simmie (2007), in a more general curriculum study of 100 senior biology teachers in Ireland, confirms that teachers who implement self-designed innovations in their respective classrooms display both commitment and creativity which suggests the individualistic approach and uniqueness noted by the teachers in this study.

3. *The teachers in this study described a gradual, evolutionary transition as they introduced laptop instruction in their respective classrooms. They uniformly viewed integrating computers into instruction as, at a minimum, a multiyear project that demands patience, steadfastness, and continuing commitment.*

This perception of an evolutionary approach to integrating laptop computers into instruction is also consistent with the advice (See Finding 8) teachers in the sample would give to new colleagues who are starting to implement laptops into their instruction, regardless of the new colleagues' experience as biology teachers or the level of their technology skills.

Studies on integrating laptop computers into instruction in which science teachers were involved, have tended not to focus on the complexity of the implementation that the teachers undertake or the nature of the implementation, whether evolutionary or revolutionary. Stolarchuk (2001a) appears to favor a revolutionary approach, recommending that science teachers have a year to prepare before implementing laptop computers. I saw nothing in the literature to suggest this revolutionary pattern of preparation was occurring in practice.

Although the sample is small, more experienced teachers perceived the ongoing nature of an innovation such as laptop computers, while early-career

teachers were more likely to perceive that the laptops could be implemented in a given number of years.

4. *The biology teachers constituting the sample in this study reported that there are no institutional or systems experts designing, planning or supervising how they were to integrate the laptops into their instruction. Similarly, there is no appointed change agent whose role is to guide the teachers through and to coordinate the pedagogical implementation of the laptop computers.*

While implementing a laptop computer program is a school-based decision, Information Technology (IT) departments typically may not provide backup to the teachers specific to the pedagogical use of laptops as recommended by Inan et al., (2010). As a result, in addition to determining how and where they will use the laptops, the teachers are deciding their approach to using the laptops in their classrooms and if and how to introduce new teaching materials. These decisions are complex and continue to evolve as conditions change and emerge from a bottom-up dynamic which starts in the classroom. Rogan (2007) comments on the lack of understanding in schools and school systems regarding the enormity of the changes required of science teachers when they implement an innovation such as the integration of laptop computers, and the lack of detail provided by schools and school systems on how teachers might implement such large-scale innovations. Moore (2004) confirms the complexity of the implementation processes that teachers are exposed to in

schools when implementing multiple, simultaneous innovations such as the integration of laptop computers into instruction.

5. *At the same time that the teachers in this sample were attempting to integrate laptops into their biology instruction, they were dealing with a parallel set of institutional technological innovations, such as computerized systems for reporting attendance, reporting marks, and preparing report cards. Such tasks require a great deal of time and effort during a new teacher's first year in a laptop program—time which a new colleague might otherwise use to integrate laptop computers into instruction.*

Despite the IT departments' higher level of professional development activity in non-pedagogical areas, there remained a distinct lack of planning to assist and support teachers new to the laptop program. The process of using the software for attendance, reporting grades, and preparing report cards, although mastering the use of this software clearly requires a great deal of time and effort during a new teacher's first year in a laptop program—time which might otherwise have been used for the academic program.

I have found no other research that deals directly with the implications of teachers simultaneously implementing parallel sets of innovations: one set self-initiated and self-sustained over a number of years, and the other designed, and the implementation timetable established, by another agent or agency such as an IT department.

In contrast to the conditions under which teachers are integrating laptops into their instruction, teachers are also implementing administrative

innovations under very different conditions. In this instance, the teachers usually will not have participated in pilot projects of these administrative (non-pedagogical) innovations prior to their implementation, or had input on these non-pedagogical innovations such as how they are to be implemented or when they are to be implemented. Therefore, the teachers may not have had an opportunity to contribute in a middle-up pattern of implementation. In any event, in this parallel set of non-pedagogical changes, the IT departments are proactive in providing professional development opportunities for the teachers on the systems and software. The teachers in this study reported spending considerable time and energy complying with the use of the software used to manage the school, a fidelity approach to implementation usually associated with top-down decision making. I found the teachers in this study to be extremely positive about this aspect of the IT departments' role in the school. At this point, I feel it is important to note that I also found the teachers to be optimistic about the IT technicians' role in keeping the system, their laptops, and their peripherals functioning. The teachers were also content with the speed and effectiveness with which the technicians insured that the students had functioning laptop computers, although these functions did not directly affect the teachers' ability to integrate the laptops into instruction.

Despite the complexity of the implementation patterns which the teachers in the sample had observed as new teachers began teaching in a laptop program, a great many of the observations made by the participants in my study were in reference to the altered pedagogical role required of new teachers as

they entered the program. I am surprised because a great deal of the information the teachers in the sample provided during the interviews dealt with the time and effort spent in IT professional development in order to learn the technology used to manage the school's administrative functions as opposed to implementing it in the classroom.

6. *The teachers in this sample discussed their perceptions of what supported them as they integrated laptops into their instruction, including: anecdotal feedback from students, alumni/ae, and the school community; the improvement they perceived in their teaching approaches; the availability of professional development; the improvement they perceived in student learning; the positive effect of integrating laptop computers on them personally as teachers; the availability of the peripherals and software they had been able to obtain to teach biology; and by access to up-to-date technology.*

None of the teachers in the sample expressed interest in returning to pre-laptop teaching approaches to instruction. Although they expressed a sense of pedagogical isolation in the laptop program, there was general acknowledgement that a sense of collegial support had developed as they all had to deal with the problems the laptops introduced into their school life. Prior to the introduction of the laptop program, the teachers in the sample may have been able to deal with professional problems on their own, but there was a sense that that problem-solving method was no longer an option when dealing with the types of issues that the laptops introduced. They valued collegial support when dealing with the technological problems the laptops introduced and were encouraged to continue

integrating the laptop computers because other schools, by which they measured the success of their own school, also had laptop programs.

I found some validation of the teachers' perceptions in the literature. Newhouse & Rennie (2001) identify the expectations of school administrators and parents as positive factors impacting the diffusion of laptop computer use. Bell and Bell (2005) confirm that with a collaborative management style at a school, innovations are likely to be successful, especially if the collaborative management style is combined with opportunities for teacher learning, and a school culture with high expectations for teachers and students. Students can be a support and provide technical expertise as teachers implement laptop computers in their instruction (Bell & Bell, 2005) and, while I found no discussion in the literature about senior secondary science teachers, elementary science teachers were found to be encouraged by the opportunity to work alongside their students as laptop computers were implemented into the classroom (Mueller & Welch, 2006). Other supports noted by Harvey & Kamvounias (2008), Kane (2003) and McMahon (2007) include a collegial learning atmosphere, and a perception by the teachers that the laptop program had added value to their teaching and to their students' learning. Fullan reports that another important support to the success of an innovation is the perception by the teachers that the school has made an adequate and sufficient financial investment in the innovation (Fullan 2007; Fullan 2006; Fullan, 2005).

Although the sample is small, there is some evidence in the data that teachers with different years of experience perceive different supports as they

integrate laptops into their instruction. Experienced teachers cite the support of the school and the school administration. Mid-career teachers note they are encouraged that their improved instructional practices make them better teachers and by the professional development available to them. Early-career teachers observe that they are encouraged to continue integrating laptops into their instruction by the positive feedback they receive from the students.

*7. The teachers in my sample provided information on the challenges they perceived they faced, and will continue to face, when integrating laptop computers into their instruction, including: the technology they were using; the demand for novel and often untried instructional practices; teaching a laboratory science subject, such as biology, which they viewed as being more difficult than non-laboratory courses; finding appropriate professional development they could access; and the frequent lack of maturity in the teenage students enrolled in a laptop program.*

A number of researchers confirm perceptions expressed by the teachers in this study, observing that teachers need more subject-specific knowledge and assistance if they are to integrate laptop computers into instruction (Klopfer et al., 2005; Newhouse, 2001a; Siegle & Foster, 2001) and Simmie (2007) observes that a lack of appropriate, and subject-specific professional development opportunities for science teachers persists in the school system. Bell & Bell (2005) and Inan et al., (2010) confirm that the teachers need academic as well as technical support in their subject area and Bell & Bell (2005) note that teachers

prefer to receive this subject specific professional development from those who teach, or have taught, the courses they teach.

Although the sample was small, there is some evidence in the data that challenges varied with the experience of the teachers. Experienced teachers identified the acquisition of appropriate new hardware, software, and peripherals, as well as the knowledge and skills to use them in the classroom as ongoing challenges. Mid-career teachers identified the acquisition of new knowledge and skills, while early-career teachers identified varying their instructional approaches in the classroom and acquiring appropriate professional development as ongoing challenges.

8. *The teachers in the sample provided advice for new colleagues regarding the integration of laptop computers into their biology programs, including: new colleagues should be willing to modify traditional roles in teacher-centred classrooms and strive to become classroom learning facilitators; teachers new to a laptop program should be willing to learn, be open to new experiences and willing to develop new materials; new teachers should be reassured that the process of integrating laptops into instruction requires patience and perspective; teachers entering a laptop program should have a supportive administration providing adequate financial resources as this would lighten their academic or supervisory duties in the school while they made the transition to using laptop computers in their instruction; teachers new to laptop programs should, when possible, observe and model themselves after colleagues who have experience with such technology in the classroom; new*

*colleagues should focus on learning new technical skills and seek out appropriate professional development; teachers new to laptop programs should reorganize their courses starting with their favourite labs, or the labs that are important for the course; they should use laptops only when they are appropriate or pedagogically worthwhile; they should realize that it is not necessary to use laptops every day.*

Some of the teachers in this study had observed new colleagues enter the laptop program at their school, others had not. All of the teachers in the sample contributed advice that they would give to new colleagues with regard to facilitating the integration and diffusion of laptop computers in the classroom for instruction. I have found no other research where teacher's voices describe the diffusion of laptop computers to new colleagues.

9. *The teachers in this sample were of the opinion that other biology teachers would be encouraged to integrate laptops into their instruction if certain factors and experiences were present in their teaching environment, including: if the integration of laptops were a school priority; if it were expected that teachers integrate this new technology in their school; if the laptop program provided better and more flexible conditions for student learning; if students experienced increased academic success in biology courses; if there were increased student success in admission to post-secondary educational institutions; if former students experienced increased academic success at post-secondary institutions; if integrating laptops into instruction were viewed by colleagues as a*

*multi-year endeavour; and if there were continuing school-based technological support for teachers instructionally using laptops.*

The teachers who had observed the integration process (noted in Finding 8 above), discussed “new colleagues” who were experienced biology teachers, but new to a laptop program, as well as “new colleagues” who were new to biology teaching, but who possessed laptop skills. The process of integrating laptops into their instruction was seen to be equally challenging for each. I have found no other research where teacher’s voices describe the diffusion of laptop computers to new colleagues.

10. *The teachers in my study focused on new colleagues organizing and obtaining the subject-specific help they needed on what appears to be an ad hoc basis. No plans were described to assist and support the new teachers’ learning on how to use the laptops for instruction.*

Although many of the observations made by the participants in my study were in reference to the new teachers’ academic role in the classroom, the teachers in my study realized that new teachers would require assistance organizing and obtaining the subject-specific help they needed, no details were provided concerning organization to assist and support learning on how to use the laptops for instruction. Opportunities such as these have been recommended in Inan et al., (2010).

Although I am surprised by the lack of planning to assist teachers assume their new roles in a laptop program, both pedagogical and non-pedagogical, perhaps I should not have been puzzled by the different implementation

processes the teachers described as operating in the schools. What the teachers in the sample described in non-pedagogical areas of the laptop program was a process of dissemination, organized and carried out by the IT departments for functions common to all the teachers in the school. Anderson (1997) notes that teachers in schools are often asked to deal simultaneously with different implementation processes such as top-down implementation patterns (dissemination) and bottom-up implementation patterns (diffusion) of innovations. What was being described in pedagogical areas of the laptop program, requiring subject-specific knowledge and teaching skills, was a process of diffusion. I have seen no other research on the diffusion of the integration of laptop computers into instruction, although Moore (2004) observes in a study on the design and development of interactive computer environments, that peers are the best role models for teachers who are not yet using a technological innovation.

Although the sample was small, the teachers in the study provided some perspective on the likelihood of skills and knowledge diffusing to new colleagues entering the laptop program. Experienced teachers stressed the importance that support be provided at the school and by the school. Mid-career teachers stressed the ability of the new colleague to deal with the ongoing challenges of implementing new innovations in a laptop program and their willingness to change their teaching approaches and prepare new teaching materials. Early-career teachers observed that new colleagues should be encouraged by the more effective instruction possible in a laptop program, but that they should be

prepared to meet the ongoing challenges of implementing a poorly structured innovation such as laptop computers.

**Summary: Question One** How do senior grade biology teachers perceive the integration of laptop computers into high school biology programs?

The perceptions of the teachers in the sample included recognition of the challenges which they had faced in introducing laptop instruction into their classrooms, and the fact that in most instances, the teachers felt that they had met these challenges. Once the laptop program had been established in the school, the innovations in their classrooms were designed, implemented and sustained by the teachers as individuals. They perceived that integrating laptops into their courses required an ongoing implementation process for a number of reasons, including continuing changes in curriculum and course assignments and the introduction of new hardware and software.

The teachers in this study felt that the diffusion of the skills and learning required to integrate laptops into biology instruction was a unique process for each teacher entering a laptop computer program and was highly dependent on the teacher's perceptions, strengths, and experiences. At the same time, the teachers in the sample described a different pattern of decision making, a top-down, externally motivated pattern, where the innovations were designed, and the implementation determined for the teachers. The research literature confirms that teachers are often asked to deal with different patterns of innovations at the same time: fidelity, top-down, externally motivated patterns determined by others;

adaptation and middle-up patterns; as well as, enactment, bottom-up and internally motivated patterns which teachers design and implement, year after year, in response to changes affecting the innovation which they do not control.

**Question Two: How do senior grade biology teachers perceive and introduce new teaching approaches when integrating laptop computers into high school biology programs?**

I found little in the research literature that I reviewed for this study that validates the information the high school teachers in the sample provided on changing teaching approaches as they integrated laptops into their instruction. Most research studies I did locate had not been conducted at the secondary level, but at the post-secondary level, including; the use of tablet computers in tertiary education (van Oostven & Muirhead, 2007); how laptop computers made it easier for faculty at the tertiary level to design learning activities (Windschitl & Sahl, 2002); the acknowledgement by both teachers and students that teaching and learning is more interesting with the laptops (Reading et al., 2006); and that the teachers combine their technological and pedagogical content knowledge to enhance the impact of laptop computers on instruction (Ferdig, 2006). The holistic and detailed descriptions of the teachers' experiences as they integrated laptop computers into their biology programs are new to this study.

**Finding 11 and discussion**

11. *Significant changes in teaching approaches are described by the teachers in this study, including: how lessons are prepared and conducted; how course content is presented; how notes are made and notebooks maintained;*

*the nature and number of labs students complete; the nature and number of active learning experiences available to the students; the nature of homework and projects completed by the students; the process of marking student work; and the electronic communication within the school community.*

The teachers in this study deemed PowerPoint presentations to be efficient since they could be used for instruction in a number of ways, such as: to prepare lessons; as a prompt during teaching; for the students to annotate during class; and for the students to use as a guide for making notes after class. Savoy et al., (2010) can be consulted for additional perspectives on these teachers' perceptions. At the University of Ontario Institute of Technology (UOIT) researchers find PowerPoint presentations are used to display course notes and other materials during class as well as to introduce topics, organize lectures, and assist the students with note taking (van Oostven & Muirhead, 2007). The faculty report that tablet computers decrease preparation time while the outlines (augmented with graphics, annotations, drawings of diagrams and pictures, as well as audio and video clips) provide meaningful enhancements for instruction (van Oostven and Muirhead, 2007).

Researchers report that laptop use in post-secondary education has a positive effect on student learning in a number of ways: enabling students and faculty greater opportunities for collaboration and constructing knowledge; enabling the exchange of files in group projects; and enabling the exchange of ideas during synchronous and asynchronous teaching approaches (Windschitl & Sahl, 2002).

However, despite the changes the teachers were making to the nature of homework assignments, most teachers in the sample continued to mark paper copies of homework assignments. Often, this involved downloading and printing assignments which had been submitted electronically, marking the paper copy, and returning the paper copy to students. Only one teacher in a student-centred program described marking student work on a tablet laptop and returning the marked copies to the students electronically. It should be noted that tests and exams remained pen-and-paper exercises in all of the schools.

From research conducted at the post-secondary level (Landry & Hartman, 2006), faculty found downloading students' individual assignments (in one case from Blackboard) to be a very tedious process which took a great deal of time for large classes because the software does not connect directly to the student gradebook. Lacking a direct connection, instructors had to be in two places in Blackboard: at one location to view the student assignments, and then at a second location to grade the assignments (Landry & Hartman, 2006). While faculty at the post-secondary level value the opportunity of writing comments as they grade assignments (van Oostven & Muirhead, 2007), they also want to minimize the time spent collecting, grading and returning papers to students. For these reasons, the ability to write electronic comments on student papers using the tablet laptops more closely resembled their previous practice of writing comments as they graded student papers and was deemed to be of significant value to busy faculty members.

The teachers in this study believed that the laptop program had increased communication between the students in their classes, between the students and teachers and between the teachers and parents. Only one teacher noted that students had communicated with students in other schools, and there was very little evidence that the laptop program had involved students communicating with scientific experts.

**Summary: Question Two: How do senior grade biology teachers perceive and introduce new teaching approaches when integrating laptop computers into high school biology programs?**

The introduction of laptops into the teachers' instruction had an effect on the teaching approaches used in their biology courses. Significant changes in teaching approaches were described, including: how lessons were conducted; how course content was presented; how notes were made and notebooks maintained; the nature and number of labs students completed; the nature and number of active learning experiences available to the students; and the nature of homework and projects completed by the students. Although the sample was small, the emphasis on changes in teaching approaches did seem to vary between teachers with different years of experience. Experiences teachers reported changes in how lessons were prepared, mid-career teachers noted the change in how science notebooks were maintained and in the lab experiences available to the students, while early career teachers observed that there were more active learning opportunities for the students. The area of least change was assessment, where the teachers continued to mark hard copies of student

work. In the one instance where the course was student-centred, the ongoing use of tablet laptops had allowed the teacher to develop the skills necessary to collect, mark and return student assignments electronically. Tests and exams, however, remained pen-and-paper-exercises in all the schools. In most schools, the laptop program had resulted in increased communication between teachers and students, between students, and between teachers and parents. However, there was little evidence of increased communication by teachers or students with students or teachers in other schools, or with experts beyond the classroom.

The teachers described changes in their approaches to teaching their biology courses, but the changes they described in their preparation and use of teaching materials was even more significant and will be described in the next section.

**Question Three: What new teaching materials do senior grade biology teachers use when integrating laptop computers into high school biology programs?**

I had difficulty locating studies against which the use of new teaching materials described by the high school teachers in this study can be validated. In fact, the studies that I was able to locate tended to have been carried at other educational levels or in other subjects, including: the post-secondary level (Landry & Hartman, 2006; van Oostven & Muirhead, 2007); middle-school science (Kiboss et al., 2004; Moore, 2004; Rogan, 2007); junior grades of high school (Erixon, 2010); or in subjects other than science (Kearny & Schuck, 2007; Ottenbreit-Leftwich et al., 2010). Where teaching materials used with laptops for

instruction are discussed in the literature, the focus tends to be on one teaching resource or, the observations are general in nature, such as: Bell and Bell (2005) recommending that university faculty have a time allowance scheduled for the preparation of new teaching materials. The holistic and detailed description of the teachers' experience in developing and using new teaching materials as they integrate laptop computers into their respective classrooms is new to this study.

### **Finding 12 and Discussion**

12. *Teachers in the sample designed new teaching materials, modified and continued to modify their teaching materials, including their use of: hardware; peripherals; software; Internet resources; and textbooks.*

Van Oostveen and Muirhead (2007) found that laptop computers were a welcome addition to the teaching tools for science teachers at the University of Ontario Institute of Technology (UOIT). They also note that the faculty reported that tablet computers decreased preparation time. Windschitl & Sahl (2002) report that laptop computers make it easier for faculty at the post-secondary level to design learning activities.

I did find the use of peripherals such as digital cameras and interactive SMART Boards mentioned in the literature. Tatar & Robinson (2003) report examples of digital camera use and the incorporation of the resulting images into class assignments in science classes. Although they report the use of digital cameras as being sparse, the cameras are being used in a number of ways: to extend students' lab work; to introduce the students to a new form of technology;

and to alter the way students communicated with one another about their experimental work. Tatar and Robinson (2003) report that as a result of the photographs in student laboratory books, the students have better study cues to refer to when studying for examinations. Kearney & Schuck (2007) reported that teachers saw interactive SMART Boards as a type of presentation technology that supported whole-class teaching, including whole-class discussions and whole-class exercises. They also thought that SMART Boards came in handy for giving explicit directions to students. Although Kearney and Schuck's research was not conducted in senior grade science laboratory courses, this research study confirms their observations of the teachers' use of SMART Boards.

Since the introduction of the laptop program, the use of software which could be used, or adapted for use, in the classroom has become widespread. The most frequently mentioned software programs are the platforms for their teaching activities: Blackboard, First Class, and Lotus Notes. In addition to learning the platform software, the teachers are using PowerPoint and Excel for preparing graphs, and Microsoft Office for drawing. Much of the new software they described using was not specifically designed for pedagogical purposes, but was being used for administrative purposes and school management. Some teachers anticipated learning a number of new programs in the upcoming year, including software to improve assessment procedures and reporting practices, as well as to manage marks and attendance. Not only are the teachers learning a wide range of software programs, but it is evident from their observations that there is considerable variation in software used by different schools to carry out

similar functions. The teachers' observations seem consistent with a study conducted at the University of Ontario Institute of Technology, since van Oostveen and Muirhead (2007) report that tablet computers encourage the use of specific programs such as One Note, and that the use of PowerPoint by the faculty members is widespread.

The teachers in this study discussed at length the teaching materials they accessed on the Internet and how this was affecting their use of textbooks (Erixon, 2010; Woody et al., 2010). They mentioned searching for, and incorporating into their instruction, some thirty different types of teaching materials including: animations, simulations, webquests, databases and scientific journals. Increasingly, the teachers remarked that they were accessing free teaching materials posted on the Internet by universities, non-governmental organizations (NGOs), medical institutes, and government departments (see Appendix F). As noted above with respect to the use of software, it is apparent that there is great variation in the Internet sites being selected by the teachers and how the materials they choose are incorporated into their instruction. Creating customized teaching materials (Ottenbreit-Leftwich et al., 2010) involved a personal search and selection process which they carried out with considerable care and which takes a great deal of their time.

Barab & Dede (2007) found that game-like virtual learning experiences provide a strong sense of engagement and opportunities for student learning. They developed a series of simulations for use during their research study. Although these simulations were not made available to the teacher participants

for use in their instruction, Barab and Dede found that the teachers were already providing somewhat similar experiences for their students. Computer simulations have the capability to teach concepts that are either too dangerous or too difficult to teach using traditional methods (Kiboss, 2000). In the past, some of the teaching methods used posed problems of understanding for students (Kiboss et al., 2004). These researchers used the process of cell division to illustrate the benefit of using computer simulations. They note that the current recommended practical work in biology for learning cell theory includes the use of squashed young onion root tip, charts or electron micrographs. Unlike these static presentations of the stages of cell division, simulations available for use with laptop computers successfully illustrate the dynamic nature of the process of cell division (Kiboss et al., 2004).

### **Summary: Question Three**

The teachers in the sample responded to the introduction of the laptop program by increasing the type and number of teaching materials they used for instruction. Laptops appeared to have solved many of the problems they had associated with using the desktop computers in the school for instruction. The teachers I interviewed accommodated periodic updates of the laptops and the unintended consequences of incompatibility between new laptops and older laptops, with the perception that newer hardware was faster and easier to use. The teachers, especially experienced teachers, used new peripherals with the laptops and accommodated the incompatibilities between these new peripherals

and the laptops on an ongoing basis. Much of the new software they described using was not specifically designed for pedagogical purposes, but the biggest change in new teaching materials, especially for early-career teachers, was in the teaching resources they could access on the Internet. Individual teachers reported spending a great deal of time on checking, updating, and improving this type of teaching material.

In contrast to the increasing use of Internet resources, textbooks appeared to be a less important teaching resource in a laptop program, in many instances they had been eclipsed or replaced by electronic and/or hardcopies of teacher prepared material that the students could access on their laptops from the class database. Some teachers expressed interest in exploring electronic textbooks. One school had just adopted an electronic textbook that an early-career teacher was beginning to explore with a view to integrating the range of options an electronic textbook could provide for students.

### **Design of the Study**

Based on my academic and professional experience as a science teacher and school administrator, I am of the opinion that the teachers in this study were exploring the perceptions and lived experiences which guided their decisions as they answered the interview questions on integrating laptop computers into their instruction. The teachers responded positively to the personal interview process and commented on alternative methods which might have been used for collecting the data such as questionnaires, telephone interviews, or video

conferencing. The teachers observed that the ongoing pace and rhythm of schools meant they normally would not reflect on teaching in a laptop program as they had been able to do when answering the interview questions. They expressed satisfaction, not only with the fact that they had been able to undertake this examination of their teaching, but also with the gains they realized had been made during their years in the laptop program. I thought one of the early-career teachers described the benefits of the study design best:

Did you come down [from Ottawa] again today? That's a lot of work for you ... because otherwise how would you get ...? It would be difficult. Yes I don't see any other way you could do it. Honestly, you wouldn't capture the same ... you wouldn't. (Zoe, III - 27).

Because I think the feedback you're getting ... it's interesting. I was actually saying to [the Head of Science Department] this morning, it has made me reflect on the course in a way that I haven't really ever taken the time to reflect. You know, you really just don't have the time (Zoe, III - 43).

Yes, so it's been interesting for me to think ... what we are doing here, and some of the comments I've made to you, I'm thinking ... this is working, you know (Zoe, III - 24).

And you would not have accessed this (information) in any other format, I'm telling you. I would not have written it out in an email or anything (Zoe, III - 51).

Gregoire Gill (2006) acknowledges the importance of perceptions on curricular and pedagogical decisions affecting classrooms, but discusses the difficulty researchers face in ascertaining the effect of these perceptions and experiences on instruction and learning. According to Gregoire Gill, interviews, a common method of collecting information can be viewed as problematical. However, Marshall and Rossman (2006) state that in-depth interviews can be used as a method of collecting information about perceptions and experiences, and as the sole source of collecting data, if the subjective view of events is what is important, and if the purpose of the study is to uncover and describe the teachers' perspectives. Seidman (2006) supports this view, stating that interviewing not only provides the context of teachers' behaviour, but also provides the researcher with a means of understanding that behaviour.

Every research method has its limits and strengths. In-depth interviewing's strength is that through it we can come to understand the details of people's experience from their point of view. We can see how their individual experience interacts with powerful social and organizational forces that pervade the context in which they live and work, and we can discover the interconnections among people who live and work in a shared

context (Seidman, 2006, p.130).

Pertinent to this study, Seidman (2006) lists the strengths of interviews, such as: fostering face-to-face interactions with participants; useful for uncovering participants' perspectives; facilitating immediate follow-up for clarification; useful for describing complex interactions; facilitating discovery of nuances in culture; facilitating analysis, validity checks and triangulation; and for obtaining a large amount of data quickly.

### **Concerns-Based Adoption Model (CBAM)**

Using the Concerns-Based Adoption Model (CBAM) as a guide kept the research and the researcher focused on the classroom teachers in the sample, on their perceptions of the innovation they had undertaken (Donovan, 2007), and on their perceptions of the conditions under which the innovation they had undertaken would be successfully integrated by new colleagues.

The rubric developed from the Stages of Concern indicates that the teachers' concerns are clustered around the highest three levels—levels six to four—with only one teacher expressing concerns at level three. As the researcher, I used CBAM as a guide when examining the teachers' perceptions. Specifically, I evaluated the teachers' perceptions against the levels found in the Stages of Concern. At the highest levels, CBAM anticipates teachers will be focusing on concerns, such as:

Level 6—Refocusing—*I have some ideas about something that*

*would work even better.*

Level 5—Collaboration—*How can I relate what I am doing to what others are doing?*

Level 4—Consequence—*How is my use affecting learners? How can I have more impact?*

Level 3—Management—*I seem to be spending all my time getting materials ready. How do I implement this change? What do I need to do to make this change happen with my students?* (Hord et al., 1987; Loucks-Horsley, 1996).

CBAM was helpful as a guide when analyzing the participating teachers' concerns about integrating the laptops into instruction at Level 6 (Refocusing), and Level 4 (Consequence). At Level 5 (Collaboration), CBAM was not as helpful as I had anticipated for a number of opposing reasons: the teachers in this study tended to be either the only biology teacher in the school, or they were the only teacher teaching a specific biology course. In a sense, they were physically or pedagogically isolated, but at the same time, the norms for teaching have become more collegial since CBAM was developed in 1975 (Anderson, 1997), which again diminished the usefulness of this stage of concern. The teacher with the least teaching experience, while expressing concerns similar to the other teachers at Level 6 and Level 4, also expressed some concerns at Level 3 (Management)—concerns the more experienced teachers were not articulating. Concerns at the highest levels indicate the willingness of the teachers to

implement and sustain an innovation, in this instance the integration of laptop computers into their instruction.

The rubric developed from Levels of Use (LoU)) indicates a high level of use of new teaching approaches by all the teachers in the sample. The rubric developed from LoU indicated that the teachers were in the highest categories for use of new teaching approaches—Level VI (Renewal) and Level IVB (Refinement). Level V (Integration), once again proved difficult for the analysis since many of the teachers in this study are the only teachers in the school teaching the biology courses they are teaching. However, despite the challenges to academic integration with comparable biology teachers, I did note that some integration of policy for the use of the laptops was being established by science departments. In the two instances described to the researcher, the policies both dealt with the beginning of classes. Somewhat ironically, in one school the teachers in the science department made the decision that all classes would start with the laptop computers closed and the laptops were to remain off until the teacher indicated that they should be turned on. In the other school, the teachers in the science department made the decision that the laptops were to be open and functioning at the beginning of classes.

The rubric for Innovation Configuration (IC) indicated that in six of the eight categories describing what the integration of laptops would look like in classrooms, the teachers in the sample were in the highest category for use of the innovation. In six of the eight categories (access to computers, student use of computers in subject area; classroom organization; learning activities; nature

of task environment; and technological literacy), the teachers in the sample were in Level 1, the highest category. The remaining two categories in this rubric, teacher-student relationships and independent learning, differentiated between the teaching approaches of nine of the teachers in the sample and the teaching approach of the tenth teacher. The nine programs (rated in the second highest level for independent learning and teacher-student relationship) if no longer teacher-centred, were essentially teacher-led programs. The tenth program (rated in the highest level for independent learning and teacher-student relationship), had been reorganized as a student-centred course where the students worked independently at their own pace, or with a student partner.

I found a high level of innovation in the teachers' use of new and modified teaching materials, and very little variation in the degree of use of these new teaching materials between the teachers in this sample. The rubric developed from IC is not appropriate for focusing on the use of new and modified teaching material in the classrooms of the teachers in this sample. While the rubric deals with what the innovation looks like when new materials are implemented, it did not focus on or describe what the new teaching materials would look like. This rubric was, therefore, less useful for analysis than I had anticipated. As Scott (2008) has observed a rubric for IC is difficult to draft for unstructured innovations when there is little understanding of what the innovation would look like in a classroom when implemented. This IC rubric should be redrafted.

## Chapter Summary

Studies that focus on how different subjects at different levels in schools interact with computer technology such as laptops are not numerous (Erixon, 2010). The group of teachers who volunteered to participate in this study implemented and sustained a laptop program in their senior grade biology courses and responded to the interview questions with insight and knowledge. Research literature confirms that their academic preparation and professional experience meet the description of teachers who are willing to undertake and integrate innovations.

The teachers in this study observed that their perceptions had undergone considerable change as they implemented the laptop computers into instruction in their biology courses and that they had continued to modify their perceptions with increased experience in the laptop program. The changes in their perceptions resulted in a reorganization of their lessons and biology courses. Only one program, however, could be described as having adopted a student-centred learning approach, as opposed to a teacher-led approach.

Although the sample was small, there is some evidence in the data that experienced teachers perceived the ongoing nature of implementing innovations in a laptop program, valued the support of the administration, described their main challenge as the ongoing acquisition of new hardware and knowledge and skills they needed. They noted that support by the school and at the school was important as new teachers entered the laptop program. Mid-career teachers were encouraged as they felt their instructional practices had been improved in the

laptop program and that professional development was available to improve Knowledge and skills. They identified the ability to deal with challenges, and the willingness to change teaching approaches and prepare new teaching materials as important if new colleagues were to be successful in a laptop program. Early-career teachers observed that while it would take years for them to integrate laptops into their instruction, they were encouraged by positive feedback from their students, felt challenged by the need to vary their instructional approaches and the need to access appropriate professional development. They observed new teachers would be encouraged by the more effective instructional practices available in a laptop program, but only if they could cope with the ongoing nature of implementing innovations in a laptop program.

The introduction of laptops into their instruction affected the teaching approaches the teachers used in their biology courses. The teachers in the sample modified most aspects of instruction, including: how lessons were conducted; how course content was presented; how notes were made and notebooks maintained; the nature and number of labs students completed; the nature and number of active learning experiences available to the students; and the nature of the homework and projects completed by the students. The smallest change appeared to be in assessment procedures where the teachers continued to mark hard copies of students' work. Until new technology and software are available, and implemented in their schools, collecting and returning assignments and homework electronically will remain a challenge. Communication increased between students and teachers and within the school

community, but there was little evidence that the laptop program had increased the amount or nature of communication beyond the walls of the classroom.

Although the sample was small, there is some evidence in the data that experienced teachers observed changes in how lessons were prepared, mid-career teachers observed changes in how science notebooks were maintained and increased laboratory experiences for students, while early-career teachers noted the increased active learning experiences for students in the laptop program.

The teachers responded to the introduction of the laptop program by increasing the type and number of teaching materials they used for instruction. Much of the new software they described using was either not specifically designed for pedagogical means or was being used for administrative purposes or school management. New software which would allow for the electronic collection, marking and return of student assignments and homework was eagerly anticipated. In many ways, the teachers believed their classroom teaching had become easier, although they continued to cope with challenges and incompatibilities associated with the updating of hardware, peripherals, software, teaching resources obtained from the Internet, and with the changing role of textbooks in their respective classrooms. Although the sample was small, there is some evidence in the data that more experienced teachers focus on new peripherals for teaching with laptops, less experienced teachers focus on the use of textbooks in a laptop program, while early-career teachers focus on the use of hardware, software and preparing teaching materials from the internet

A rubric developed from CBAM Stages of Concern (SoC) indicated that the teachers' perceptions in this sample were consistent with teacher concerns at the higher end of the scale describing the integration of an innovation. The interview process used to collect data was found to be an effective design for the study, as teachers' viewpoints are a crucial indicator of teacher behaviour.

A rubric based on CBAM Stages of Concern (SoC) indicated that the concerns of the teachers in the sample reflected a high level of implementing an innovation such as the laptop computers, including such concerns as how the laptop computers could be used more effectively in their respective classrooms and have more impact on student learning. A rubric developed from LoU revealed that the teachers' use of the laptop computers indicated they were operating at a high level for implementing new teaching approaches and new teaching materials. The rubric adapted from IC indicated the teachers in the sample were operating at a high level for the integration of laptop computers, but unfortunately the rubric adapted for this study did not focus on the development and adoption of new teaching materials.

In Chapter Seven, I will take the major findings of this chapter and explore them further by discussing the context of this research study, and the study's contribution to the research literature. The practical applications of this research will include recommendations for schools and school systems based on the findings discussed in this chapter.

## **CHAPTER SEVEN: CONCLUSIONS**

This chapter examines the findings and implications of this study: its practical and theoretical contributions to the literature on innovation, and the limitations of the study. The chapter also includes recommendations for future research.

### **Major Findings of the Study**

#### **Question One: How do senior grade biology teachers perceive the integration of laptop computers into high school biology programs?**

The teachers' perceptions of the integration of laptop computers into their instruction were remarkably consistent. They considered the integration of laptop computers into instruction to be a teacher initiated innovation in that they decided which changes were integrated into instruction in their respective classrooms and they decided how the changes they integrated into instruction varied from class to class. Their decisions about instructional changes were influenced most by teaching colleagues. They described managing an evolutionary pattern of change in the classroom and they expected they would be dealing with new and continuing adaptations affecting their instruction in years to come. They said the diffusion (the gradual spread of information and ideas, previously unfamiliar, that may result in the adoption of an innovation) of the integration of laptops into instruction in other teachers' classrooms depended on the other teachers' perceptions, their willingness to change their teaching approaches, and their willingness to develop new teaching materials. Much of the integration of laptop computers in schools that the teachers in the sample described was not

pedagogical in nature, and they described a process of dissemination (the planned spread of an innovation to teachers, often involving a change agent responsible for having the teachers initiate new practices), not diffusion, for this non-pedagogical type of change.

**Question Two: How do senior grade biology teachers perceive and introduce new teaching approaches when integrating laptop computers into high school biology programs?**

For the majority of the teachers, the changes to their instruction had been profound. Initially, laptops were used as add-ons to the program they had been teaching, or had been trained to teach, but the original role of the laptops was systematically expanded to affect almost all aspects of their teaching, with the possible exception of assessment procedures and marking student work. The teachers had introduced different teaching approaches, including; how lessons were prepared and delivered in the classroom; by increasing the number and improving the nature of the labs the students completed; the inclusion of active learning experiences including more pertinent and interesting homework assignments; and more communication with the students outside of the classroom. As a result of the new teaching approaches they introduced, the teachers listed a number of ways the courses they were now teaching were better, including terms such as: more relevant; more up to date; more interesting to the students; more student-centered than before; and, providing a better preparation for studying biology at the post-secondary level. While they believed that their new approaches to teaching in the laptop program had increased communications between students, between teachers and students and between

parents and teachers, there was still very little evidence of increased electronic communication beyond the walls of the school, between students in different schools, between teachers in different schools, or with experts in appropriate scientific fields.

**Question Three: What new teaching materials do senior grade biology teachers use when integrating laptop computers into high school biology programs?**

Prior to the introduction of the laptop program, most of the teachers in the sample had not chosen to use the desktop computers available in their schools for instruction. Following the introduction of the laptop program, they were using the laptops for instruction and a broader spectrum of teaching materials such as peripherals, software and resources they located on the Internet. These new teaching materials were researched and assembled with considerable care and expenditure of teachers' time, but there was little evidence that these materials were being shared or were even similar to teaching materials other teachers had developed or were using. While the acquisition and use of new teaching materials was considered an important aspect of integrating laptops into instruction, acquiring and using new teaching materials appeared to be a highly individual process.

**Ongoing Challenges**

The teachers participating in this study identified a number of ongoing challenges that they continue to face as they develop their use of laptops for

instructional purposes including: finding professional development appropriate for senior grade biology teachers in a laptop program; having the opportunity to see other teachers teach biology in a laptop program; accessing ideas for new teaching approaches; and, finding, locating and obtaining new teaching materials they can use in their respective classrooms. These challenges are exacerbated by the relative isolation within which even teachers who share similar courses, and learning and teaching objectives typically were functioning. There was, for example, little evidence that any of the teachers interviewed for this study knew one another, even though they shared similar pedagogical challenges and aspirations, and their schools were within a 500-kilometre radius of one another and participated in common sports competitions, drama and music festivals.

### **Strengths and Limitations of the Study**

In this section I discuss possible limitations of the present study, focusing on: the research questions; the design of the study; the replicability of the study; the transferability of the findings of the study to other settings; the size of the sample; and, the strengths and weaknesses of collecting data through an extended interview process.

In this study, I developed the research questions following a review of the literature. According to Marshall and Rossman (2006), research questions developed in advance of a qualitative study should be general enough so that they do not constrain the investigation of the topic while establishing the limits of the study. Achieving this balance is challenging (Marshall & Rossman, 2006),

but I feel that the research questions for this study met this criterion. While functioning as guidelines for my data gathering and data analysis, the research questions themselves were never shared explicitly with the teachers included in the sample who were uniformly asked a roster of twenty-eight interview questions (see Appendix E). Described by Marshall and Rossman (2006, p. 159) as an “analyst constructed typology,” the research questions provided an initial framework for generating themes and categories to be explored, and eventually for the analysis and presentation of the data subsequently gathered.

An exploratory review of ten models frequently used to understand change and the implementation and diffusion of innovations were reviewed in seeking to develop a conceptual framework appropriate for the present study. Six of these models were dismissed as not being usable, and four were given further scrutiny. Of these only one, the Concerns Based Adoption Model (CBAM), seemed appropriate as it focused on individual teachers and could be used to investigate a number of factors pertinent to this study, including: teacher concerns during the innovation and implementation process; how the teachers actually made use of the innovation in their respective classrooms; and, what the innovation would look like when implemented in individual classrooms.

These elements of CBAM were selected and incorporated into the conceptual framework for the study. As the analysis of the data proceeded, rubrics were prepared based on three components of CBAM: Stages of Concern (SoC), Levels of Use (LoC), and Innovation Configuration (IC). A review of the data provided by the teachers, using these rubrics, confirmed that all ten

teachers in the sample were functioning at the highest levels of the rubric, Level 6 (Refocusing/Renewal), Level 5 (Collaboration/Integration) and Level 4 (Consequence/Refinement). The least experienced teacher also expressed Management/Concerns (Level 3) about using the innovation in the classroom, concerns that were not being articulated by the more experienced teachers. I found that the Level 5 rubrics were not helpful in the analysis of collegiality and cooperation between the teachers in this study. Norms on collegiality and cooperation between teachers in schools have changed since CBAM was developed and the criteria were not useful, but even more importantly for this study, the teachers in the sample tended to be either the only teacher in the school teaching the particular biology course they were teaching, or the only teacher in the school teaching biology. They were in many cases pedagogically isolated or had limited opportunities to cooperate with colleagues.

Qualitative methodology was used to collect information and to interpret the teachers' perceptions of the innovation they undertook, specifically how their teaching approaches, and their use of materials changed in the course of implementation. As is characteristic of descriptive studies, a rich description of the perceptions and experiences of the participating teachers allows readers of this study to determine where, specifically, they find particular points of interest that they may apply to their own work, transfer to similar settings, or transfer to other settings. Although the immediate focus is upon innovations in high school biology teaching, teachers in other subject areas and other levels may well find results that can be transferred.

The number of schools included in this study and the number of teachers included in the sample is purposefully small. In assembling such a purposeful sample, the researcher was not able to avoid an unexpected limitation resulting from teaching experience and gender. All the more experienced teachers who volunteered for the sample were male, all at the midpoint of their careers, and the less experienced teachers who volunteered were uniformly female. Therefore, it was not possible to distinguish the effect of the number of years of teaching experience from the gender of the teachers upon the data they contributed to the study. Studies that concentrate on such factors as years of experience of teachers and gender remain interesting avenues for future research.

There are strengths and weaknesses associated with every method of collecting data. The design of this descriptive study relied on collecting data through a series of semi-formal and informal interviews, and documents used in teaching biology with laptop computers, as described by Marshall & Rossman (2006) and Seidman (2006). While collecting, analyzing, and organizing the data for this study I was impressed with the strengths of the interview design, including: the process promotes face-to-face interactions with teachers; the process is useful for uncovering teachers' perceptions; the process facilitates clarifying information or questions that may be misunderstood; the process is useful for describing complex interactions such as integrating laptop computers into biology courses; the process is good for obtaining information on non-verbal behaviour and non-verbal communications during the interviews; the process facilitates the discovery of nuances in the culture of the school and classroom;

and the interview process provides contextual information about the teachers' experiences in the schools.

Having read a number of studies where researchers undertook to include science teachers in participant samples (Newhouse, 2001; Sclater, 2006) and the senior science teachers chose not to participate in the research or did not choose to implement, or fully implement, the innovation being studied, I was concerned about assembling a purposeful sample of senior science teachers for this study. This study was designed to make it as easy and efficient as possible for these senior science teachers to participate and I was pleased that the teachers in the sample volunteered to have interviews scheduled as the academic year came to a close, through examination schedules, professional development days, and even during the summer. They appreciated the ease and convenience of having the interviews scheduled at their school and at times convenient for their schedules. A number of the teachers actually raised the labour-intensive nature of an extended interview approach to qualitative research, including the time required travelling to the schools and the time spent interviewing participants. There was a general consensus that these accommodations had positively influenced decisions to participate in the research study and that they would have been less likely to participate if providing information had required telephone interviews, video-conferencing, or filling out questionnaires.

Acknowledging that weaknesses can be ascribed to any method of data collection (Marshall & Rossman, 2006), I believe the strengths of the design of the study were appropriate to the research questions providing a depth of

information about the perceptions and lived experiences of the teachers in the sample which allows readers to determine the transferability of the findings of the study to their own work.

## **Implications of the Study**

### **Practical Contributions on Educational Innovations**

Existing research on the pedagogical implementation of new technologies, research that is largely quantitative in nature, identifies that more attention needs to be paid to senior science teachers and to developing qualitative research that would add to existing knowledge concerning the integration of laptop computers in science classrooms (Hakverdi, 2005, Siegle & Foster, 2001). Accordingly, the present qualitative descriptive study researches the integration of laptop computers within a selected population, senior biology teachers, and within the context of a high school laboratory subject, by examining the likelihood that laptop computers will be effectively integrated into classroom instruction.

Building on recommendations from previous research (Becker, 1994; Siegle & Foster, 2001; Tebbutt, 1999), the study reported herein has collected, analyzed, and now reports data and findings concerning teacher perceptions of the integration of laptop computers in classroom instruction and the modifications required in perceptions, teaching approaches and the location and development of new materials necessary to make this integration successful.

The research undertaken for this study has examined the perceptions of biology teachers with both modest and more extensive experience in the classroom. It thus complements studies of novice teachers who have recently

graduated from teachers' college (Marrack, 2006) in that the perspectives and observations of the more experienced science teachers can be compared to those of more recent graduates. The range of experience of those included in the research sample for this study provides data and findings that should speak to teachers of similarly diverse experiential backgrounds who are concerned with the pedagogical integration of laptop computers.

This study provides a body of pedagogical knowledge on the implementation of innovation for biology teachers in the senior grades of high school, knowledge that is needed if teachers are to initiate and sustain the integration of laptops into their instructional practices. By providing insights from the perspective of the contemporary classroom, the content of this study would relieve the pedagogical, psychological, and physical isolation experienced by teachers who share in the pursuit of a significant educational initiative that has currency, importance and promise.

Referencing the review of literature presented in the second chapter, it is evident that more needs to be researched and understood about how innovations in science instruction can be made both pedagogically and institutionally successful. Indeed, there is a predominant perspective among researchers that there is a puzzling lack of innovation in senior science classrooms. Given the relative scarcity of research concerning the role that teachers play in implementing innovations, studies like the one reported herein can help researchers, teachers, policy-makers, school and school system administrators better understand what can be done to enhance both the implementation and

dissemination of innovations that promise to create improved pedagogy and student learning. In mapping the lived experience of teachers who work daily within the complex world of the classroom and the school, educators may understand more fully how the adoption of promising innovations can be encouraged and how the dissemination of success can be facilitated.

This study makes a number of practical contributions to the literature on the effective pedagogical implementation of an innovation in the classroom by identifying needs which are now being identified, or, despite the recommendations of earlier researchers, the teachers say have not been met. Teachers identify the need for ongoing professional support (e.g. the provision and mastery of software and peripherals in their subject area), specifically directed to pedagogic matters, and pedagogical concerns. Communication amongst teachers seeking to introduce innovations remains an issue. Teachers would be encouraged by building working groups through the use of technology, thus utilizing the new technology to implement pedagogical innovations focused upon it. Teachers still identify a need for administrators to foster, maintain, and actively support working groups within specific school sites of teachers who are participating in efforts to introduce innovations in their respective classrooms. It is important to teachers that administrators schedule time during the school day for teachers actively implementing classroom innovations to work and learn together. There remains a need for periodic face-to-face meetings and workshops for teachers implementing innovations when geographically feasible, and visits to sites that have enjoyed implementation success. The teachers

identify an ongoing need for professional development opportunities targeted to specific innovations conducted, where and when possible, by teachers who have successfully implemented the innovation concerned. In many instances the teachers do not have an opportunity to understand the relevance of an innovation, and need details concerning what teachers are expected to implement in their classrooms, including exemplars of what the innovation should look like, and rubrics that can be used to evaluate how well they are progressing. Teachers' progress in implementing innovations is affected by the number and type of innovations that they are required to implement at a given time. Many innovations are multi-year projects and innovations introduced in subsequent years require teachers' time, energy and focus. The success of previous implementations in classrooms, which may have been only partially implemented, is at risk. Lastly, maintaining teacher confidence is important when implementing and innovation. Administrators should ensure that a plan is in place for experienced colleagues to provide pedagogical support so that teachers can perform adequately in the first year of implementing an innovation in their classrooms.

### **Contributions on the Implementation of Educational Innovations**

Studies have consistently indicated that teachers, especially teachers in the senior high school grades, and teachers of science, have not integrated computers, not even laptop computers, into their instructional practices to the extent anticipated by researchers. Existing studies on the pedagogical

integration of laptops have not focused on the role of the teacher, focusing instead on student attitudes and on measuring possible gains in student achievement. Research studies also have indicated that the use of computers for instruction does not diffuse easily from teacher to teacher although, not having been designed to ascertain why this was so, they cannot speak to the dynamics that militate against dissemination. Through concentrating on the *perceptions of teachers who are either charged with or who self-initiate the pedagogical integration of laptop computing in their respective senior science classrooms*, the present study would contribute to the theoretical knowledge requisite to implementing this initiative in the classroom and diffusing potential success among teachers, schools, and school systems.

Much of the existing research focused on the implementation of educational innovations studies externally motivated change where the innovation was designed and planned by experts and where the teachers were simply expected to implement the innovation provided to them in their classrooms. This existing research focuses largely on the top-down implementation of well-structured innovations. This concept of innovation gives insufficient consideration to the realities and the needs of individual teachers, including: their learning as they implement innovations in their subject area; the multiple types of changes they deal with in schools; the complexities of their roles in their schools; and, the implications of implementing poorly structured innovations, particularly innovations that would engage new technologies. In order to address this shortcoming, this study investigated the process of

innovation initiated, implemented and sustained by teachers and characterized by a bottom-up implementation where individual teachers organize and manage the implementation of innovations in their subject area and within their own classrooms by relying largely upon their personal knowledge, skill levels, and interests. By building knowledge about how teachers perceive, understand, and act to implement laptop computing in their instructional work, this study would speak to the broader and potentially more significant issue of how innovation can be better designed so that it can more expeditiously achieve the educational ends it would accomplish.

The research reported herein is among the first to study change in practices when integrating laptops into instruction in senior biology courses. It provides a snapshot of teachers who have integrated laptop computers into their instruction and offers insight into their perceptions, concerns, and how they use this innovation in their respective classrooms. It gives in-depth information on the implementation of a particular innovation in their classrooms, and how that innovation was initiated and sustained. In addition to contributing to the knowledge required for the development of theory about and pedagogy concerning the integration of innovations involving new technologies, the research I have completed can be useful to those who would study similar or other innovations and how they can be effectively integrated in the contemporary classroom and how the diffusion of successes can be facilitated.

In summary, the data in this descriptive study can augment the work of those who research and those who design and implement educational

innovations that would successfully engage the new technologies for educational purposes. This study, then, would speak to a broad range of individuals and groups committed to educational improvement. This list includes, but is not limited to practicing teachers, school and school system administrators, educational policy-makers, those who are preparing to become teachers and those who instruct them, parents and parent councils, and students.

### **Recommendations for Future Research**

Since time has passed since the data for this study was collected, repeating this research could produce somewhat different results. As I have argued in this study, the integration of laptop computers is a poorly structured innovation which continues to evolve, and the teachers in the sample will have dealt with many changes since the data for this study was collected. As previously mentioned, this is a study which will be useful for researchers planning further quantitative or qualitative research on this topic.

Future research, for example, might focus on biology teachers in laptop programs in a wider variety of high schools, or biology teachers who teach with their own laptops in schools where students do not have laptops. It would be worthwhile in future studies to focus solely on teaching approaches in laptop programs, or on teaching materials used in laptop programs. With more time and fewer teachers in the sample, classroom observations of laptop programs could be included in study methodology. This study may also instigate future research

on laptop program implementation in reference to the gender of teachers and students, in boys' schools, girls' schools and co-ed schools.

During the interview process the teachers were asked to consider topics that might have been, but that were not included in this study, and topics they, as biology teachers, would like to have researched in future studies. If research on issues is to be relevant and useful to teachers in their classrooms, at least some of the questions concerning how teachers change instructional practices when implementing innovations need to come from the teachers themselves.

All the teachers in this study suggested additional questions that might have been addressed as part of this study. Most of their questions dealt with Question Three, new teaching materials.

We dropped textbooks after one year in the laptop program and many teachers are grappling with whether to keep a \$150-200 textbook. What about the use of textbooks?

What about online texts?

Some questions they suggested dealt with Questions Two, new teaching approaches.

As more schools go into laptop programs, some teachers might resist. Why would they resist? What could be done to result in more enthusiasm?

The teachers were also asked to provide topics for future research which they felt would enhance their teaching when implementing innovations. The topics they raised included: changes in student learning when students are in

laptop programs; assessment of student learning in laptop programs; feedback from students in laptop programs; and, non-instructional use of laptops by students.

Given that the nature of assessment in the schools may not change and that some things that can be done with laptops don't need to be tested, can we ascertain assessment differences reflecting the fact that a biology course has been taught in a laptop program?

Science is a body of knowledge. How do the laptops change student thinking, knowledge acquisition, and problem solving skills?

### **Concluding Remarks**

Through this research study I found that integrating laptop computers into instruction was a positive experience for the biology teachers interviewed and that the changes in practice required of them were more wide-ranging than simply those required to integrate laptop computers into instruction. Through the literature review, and the collection and analysis of the teachers' perceptions, I gained an understanding of the conditions which allowed them to successfully integrate laptop computers in their biology classrooms and programs, the challenges they faced during the implementation, and the areas for further

research which they think will help them sustain and improve this innovation in their and in other classrooms.

This study started with the premise that teachers who undertake the implementation of significant innovations that would engage the new technologies in learning and teaching must alter their perceptions, their teaching approaches, and the materials they use in their respective classroom settings.

This premise was the basis of the three research questions asked in this study:

**Question One: How do senior grade biology teachers perceive the integration of laptop computers into high school biology programs?**

**Question Two: How do senior grade biology teachers perceive and introduce new teaching approaches when integrating laptop computers into high school biology programs?**

**Question Three: What new teaching materials do senior grade biology teachers use when integrating laptop computers into high school biology programs?**

In pursuing these questions, the data derived from teacher interviews suggests how colleagues, students, individual personnel and professional backgrounds, and the nature of pedagogical initiatives themselves all shape teachers' perceptions about, and approaches to how an innovation is successfully implemented in classroom and school settings. In addition to identifying specific factors that would enhance the implementation of pedagogical innovation, the data suggest specific areas in which teachers need additional support and guidance in order to make implementation successful.

A qualitative approach was adopted in this descriptive study precisely because the focus of the research undertaken is upon teachers' perceptions, and their

lived experiences as they develop the personal and professional skills required to integrate laptop computers successfully in their classroom work. This focus upon teachers was realized through a series of three visits to the schools in which they teach, the conducting of in-depth interviews with them, and participant validation of the data collected through the interview process. The data that emerged from these rich encounters provides practical insight into how the teachers in this study understand both the significance and the challenges posed by the implementation and pedagogical integration of laptop computing in their respective classrooms. The primary fact that emerges from the present study is the central and critical role that teachers play and must play in the development, implementation, and diffusion of the new instructional technologies. If we are to succeed as educators in implementing innovation, we must begin to listen to the voices of teachers. The voices that speak in and through this study are an invitation to deepen and extend this encounter with teachers—an encounter that will help us to ensure the success of initiatives that can be truly transformative.

## REFERENCES

- Ainley, J., Banks, D., & Fleming, M. (2002). The influences of IT: Perspectives from five Australian schools. *Journal of Computer Assisted Learning*, 18, 395-404.
- Albion, P. (1999). Laptop orthodoxy: Is portable computing the answer for education? *Australian Educational Computing*, 14(1) 5-9.
- Alonso, J. L. (1996). *The effect of different instructional groupings on student achievement and attitudes from a computer-based interactive videodisc biology unit*. Unpublished Ed.D. Thesis, Florida International University.
- Amankwatia, T. B. (2008). *Teaching with technology for 21<sup>st</sup>-century learning: A multiple case study of a school district's high school laptop initiative*. Unpublished Ph.D. Thesis, Lehigh University.
- Anderson, M. S. (1995). *Technology changes curriculum: Or does it?* Gonzago University. Available at:  
<http://curryedschool.virginia.edu/aace/download/site/HTML1995/2011.HTM> [2002, 26 February].
- Anderson, S. E. (1997). Understanding teacher change: revisiting the Concerns Based Adoption Model. *Curriculum Inquiry*, 27(3), 331-367.
- Aubusson, P. (1994). Intention and practice on school science education. *Research in Science Education*, 24, 21-30.
- Bagby, S. S. (2007). *Stages of concern: Measuring the affective dimension of faculty implementing an instructional innovation*. Unpublished Ed.D. thesis, University of West Georgia.
- Baggott La Velle, L., McFarlane, A., and Brawn, Richard (2003). Knowledge transformation through ICT in science education: A case study in teacher-driven curriculum development – Case Study 1. *British Journal of Educational Technology* 34(2), 183-199.
- Bain, A., & Weston, M. E. (2009). The future of computers an 1:1 laptop initiatives: Which side of the border are you on? *Independent School*, 68(2), 50-56.
- Bajkiewicz, T. E. (2002). *Teens, technology and teaching science: A case study in media literacy, science literacy, and student authored hypermedia*. Unpublished Ph.D. Thesis, University of North Carolina at Chapel Hill, Chapel Hill.

Barab, S., & Dede, C. (2007). Games and immersive participatory simulations for science education: An emerging type of curricula. *Journal of Science Education and Technology*, 16(1), 1-3.

Beadle, M. E. (1995, Nov 18-21, 1995). *Technopoly, media monopolies and curriculum*. Paper presented at the Annual Meeting of the Speech Communication Association, 81<sup>st</sup>, San Antonio, Texas.

Becker, H. J. (2000). *Findings from the Teaching, Learning and Computer Study: Is Larry Cuban right?* Paper presented at the School Technology Leadership Conference of the Council of Chief State School Officers, Washington, DC.

Becker, H. J. (1994). How exemplary computer-using teachers differ from other teachers: Implications for realizing the potential of computers in the schools. *Journal of Research on Computing in Education*, 26(3), 291-321.

Becker, H.J., & Ravitz, J. (1999). The influence of computer and Internet use on teachers' pedagogical practices and perceptions. *Journal of Research on Computing in Education*: Washington, 31(4), 356-375.

Becker, H. J., Ravitz, J. L., & Wong, Y. T. (1999). *Teacher and teacher-directed use of computers and software*. (Research Report #3). Center for Research on Information Technology and Organizations, University of California, Irvine and University of Minnesota: U. S. Department of Education Research on Education Policy and Practice at the National Science foundation and the Office of Educational Research and Improvement.

Belanger, Y. (2000). *Laptop computers in the K-12 classroom*. World of Education. Available at: [library.educationworld.net/a5/a5-63.html](http://library.educationworld.net/a5/a5-63.html) [2005, 4 March].

Bell, M., & Bell, W., (2005). It's installed ... now get on with it! Looking beyond the software to the cultural change. *British Journal of Educational Technology*, 36(4), 643-656.

Bencze, L., Di Giuseppe, M., Hodson, D., Pedretti, E., Serebrin, L., & Decoito, I. (2003). Paradigmatic road blocks in elementary school science "reform": Reconsidering nature-of-science teaching within a rationalist-realist milieu. *Systemic Practice and Action Research*, 16(5), 285-308.

Berman, P., & McLaughlin, M. (1975). Implementation of educational innovation. *Educational Forum*, 40(3), 324-370.

Bermel, J. R., (2008). *Implementing a curriculum innovation with sustainability: A case study from upstate New York*. Unpublished Ed. D. Thesis, State University of New York at Buffalo, New York.

Blumenfeld, P.C., Mark, R.W., Soloway, E. & Krajcik, J. (2003). Learning with peers: From small group cooperation to collaborative communities. *Educational Researcher*, 25(8), 37-40.

Blumenthal, P.G. (2003). *Evaluating ubiquitous access to technology: Teacher and administrator perceptions of effective classroom practices*. Unpublished Ph.D. Thesis, Virginia Commonwealth University, Virginia.

Bogdan, R. C., & Biklen, S. K. (1992). *Qualitative research for education: An introduction to theory and methods*. Boston, MA: Allyn & Bacon.

Boulton-Lewis, G. M., Smith, D. J., Mc Crindle, A. R., Burnett, P. C. & Campbell, J. (2001). Secondary teachers conceptions of teaching and learning. *Learning and Instruction*, 11(1), 35-51.

Breslow, L. (2007). Lessons learned: Findings from MIT initiatives in educational technology (2000-2005). *Journal of Science and Technology*, 16(4), 283-297.

Bybee, R. W. (1996a). The Concerns-Based Adoption Model (CBAM): A model for change in individuals. In Rodger Bybee (Ed) *National Standards and the science curriculum*. Dubuque, Iowa: Kendall Hunt Publishing Co.

Bybee, R. W. (1996). Unintentional consequences of an unacceptable evaluation. *The American Biology Teacher*, 63 (1), 2-4.

Carmack, G. L. D. (2000). *The effects of computer-simulated experiments on high school biology students' problem solving skills and achievement*. Unpublished Ph.D. Thesis, University of Texas at Austin, Austin.

Chamblee, G. E., & Slough, S. W. (2002). Implementing technology in secondary school science and mathematics classrooms: A perspective on change. *Journal of Computers in Mathematics and Science Teaching*, 21(1), 3-15.

Chen, A. Y., & Looi, C.-K. (1999). Teaching, learning and inquiry strategies using computer technology. *Journal of Computer Assisted Learning*, 15, 162-172.

Chang, C.-Y., & Tsai, C.-C., (2005). The interplay between different forms of CAI and students' preferences of learning environment in the secondary science class. *Science Education*, 89(5), 707-724.

- Cho, J. (1998, April 13-17). *Rethinking curriculum implementation: Paradigms, models and teachers' work*. Paper presented at the Annual Meeting of the American Educational Research Association, San Diego, CA.
- Clark, D., & Guba, E. (1972). A re-examination of a test of the Research and Development Model of Change. *Educational Administration Quarterly*, 8(3), 93-103.
- Clark, S. P. (2006). *Teachers and technology: Unpacking illusions of a one-to-one computer initiative*. Unpublished Ph.D. Thesis, The Pennsylvania State University.
- Coffland, D. A. & Strickland, A. W. (2004). Factors related to teacher use of technology in secondary geometry instruction. *Journal of Computers in Mathematics and Science Teaching*, 23(4), 347-365.
- Cole, M. (2009). Using Wiki technology to support student engagement: Lessons from the trenches, *Computers & Education*, 52, 141-146.
- Connelly, F. M. & Clandinin, J. (1990). Stories of experience and narrative inquiry. *Educational Researcher*, 19(4), 2-14.
- Connelly, F. M., Crocker, R. K., & Kass, H. (Eds.) (1985). *Science Education in Canada: Policies, practices and perceptions* (Vol. 1). Toronto, ON: OISE Press.
- Cresswell, J. W. (1998). *Qualitative Inquiry and Research Design: Choosing among five traditions*. Thousand Oaks, CA: Sage Publications.
- Cuban, L. (1995). *The hidden variable: How organizations influence teacher responses to secondary science curriculum reform*. *Theory into Practice*, 34(1), 4-11.
- Cuban, L. (1983). *How did teachers teach, 1880 – 1980?* *Theory into Practice*, 22(3), 159-165.
- Davis, E. A., Petish, D., & Smithey, J. (2006). Challenges new science teachers face. *Review of Educational Research*, 76(4), 607-651.
- Davis, K. S. (2003). "Change is hard": What science teachers are telling us about reform and teacher learning of innovative practices. *Science Education*, 87(1), 3-30.
- Davis, N. E., & Roblyer, M. D. (2005). Preparing teachers for the "Schools that Technology Built": Evaluation program to train teachers for virtual schooling. *Journal of Research on Technology in Education*, 37(4), 399-409.

Dean, D. E. (2000). *Infusing Technology in K-12 classrooms: A study of one method used to prepare teachers to integrate information technologies into their teaching*. Unpublished Ph.D. Thesis, Gonzaga University.

DeHann, R. L. (2005). The impending revolution in undergraduate science education. *Journal of Science Education and Technology*, 14 (2), 253-269.

Demb, A., Erickson, D. & Hawkins-Wilding, S. (2004). The laptop alternative: Student reactions and strategic implications. *Computers and Education*, 43(4), 383- 401.

Dexter, S. L., Anderson, R. E. & Becker H. J. (1999). Teachers' views of computers as catalysts for changes in their teaching practice. *Journal of Research on Computing in Education*, 31(3), 221-239.

Dickson, L. A., & Irving, M. M. (2002). An Internet survey: Assessing the extent of middle/high teachers' use of the Internet to enhance science teaching. *Journal of Computers in Mathematics and Science Teaching*, 21(1), 77-97.

Donovan, L., Hartley, K., & Strudler, N. (2007). Teacher concerns during Initial Implementation of a one-to-one laptop initiative at the middle school level. *Journal of Research on Technology in Education*, 39(3), 263-286.

Donovan, L. (2005). *Exploring relationships between configurations of laptop use and student off-task behaviour*. Unpublished Ph. D. Thesis, University of Nevada, Las Vegas, USA.

Dottin, E. S. (2001). *The development of a conceptual framework: The stimulation for coherence and continuous improvement in teacher education*. ED 459141.

Dottin, E. S. (1999). *Utilizing the concept of "conceptual framework" in National Accreditation*. ED 429062.

Dunleavy, M. & Heinecket, W. F. (2008). The impact of 1:1 laptop use on middle school math and science standardized test scores. *Computers in the Schools*, 24(3&4), 7-22.

Dunleavy M., Dextert, S. & Heinecket, W.F. (2007). What added value does a 1:1 student to laptop ratio bring to technology-supported teaching and learning? *Journal of Computer Assisted Learning*, 23, 440-452.

Elliott, J. (1980). *The implications of classroom research for the professional development of teachers*. World Yearbook in Education.

Ellis, J. D. (1993). *Fostering change in science education*. National Science Foundation. Available at: [http://www.ehr.nsf.gov/EHR/REC/pubs/NSF\\_EF/ellis.htm](http://www.ehr.nsf.gov/EHR/REC/pubs/NSF_EF/ellis.htm) [2004, 08 February].

Ennis, C. D. (1986). Conceptual frameworks as a foundation for the study of operational curriculum. *Journal of Curriculum and Supervision*, 2(1), 25-39.

Erixon, P.-O. (2010). School subject paradigms and teaching practice in lower secondary Swedish schools influenced by ICT and media. *Computers & Education*, 54, 1212-1221.

Feldman, C. S., (2004). *Believe it or not: A case study of the role beliefs play in three middle school teachers' use of computers in teaching science*. Unpublished Ph.D. Thesis, University of California, Davis.

Ferdig, R.E. (2006). Assessing technologies for teaching and learning: Understanding the importance of technological pedagogical content knowledge. *British Journal of Educational Technology*, 37(5), 749 -760.

Fried, C. B. (2008). In-class laptop use and its effect on student learning. *Computers and Education*, 50, 906-914.

Friedman, A. (2006). K-12 Teachers' use of course websites. *Journal of Technology and Teacher Education*, 14(4), 795-815.

Friedrichsen, P. M. & Dana, T. M. (2005). Substantive-level theory of highly regarded secondary biology teachers' science teaching orientations. *Journal of Research in Science Teaching*, 42(2), 218-244.

Fullan, M. (2007). Change the terms for teacher learning. *Journal of Staff Development*, 28(3).

Fullan, M. (2006). Think "system" and not "individual school" if the goal is to fundamentally change the culture of schools. *The School Administrator*, November, 10-14.

Fullan, M. (2005). Turnaround leadership. *The Educational Forum*, 69(Winter), 174 – 181.

Fullan, M. (1998). Leadership for the 21<sup>st</sup> century: Breaking the bonds of dependency. *Educational Leadership*, April, 6-10.

Fullan, M. (1993). *Changing forces: Probing the depths of educational reform*. London, UK: The Falmer Press.

- Fullan, M. (1982). *The meaning of educational change*. New York: Teachers College Press.
- Fullan, M., Anderson, S. E., & Newton, E. E. (1986). *Support systems for implementing curriculum in school boards*. Toronto: Ontario Ministry of Education.
- Fullan, M. & Levin, B. (2008). Learning about system renewal. *Educational Management Administration and Leadership*, 36 (2), 289 -303.
- Fullan, M. & Park, P. (1981). *Curriculum Implementation*. The Minister of Education: Queen's Park, Ontario.
- Fullan, M., & Pomfrey, A. (1977). Research on curriculum and instruction implementation. *Review of Educational Research*, 47(1), 335-397.
- Fullan, M., & Stiegelbaum, S. (1991). *The new meaning of educational change*, (2<sup>nd</sup> ed.). New York, NY: Teachers College Press.
- Galanouli, D., Murphy, C., & Gardiner, J. (2004). Teachers' perceptions of the effectiveness of ICT-competence training. *Computers and Education*, 43(1-2), 63-79.
- Gardiner, P. G., & Farragher P. (1999). The quantity and quality of biology laboratory work in British Columbia high schools. *School Science and Mathematics*, 99(4), 197-204.
- Gardiner, P. G., Morrison & Jarman (1993). The impact of access to computers on learning. *Journal of Computer Assisted Learning*, 9 (1), 2-16.
- Germann, P. J., & Sasse, C. M. (1997). Variations in concerns and attitudes of science teachers in an educational technology development program. *The Journal of Computers in Mathematics and Science*, 16(2/3), 405-423.
- Gershner, V. T., & Snider, S. L., (2001). Integrating the use of the Internet as an instructional tool: Examining the process of change. *Journal of Educational Computing Research*, 24(3), 289-300.
- Giddings, G., & Waldrip, B. G. (1996). *A comparison of science laboratory classrooms in Asia, Australia, South Pacific and USA: An international study*. Paper presented at the Annual Meeting of the American Educational Research Association, New York, NY.
- Gilbertson Anderson, M. S. (1992). *The diffusion of computers as an innovation in a rural school district*. Unpublished Ed.D. Thesis, Gonzaga University.

- Godfrey, C. (2001). Computers in schools: Changing pedagogies. *Australian Educational Computing*, 16 (2), 14-17.
- Gregoire Gill, M., & Hoffman, B (2009). Shared planning time: A novel context for studying teachers' discourse and beliefs about learning and instruction. *Teachers College Record*, 111(5).
- Greenberg, R., Raphael, J., Keller, J.L., & Tobin, S. (1998). Teaching high school science using image processing: A case study of implementation of computer technology. *Journal of Research in Science Teaching*, 35(3), 297-327.
- Hakverdi, M. (2005). *Factors influencing exemplary science teachers' levels of computer use*. Unpublished Ph.D. Thesis, University of Florida.
- Hall, G., George, A., & Rutherford, W. (1979). *Measuring stages of Concern about the innovation: a manual for the use of the SoC questionnaire*. Research and Development Centre for Teachers Education, University of Texas at Austin.
- Hall, G. E., & Hord, S. M. (1987). *Change in schools: Facilitating the process*. State University of New York Press: Albany, NY.
- Hall, G. E. & Loucks, S. (1978). Teacher concerns as a basis for facilitating and personalizing staff development. *Teachers College Record*, 80(1), 35-53.
- Hall, G., Loucks, S., Rutherford, W. & Newton, B. (1975). *Levels of use of an innovation: A framework for analyzing innovation adoption*. *Journal of Teacher Education*, XXVI(1), 52-57.
- Harvey, A. & Kamvounias, P. (2008). Bridging the implementation gap: A teacher-as-learner approach to teaching and learning policy. *Higher Education Research and Development*, 27(1), 31-41.
- Havelock, K. (1969). *A comparative study of the literature on the dissemination and utilization of scientific knowledge*. ERIC Document Reproduction Service No. 3. ED 029 171.
- Hendren, K. L. (2000). *The effect of first and second order barriers on the ideal and actual integration of computer technology into the high school science classroom*. Unpublished Ph.D. Thesis, Ohio State University.
- Herson, K., Sosabowski, M. H., & Lloyd, A. W. (1999). Intranet-based learning: A one-year study of student utilization. *Journal of Computer Assisted Learning*, 15, 269-278.

Hewson, P. W., Tabachnik, B. R., Zuckner, K. M., Blohiker, K. B., Meijer, H., Lemberger, J., Park, H. J. & Toolin, R. (1999). Educating prospective teachers of biology: Introduction and research methods. *Science Education*, 83 (3), 247-273.

Higgins, T. E., & Spitunik, M. W. (2008). Supporting teachers' use of technology in science instruction through professional development: A literature review. *Journal of Science Education and Technology*, 17, 511-521.

Hiller, N. A. (1995). The battle to reform science education: Notes from the trenches. *Theory into Practice*, 34(1), 60-65.

Hodson, D. (2001). What counts as good science education? Paper presented at Science Coordinators & Consultants Association of Canada. Available at: [http://www.sccao.org/oise\\_papers\\_toc\\_vol2.html](http://www.sccao.org/oise_papers_toc_vol2.html). [2004 January 29]

Hodson, D. (1999). Going beyond cultural pluralism: Science education for socio-political action. *Science Education*, 83(6), 775-796.

Hofstein, A., & Lunetta, V. N. (1982). The role of the laboratory in science teaching: Neglected aspects of research. *Review of Educational Research*, 52(2), 201-217.

Horsley, D. L. & Loucks, S. (1998). CBAM brings order to the tornado of change. *Journal of Staff Development*, 19(4), 17-20.

Horwood, R. H. (1988). Explanation and description in science teaching. *Science Education*, 72(1), 41-49.

Inan, F. A., & Lowther, D. L. (2010a). Factors affecting technology integrations in K-12 classrooms: a path model. *Educational Technology Research and Development*, 58, 137-154.

Inan, F. A., & Lowther, D. L. (2010b). Laptops in K-12 classrooms: Exploring factors impacting instructional use. *Computers & Education*, 55, 937-944.

Inan, F. A., Lowther, D. L., Ross, S. M., & Strahl, D. (2010). Pattern of classroom activities during students' use of computers: Relations between instructional strategies and computer applications. *Teaching and Teacher Education*, 26, 540-546.

*International Encyclopedia of Education* (1994). T. Husen & T. N. Postlethwaite (Eds.). Tarrytown, NY: Pergamon Press.

Ivany, G., Sherwood, A., & Wideen, M. (1987). The Science Council of Canada Report, *Science for every student: A solution in search of a problem*. *Canadian Journal of Education*, 12(1), 87-104.

- Jaillet, A. (2004). What is happening with portable computers in schools? *Journal of Science Education and Technology*, 13(1), 115-128.
- Jenkins, E. W. (2001). Research in science education in Europe: Retrospect and prospect. In Barendt, Duhacke, Duit, Graber, Komeck, Kross, & Reiska (Eds) *Research in science education: Past, present, and future*. Kluwer Academic Press: Boston, MA.
- Kane, S. A. (2003). Interdisciplinary faculty development seminars: A model for learning emerging technologies while developing interdisciplinary partnerships. *Journal of Science Education and Technology*, 12(4), 421-430.
- Kang, N.-H., & Wallace, C. S. (2004). Secondary science teachers' use of laboratory activities: Linking epistemological beliefs, goals and practices. *Science Education*, 89, 140-165.
- Kay, R. & Knaack, L. (2007). Evaluating the use of learning objects for secondary school science. *The Journal of Computers in Mathematics and Science Teaching*, 26(4), 261-289.
- Kearney, M., & Schuck, S. (2007). Exploring pedagogy with interactive whiteboards in Australian schools. *Australian Educational Computing*, 23(1), 8-13.
- Kelly, A. V. (1982). *Curriculum: Theory and practice*. Harper & Row: London, UK.
- Kiboss, J. K. (2000). Teacher/pupil perspectives on computer-augmented physics lessons on measurement in Kenyan secondary schools. *Journal of Information Technology for Teacher Education*, 9, 199-218.
- Kiboss, J. K., Ndirangu, M., & Wikesa, E. W. (2004). Effectiveness of a computer-mediated simulations program in school biology on pupils' learning outcomes in cell theory. *Journal of Educational Technology*, 13(2), 201-213.
- Kim, N. B. (1997). *A comparison of the effects of computer-enhanced with traditional instruction on the learning outcomes of high-school students in anatomy classes*. Unpublished Ph.D. Thesis, University of Pittsburgh.
- Kimpson, R. D. (1985). Curriculum fidelity and the implementation tasks employed by teachers: a research study. *Journal of Curriculum Studies*, 17(2), 185-195.

King, J. B. (2003). *Development and validation of an instrument to measure the implementation fidelity of teachers using integrated learning systems*. Unpublished Ph.D. Thesis, University of South Florida. Florida, USA.

Kirschner, P.A., Hendriks, M., Paas, F., Wopereis, I., & Cordewener, B. (2004). *Determinants for Failure and Success of Innovation Projects: The Road to Sustainable Educational Innovation*. Paper presented at the Association for Educational Communications and Technology, Chicago, IL.

Klieger, A., Ben-Hur, Y., & Bar-Yossef, N. (2010). Integrating laptop computers into classrooms: Attitudes, needs and professional development of science teachers – a case study. *Journal of Educational Technology*, 19, 187-198.

Klopfer, E., Yoon, S., & Perry, J. (2005). Using Palm technology in participatory simulations of complex systems: A new take on ubiquitous and accessible mobile computing. *Journal of Science Education and Technology*, 14(2), 143-145.

Kumar, M. (2007). Mixed methodology research design in educational technology. *Alberta Journal of Educational Research*, 53(1), 34-45.

Landry, B. J. L., & Hartman, S. J., (2006). Engaging students with online assignments: a replacement for digital drop boxes and paper assignments. *British Journal of Educational Technology*, 37 (5).

Latchem, C. (2004). Challenges of teaching with technology across the curriculum. *British Journal of Educational Technology*, 35(2), 235-253.

Leidener, D.E., & Jarvenpaa, S. L. (1995). The use of information technology to enhance management school education. *Management Information Systems Quarterly*, 19(3), 265-291.

Leithwood, K.A. (1986). *Planned educational change: A manual of curriculum review, development and implementation (CRDI) concepts and procedures*. Toronto: OISE Press.

Leithwood, K.A. (1981). The dimensions of curriculum innovation. *Journal of Curriculum Studies*, 13(1), 25-36.

Leithwood, K. A., Janzi, D., & Steinbach, R. (1999). *Changing leadership for changing times*. Philadelphia, PA: Open University Press.

Leithwood, K. A., & Montgomery, D. J. (1982). A framework for planned educational change: Application to the assessment of program implementation. *Educational Evaluation and Policy Analysis*, 4(2), 157-167.

- Leithwood, K. A. & Montgomery, D. J. (1980). Evaluating program implementation. *Evaluation Review*, 4(2), 193-124.
- Lemberger, J., Hewson, P. W., & Park, H. J. (1999). Relationships between secondary teachers' classroom practices and their conception of biology and teaching science. *Science Education*, 83 (3), 347- 371.
- Levin, B. & Fullan, M. (2009). Learning about System Renewal. *Educational Management, Administration and Leadership*, 36(2), 289-303.
- Light, D. (2002). *Information, knowledge and technology in a real school: A case study of a laptop program in Union City, New Jersey*. Unpublished Ph. D. Thesis, New School University, USA.
- Lippett, R. D., Watson, Y., & Westley, K. (1953). *The dynamics of planned change*. New York: Harcourt, Brace and Javanovich.
- Lowther, D. L., Ross, S. M., Morrison, G. L. (2003). When each one has one: The influences on teaching strategies and student achievement of using laptops in the classroom. *Educational Technology Research and Development*, 51(3), 23-44.
- Loucks-Horsley, S. (1996). The Concerns-Based Adoption Model (CBAM): A model for change in individuals. In R. Bybee (Ed) *National standards and the science curriculum*. Available at: <http://www.nas.edu/rise/back4a.htm> [2002, 30 March].
- Lu, C. R. (1993). *The effect of a microcomputer-based biology study center on achievement and attitudes in high school biology students*. Unpublished Ph.D. Thesis, The University of Michigan.
- MacLeod, C. D. (2006). *Learning environments associated with the using of laptop computers at Dubai Women's College*. Unpublished Ph.D. Thesis, Curtin University of Technology, Perth, Australia.
- MacMillan, K., & Honey, M (1993). *Year one of Project Pulse pupils using laptops in science and English. A final report*. Center for Technology in Education, New York, NY.
- Mara, J. (2006). *Computers as ubiquitous tools for teachers and learners: a case study of the Maine laptop initiative*. Unpublished Ph.D. Thesis, Nova Southeastern University.
- Marbach-Ad, G., & McGinnis, J. R (2008). To what extent do reform-prepared upper elementary and middle school science teachers maintain their beliefs and

intended instructional actions as they are inducted into schools? *Journal of Science Teacher Education*, 19, 157-182.

Marrack, V. (2006). *Voices of ICT integration: Understanding the conditions that support beginning teachers' implementation of information and communications technology in secondary science classrooms*. Unpublished M.Ed. Thesis, Queen's University, Kingston, Canada.

Marsh, C., & Willis, G. (1995). *Curriculum: Alternative Approaches, Ongoing Issues*. Edgewood Cliffs, NJ: Prentice-Hall.

Marshall, C., & Rossland, G.B. (2006). *Designing Qualitative Research*. Thousand Oaks: Sage.

Martin-Blas, T., & Serrano-Fernandez, A. (2009). The role of new technologies in the learning process: Moodle as a teaching tool in Physics. *Computers & Education*, 52, 35-44.

Mayer-Smith, J., Pedretti, E., & Woodrow, J. (1998). An examination of how science teachers' experiences in a culture of collaboration inform technology implementation. *Journal of Science Education and Technology*, 7(2), 127-134.

McDonald, B., & Walker, R. (1976). *Changing the curriculum*. London: Open Books.

McFarlane, A. & Sakellariou, S. (2002). The role of ICT in science education. *Cambridge Journal of Education*, 32(2), 219-232.

McGrail, E. (2007). Laptop technology and pedagogy in the English language arts classroom. *Journal of Technology and Teacher Education*, 15(2), 59-85.

McMahon, G.P. (2007). *Getting the HOTS with what's in the box: Developing higher order thinking skills within a technology-rich environment*. Unpublished Ph.D. Thesis, Curtin University of Technology.

McRobbie, C., & Thomas, G. P. (1998). *The use of microcomputer-based learning in senior chemistry: Does technological innovation always result in improved student learning?* [2004, 01 March].

Merriam, S. B. (1988). *Case study research in education: A qualitative approach*. San Francisco, CA: Jossey-Bass Publishers.

*Merriam-Webster Student Dictionary* (2007). Available at <http://wordcentral.com> [2009].

*Merriam Webster Online Dictionary*. Available at <http://www.merriam-webster.com> [2009].

- Meyer, R. C. (2007). *A case study of one-to-one computing: The effects on teaching and learning*. Unpublished Ed.D. Thesis, University of Nebraska, Lincoln, Nebraska.
- Miller, J. P. (1983). *The educational spectrum: Orientation to curriculum*. New York, NY: Longman.
- Miller, J. P., & Seller, W. (1990). *Curriculum: Perspective and Practice*. Mississauga, ON: Copp Clark Pitman.
- Moore, J. L. (2004). Designing and implementing performance technology for teachers. *Canadian Journal of Learning and Technology*, 30(2).
- Morrison, H., Gardiner, J., Reilly, C., & McNally, H. (1993). The impact of portable computers on pupils' attitudes to study. *Journal of Computer Assisted Learning*, 9, 130-141.
- Mouza, C. (2008). Learning with laptops: Implementation and outcomes in an urban, underprivileged school. *Journal of Research on Technology in Education*, 40(4), 447-472.
- Mueller, A. & Welch, M. (2006). Classroom-based professional development: Teachers' reflections on learning alongside students. *Alberta Journal of Educational Research*, 52(2), 143-158.
- Munby, H. (1984). A qualitative approach to the study of a teacher's beliefs. *Journal of Research in Science Education*, 21(1), 27-38.
- Newhouse, C. P. (2001a). A follow-up study of students using portable computers at a secondary school. *British Journal of Educational Technology*, 32(2), 209-219
- Newhouse, C. P. (2001b). Applying the Concerns-Based Adoption Model to research in classrooms. *Journal of Research on Technology in Education*, 35(5), 20.
- Newhouse, C. P. (2001c). A longitudinal study of the use of student-owned portable computers in a secondary school. *Computers & Education*, 36, 223-243.
- Newhouse, P. (1999a). Examining how teachers adjust to the availability of portable computers. *Australian Journal of Educational Technology*, 15(2), 148-166.

Newhouse, P. (1999b). *Portable computers supporting secondary school learning*. Paper presented at the Western Australian Institute for Educational Research Forum 1999, Freemantle, Australia.

Newhouse, P. (1998a). The impact of portable computers on classroom learning environments. *Australian Educational Computing*, 13(1), 5-11.

Newhouse, P. (1998b). *A model to assist in the understanding of teachers' responses to high access computing environments*. Paper presented at the Western Australian Institute for Educational Research Forum, 1998.

Newhouse, C.P. (1997). *Teachers' responses and classroom learning environments associated with student access to portable computers*. Unpublished Ph.D. Thesis, Curtin University of Technology, Perth, Australia.

Newhouse, P. & Rennie, L. (2001). A longitudinal study of the use of student-owned portable computers in a secondary school. *Computers and Education* 36 (3) 223-243.

Newton, L. R. (1997). Information technology in biology teaching: Challenges and opportunities. *Journal of Biological Education*, 31(4), 274-278.

Niles, R. (2006). *A study of the application of emerging technology: Teacher and student perceptions of the impact of one-to-one laptop computer access*. Unpublished Ed.D. Thesis, Wichita State University, Kansas.

Nitti, J. (2000). *A qualitative case study of teacher perceptions and concerns during the implementation of literacy folders in a select elementary school in Broward County, Florida*. Unpublished Doctoral Thesis, Florida International University, Miami, Florida.

Norton, S., McRobbie, C., & Cooper, T. J. (2000). Exploring secondary mathematics teachers' reasons for not using computers in their teaching: Five case studies. *Journal of Research on Computing in Education*, 33(1), 87-109.

O'Leary, Z. (2009). *The essential guide to doing research*. Thousand Oaks, CA: Sage Publications.

Ontario Department of Education (1973). *Environmental Science Guidelines*. Toronto, ON: Queen's Printer.

Ontario Ministry of Education (2000). *The Ontario Curriculum, Grades 11 and 12: Science*. Queen's Printer for Ontario.

- Osborne, B. (1993). *Understanding change in a time of change*. Paper presented at the 2<sup>nd</sup> Annual Conference on Creating the Quality School, Oklahoma City. ED358544.
- Ottenbreit-Leftwich, A. T., Glazewski, K. D., Newby, T. J., & Ertmer, P. A. (2010). Teacher value beliefs associated with using technology: Addressing professional and student needs. *Computers & Education*, 55, 1321-1335.
- Owen, J. M., & Lambert, F. C. (1998). The notebook curriculum: An innovative approach to the use of personal computers in the classroom. *AACE Journal*, 26, 25-31.
- Owusu, K. A., Monney, K. A., Appiah, J. Y., & Wilmot, E. M. (2010). Effects of computer-assisted instruction on performance of senior high school biology students in Ghana. *Computers & Education*, 55, 904-910.
- Oxford Dictionary, Thesaurus and Wordpower Guide* (2003). Oxford University Press, New York, NY.
- Parker, M. J. (1998). *The effects of a shared, Intranet science learning environment on the academic behaviours of problem-solving and metacognitive reflection*. Unpublished Ed.D. Thesis, Baylor University.
- Parker, Z. J. (1995). *An exploratory study of experiential hands-on learning vs computer simulation in a high school biology class*. Unpublished Ph.D. Thesis, Pennsylvania State University.
- Parr, J. M. (1999). Extending educational computing: A case of extensive teacher development and support. *Journal of Research on Computing in Education; Washington*, 31(3), 280-288.
- Passerini, K., & Grainger, M. J. (1989). *Information technology-based instructional strategies*. Paper presented at the International Academy for Information Management (IAIM) Annual Conference (13), Helsinki, Finland.
- Patton, M. Q. (2002). *Qualitative research and evaluation methods*. Thousand Oaks, CA: Sage Publications.
- Patton, M. Q. (1990). *Qualitative evaluation and research methods*. Newbury Park, CA: Sage Publications
- Paul, T. (2005). *The impact of collaborative computer software on the enhancement of learning in a secondary science course*. Unpublished D Ed Thesis, Boston College.

- Pedretti, E., Mayer-Smith, J. & Woodrow, J. (1999). Teaming technology enhanced instruction in the science classroom and teacher professional development. *Journal of Technology and Teacher Education*, 7(2), 121-143.
- Pedretti, E., Mayer-Smith, J. & Woodrow, J. (1998). Technology, text, and talk: Students' perspectives on teaching and learning in a technology-enhanced secondary science classroom. *Science Education*, 82, 569-589.
- Petrosino, A. J. (2004). Integrating curriculum, instruction, and assessment in project-based instruction: A case study of an experienced teacher. *Journal of Science Education and Technology*, 13(4), 447-460.
- Phillips, R., Bailey, M., Fisher, T., & Harrison, C. (1999). Questioning teachers about their use of portable computers. *Journal of Computer Assisted Learning*, 15, 149-161.
- Pilling, G. M., & Waddington, D. J. (2005). Implementation of large-scale science curricula: A study in seven European countries. *Journal of Science Education and Technology*, 14 (4), 393-407.
- Pinar, W. F., Reynolds, W. M., Slattery, P., & Taubman, P. M. (1995). *Understanding Curriculum: An Introduction to the Study of Historical & Contemporary Curriculum Discourses*. (2000 ed. Vol 17) New York, NY: Peter Lang.
- Polman, J. P., & Pea, R. D. (2001). Transformative communication for inquiry science. *Science Education*, 85, 223-238.
- Pondar, G. & Kelly, J. (1997). Evolution, chaos or perpetual motion? A retrospective trend analysis of secondary school science curriculum advocacy, 1955-94. *Journal of Curriculum and Supervision*, 12 (Spring), 228-245.
- Postman, N. (1993). *Technopoly: The surrender of culture to technology*. New York, NY: Vintage Books.
- Reading, C., Fluck, A., Trinidad, S., Smith, H., Shaw, G., Anderson, N., McLoughlin, C., & White, B. (2006). Focusing on ICT in rural and regional education in Australia. *Australian Educational Computing*, 21(2), 20-24.
- Reid, S. (2008). *The adoption of asynchronous online courses by professors at Memorial University of Newfoundland: A case study*. Unpublished Ph.D. Thesis, University of Ottawa, Canada.
- Reid, S. (2002a). The integration of information and computer technology into classroom teaching. *The Alberta Journal of Education*, 48 (1), 30-46.

- Reid, S. (2002b). Teachers' views on technology and the future of teaching. *International Electronic Journal for Leadership in Education*, 6 (21), 12.
- Reid-Griffin, A., & Carter, G. (2004). Technology as a tool: Applying an instructional model to teach middle school students to use technology as a mediator of learning. *Journal of Science Education and Technology*, 13(4), 495-504.
- Richards, T. J. & Richards, L. (1994). Using computers in qualitative research. In N. K. Denzin & Y. S. Lincoln (Eds.), *Handbook of qualitative research* (pp 445-462). Thousand Oaks, CA: Sage.
- Richardson, C. R. (1999). *Exploring the changes in teaching strategies enabled by the Internet and communications technology*. Unpublished Ed.D. thesis, University of Toronto, Toronto, Canada.
- Robson, C. (1994). *Real world research: A resource for social scientists and practitioner-researchers*. Oxford, UK: Blackwell Publishers.
- Rogan, J. M. (2007). An uncertain harvest: A case study of implementation of innovation. *Journal of Curriculum Studies*, 39 (1). 97- 121.
- Rogan, J., & Aldous, C. (2005). Relationships between the constructs of a theory of curriculum implementation. *Journal of Research in Science Education*, 42(3), 313- 336.
- Rogers, E. M. (1995). *Diffusion of innovations*. New York, NY: The Free Press.
- Rogers, L. & Finlayson, H. (2003). Does ICT in science really work in the classroom? Part 1, The individual teacher experience. *School Science Review*, 84 (309), 105-111.
- Ross, J. A. & Cousins, B. (1995). Giving and receiving explanations in cooperative learning groups. *Alberta Journal of Educational Research*, XLI(1), 103-121.
- Rowan, B. (1990). Commitment and control: Alternative strategies for the organizational design of schools. *Review of Research in Education*, 16, 353-392.
- Runge, A., Spiegel, A., Pytlik, L. M., Dunbar, S., Fuller, R., Sowell, G., & Brooks, D. (1999). Hands on computer use in science classrooms: The skeptics are still waiting. *Journal of Science Education and Technology*, 8(1), 33-44.
- Russell, D. W., Lucas, K. B., & McRobbie, C. J. (2004). Role of the micro-computer based laboratory display in supporting the construction of new

understandings in thermal physics. *Journal of Research in Science Teaching*, 41(2), 165-185.

Russell, J. W. (2006). *Secondary school biology teaching, 1983-2004: Objectives as stated in periodical literature*. Unpublished Ed.D. Thesis, Texas A&M University, Texas, USA.

Ruth, A. & Houghton, L. (2009). The wiki way of learning. *Australasian Journal of Educational Technology*, 25(2), 135-152.

Rutherford, F. J. (2005). The 2005 Paul F-Brandwein lecture: Is out past our future? Thoughts on the next 50 years of science education reform in light of judgements on the past 50 years. *Journal of Science Education and Technology*, 14(4), 367-386.

Ruthven, K., Hennessy, S., & Deaney, R. (2005). Incorporating Internet resources into classroom practice: Pedagogical perspectives and strategies of secondary-school subject teachers. *Computers & Education*, 44, 1-34.

Ruthven, K., Hennessy, S., & Brindley, S. (2004). Teacher representations of the successful use of computer-based tools and resources in secondary-school English, mathematics and science. *Teaching and Teacher Education*, 20(3), 259-275.

Sandoval, W. A., & Daniszewski, K. (2004). Mapping trade-offs in teachers' integration of technology-supported inquiry in high school science classes. *Journal of Science Education and Technology*, 13(2), 161-178.

Sasseville, B. (2004). Integrating information and communications technology in the classroom. *Canadian Journal of Learning and Technology*, 30(2), 1-26.

Savoy, A., Proctor, R. W., & Salvendy, G. (2009). Information retention from PowerPoint and traditional lectures. *Computers & Education*, 52, 858-867.

Schelling, T. (1963). *The strategy of conflict*. London: Oxford University Press

Schmuck, R. A., & Runkel, P. (1972). *Handbook of organizational development in schools*. Jolla, CA: University Associates.

Schon, D. (1971). *Beyond the stable state*. London: University Press.

Schotsberger, P. G., & Crawford, A. R. (1996, April 8-12). *An analysis of the validity, and reliability of the Concerns Based Adoption Model for teacher concerns in education reform*. Paper presented at the Annual Meeting of the American Educational Research Association, New York, NY. ED400278.

Schumacher, S., (1972). *Limitations of a research, development and diffusion (RD and D) strategy in diffusion: A case study of nine local implementations of a state-adopted curriculum*. Paper presented at the National Council for the Social Studies Annual Meeting, Boston. ED 076 464.

Schwab, J. J. (1963). *Biology teachers' handbook*. New York, NY: John Wiley and Sons.

Schubert, W. M. (1986). *Curriculum perspective, paradigm, and possibility*. New York, NY: Macmillan.

Sclater, J., Sicol, F., Abrami, P.C., & Wade, C. A. (2006). Ubiquitous technology integration in Canadian public schools: Year one study. *Canadian Journal of Learning and Technology*, 32(1), 1-26.

Scott, C. C. (2005). *Exploring the impact of a teachers preparation program's laptop initiative on the Faculty's teaching and learning experience*. Unpublished Ph.D. thesis, University of Texas at Austin.

Seidman, I. E. (1991). *Interviewing as qualitative research: A guide for researchers in education and the social sciences*. New York, NY: Teachers College Press.

Sieber, S. (1981). Knowledge utilization in public education: Incentives and disincentives. In R. Lehming & M. Kane (Eds.) *Improving schools: Using what we know*. Beverly Hills, CA: Sage.

Siegle, D., & Foster, D. (2001). Laptop computers and multimedia and presentation software: Their effects on student achievement in anatomy and physiology. *Journal of Research on Technology and Education*, 34 (1) 29-37.

Silvernail, D.L. (2008). Laptops for all. *T H E Journal (Technical Horizons in Education)*, 35(7), 23-26.

Simon, E. J. (2001). Collaborative web site construction: Students and teachers teaming up to build resources on the web. *Journal of College Science Teaching* 30(6), 382-384.

Simmie, G. M. (2007). Teacher design teams (TSTs) – building capacity for innovation, learning and curriculum implementation in the continuing professional development of in-career teachers. *Irish Educational Studies*, 26(2), 163-176.

Simmons, P. E., Brunkhorst, H., Lunetta, V. N., Penick, J., Peterson, J., Pietruchka, B., & Staver, J. (2005). Developing a research agenda in science education. *Journal of Science Education and Technology*, 14(2), 239-252.

Slough, S. (1997). *High school teachers' perceptions of telecommunications utilizing a Concerns-Based Adoption Model (CBAM)*. Unpublished Ed.D. Thesis, University of Houston, Texas, USA.

Slough, S. W. & Chamblee, G. E. (2007). Technology as an innovation in science and mathematics teaching. *School Science and Mathematics Teaching*, 107(6), 222.

Smith, G. R., Dilts, J. A., Gabrielson, P. W., Heruth, D. P., Rettig, J. E., and Strautman, A. F. (1999). Using laptops in the biology classroom and laboratory. *Bioscene* 25(3), 11-12.

Snyder, J., Bolin, F., & Zumwalt, K. (1992). Curriculum implementation. In P. Jackson (Ed.) *Handbook of Research on Curriculum* (pp 402-435). New York, NY: Macmillan.

Stager, G. S. (2003). School laptops – reinventing the slate: Silicon Valley giveth, schools taketh away. *District Administration Magazine*, March, 3.

Stager, G. S. (2002). *Girls and Technology – overcoming myths and malpractices*. Paper presented at Pepperdine University.

Stager, G. S. (1998). Laptops and learning: Can laptop computers put the “C” (for constructionism) in learning? *Curriculum Administrator*, October.

Stager, G. S. (1995). Laptop schools lead the way in professional development. *Educational Leadership*, 53 October 78-81.

Stake, R.E. (1994). Case Studies, Strategies of Inquiry. In N. K. Denzin & Y. S. Lincoln (Eds.), *Handbook of Qualitative Research* (pp. 236-247). Thousand Oaks, CA: Sage.

Statistics Canada (1999). *The Daily*. Available at: <http://statcan.ca/Daily/English/991012/d991012a.htm>. [9 October 2004]

Stolarchuk, E., & Fisher, D. (2001a). First years of laptops in science classrooms result in more learning about computers than science. *Issues in Educational Research*, 11(1), 25-39.

Stolarchuk, E., & Fisher, D. (2001b). An investigation of teachers-student interpersonal behaviour in science classrooms using laptop computers. *Journal of Computing Research*, 24(1), 41-55.

Stolarchuk, E. (1997). *An evaluation of the effectiveness of laptop computers in science classrooms*. Unpublished Ph.D. Thesis, Curtin University of Technology, Perth, Australia.

- Stylianidou, F., Boohan, R., & Ogborn, J. (2005). Science teachers' transformations of the use of computer modeling in the classroom: Using research to inform training. *Science Education*, 89, 56-70.
- Surry, D. W. (1997). *Diffusion theory and instructional technology*. Paper presented at the Annual Conference of the Association for Educational Communications and Echnology (AECT), Albuquerque, New Mexico.
- Sweeny, B. W. (2003). *CBAM*. Available at: <http://www.mentoring-association.org> [2008, December, 24].
- Taber, K. S. (2000). Case studies and generalizability: Grounded theory and research in science education. *International Journal of Science Education*, 22(5), 469-487.
- Tamir, P. (2004). Curriculum implementation revisited. *Journal of Curriculum Studies*, 36(3), 281-294.
- Tamir, P. (1983). Teachers' self report as an alternative strategy for the study of classroom teaching. *Journal of Research and Science Teaching*, 20(9), 815-823.
- Tatar, D., & Robinson, M. (2003). Use of the digital camera to increase student interest and learning in high school biology. *Journal of Science Education and Technology*, 12(2).
- Tebbutt, M. (1999). Information and communications technology in the science curriculum: An Australian case study, *Journal of Information Technology for Teacher Education*, 8(1), 25-40.
- Thomas, G. P., Man-Wai, P. F., & Tsang Po-keung, E. (2004). Students' perceptions of early experiences with micro-computer-based laboratories (MBL). *British Journal of Educational Technology*, 35(5), 699.
- Thomas, G. P (2001). Toward effective computer use in high school education: Where to from here? *Education and Information Technologies*, 6(1), 29-41.
- Tiberghien, A. L., Veillard, L., Le Maréchal, J.-F. & Buty, C (2001). An analysis of labwork tasks used in science teaching at upper secondary school and university levels in several European countries. *Science Education*, 85(3), 483- 508.
- Trimmel, M. (2004). Cognitive, social, motivational and health aspects of students in laptop classrooms. *Journal of Computer Assisted Learning*, 20(2), 151-158.

- Vallance, M. (2006). Responsibility without power: Reflections of an IT coordinator. *Perspectives*, 10(4), 109-114.
- van Driel, J. H., Bulte, A. M. W., & Verloop, N. (2005). The conceptions of chemistry teachers about teaching and learning in the context of a curriculum innovation. *International Journal of Science Education*, 27(3), 303-322.
- Van Oostveen, R., & Muirhead, W. (2007). Faculty use of tablet computers at the University of Ontario Institute of Technology. *Canadian Journal of Learning and Technology*, 33(1).
- Varma, K., Husic, F., & Linn, M. C. (2008). Targeted support for using technology-enhanced science enquiry modules. *Journal of Science Education and Technology*, 17, 341-356.
- Ward, L. & Parr, J. M. (2010). Revisiting and reframing use: Implications for the integration of ICT. *Computers & Education*, 54, 113-122.
- Webb, M. E. (2005). Affordances of ICT in science learning: implications for an integrated pedagogy. *International Journal of Science Education*, 27(6), 705-735.
- Webster's Universal College Dictionary (1997). Random House, New York, NY.
- Weiss, I. R. (1997). Comparing Teacher views and classroom practice to National Standards. Available at: [http://www.wisc.edu/NISE/publications/Briefs/Vol\\_1\\_No\\_3](http://www.wisc.edu/NISE/publications/Briefs/Vol_1_No_3). Available 28 June 2001.
- Welch, W.W. (1979). Twenty years of science curriculum development: A look back. In D. Berliner (Ed.), *Review of research in education* (Vol 7, pp 282-306) Washington, D.C.: American Educational Research Association.
- Weyker, B. S. (2002). *A study of the pedagogical beliefs, practices, and computer uses of classroom teachers*. Unpublished Ed.D. Thesis, University of North Carolina at Charlotte, North Carolina.
- Willis, J., & Jost, M. (1999). Computers and qualitative research. *Educational Research and Statistics*, 15(3-4), 21-52.
- Windelspecht, M. (2001). Technology in the freshman biology classroom: Breaking the dual learning curve. *The American Biology Teacher*, 63(2), 96-101.
- Windschitl, M., & Lesehm-Ackerman, A. (1997). Learning teams, students and the college e-mail culture. *Journal of the Freshman Year Experience and Students in Transition*, 9(2), 53-82.

Windschitl, M. & Sahl, K. (2002). Tracing teachers' use of technology in a laptop computer school: The interplay of teacher beliefs, social dynamics and institutional culture. *American Educational Research Journal*, 39(1), 165-205.

White, R. T., & Tisher, R. P. (1986). Research on natural sciences. In M. C. Wittrock (Ed.), *Handbook of research on teaching* (Third ed., pp 874-904). New York, NY: Macmillan.

Woody, W. D., Daniel, D. B., & Baker, C. A. (2010). E-books or textbooks: Students prefer textbooks. *Computers & Education*, 55, 945-948.

Yang, C-C (2002, June 24-29, 2002). *Integration of laptops into a K-12 learning environment: A case study of a science teacher in the middle school*. Paper presented at the ED-MEDIA 2002 World Conference on Educational Multimedia, Hypermedia & Telecommunications, 14<sup>th</sup>, Denver, Colorado.

Yerrick, R., & Hoving, T. (1999). Obstacles confronting technology initiatives as seen through the experience of science teachers' beliefs, planning & practice. *Journal of Science Education and Technology*, 8(4), 291-307.

Yin, R.K. (1994). *Case study research: Design and Methods*. Thousand Oaks, CA: Sage Publications.

Zucker, A.A., & Hug, S.T. (2008). Teaching and learning physics in a 1:1 laptop school. *Journal of Science Education and Technology*, 17, 586-594.

## **Appendix A: DETAILED DESCRIPTION OF THE FINDINGS**

This research was based on the premise that the successful integration of laptop computers into curriculum in the classroom depended on the willingness of individual teachers to change their perceptions, their teaching materials and their instructional practices. The objectives of the study were to examine the perceptions of ten biology teachers and offer an opportunity to learn from these early implementers. Three research questions were drafted and a model developed to meet these objectives. The research questions were combined with a model, CBAM, and a qualitative descriptive case study was carried out. Data was collected through three in-depth interviews, informal interviews, and the gathering of teaching materials that had been developed.

This appendix provides more details than Chapter Five of the thesis on how the teachers answered the interview questions during the three semi-formal interviews. These descriptions allow readers to determine the usefulness of the teachers' perceptions and their experiences during the implementation and integration of laptop computers in their classrooms. The teachers are presented in random order and have been given pseudonyms to protect their identity: Adele, Keith, Xandra, Darby, Audrey, Zoe, Ross, Samantha, Richard and Kenneth.

The teachers represented by these pseudonyms, Adele, Keith, Audrey and the others, in a sense do not exist. Describing the teachers' perceptions and actions, no matter how carefully executed, must reflect the ongoing decisions required of the researcher while analyzing and presenting the data. Darby,

Audrey, Zoe, and the others, are necessarily a blend of the teachers interviewed and the role of the researcher in a descriptive study.

**Question One: How do senior grade biology teachers perceive the integration of laptop computers into high school biology programs?**

For the purposes of this study, a perception is considered to be an immediate or intuitive recognition or insight. The teachers' responses to the introduction of laptop computers dealt with the type of change they had implemented, the supports to change that they acknowledged, and their opinions of the challenges which they still faced.

In addition, a number of questions were asked about the teachers' perceptions of the diffusion of the use of laptops for instruction in biology courses. The teachers were asked how they might differ from biology teachers who were not teaching in a laptop program, what advice they would give biology teachers entering a laptop program for the first time, and what they thought encouraged other teachers to persist in using laptops for instruction.

**Adele: Perceptions**

As Adele talks about her experiences, one senses a pattern of biology teachers co-operating to organize courses at the school, and co-operation with teaching partners where there are multiple sections of Biology 11 and Biology 12 being taught. She mentions that dealing with the complexities of a laptop program have made teaching a less isolating experience for the teachers.

However, it also seems that it is her decision exactly how the laptops are used in her classes and what they are used for. The one group she consults with is the students.

Adele remembers that changes in instructional approaches resulting from the use of the laptops happened over time.

Over a period of time. I think it was a big adjustment for the students as well as the teachers, so it didn't happen quickly.

(Adele, I – 247)

Five years into teaching biology in the laptop program, she may review and update two out of the five or six units in a biology course each year. She can't predict what change she will be dealing with in the future because she is responding to upgrades in hardware and software every year.

When discussing what helps them as teachers change their instructional practices, Adele stresses the importance of the support provided at the school and the new, up-to-date technology made available to them. She thinks the impetus for change is sustained because the teachers are dealing with up-to-date technology. The IT department will research new software for the teachers, show them how to use it and even come to the classroom and work with the students. She expresses considerable satisfaction with the new instructional practices they have been able to adopt and with the changes in how their students learn biology. The perception that the students are better prepared for

studying biology at post-secondary institutions encourages their efforts, although the teachers have come to realize that in many instances undergraduate programs are not as technologically advanced as they had thought. The opportunity to see what teachers do in other schools and see new ideas during professional development are also mentioned as being important to sustaining changes they have implemented.

Adele identifies challenges to sustaining the laptop program, including: the ongoing upgrades of hardware and software; the additional peripherals for teaching biology; and, obtaining further training in the use of technology associated with the laptop program. She realizes that upgrades to hardware and software sometimes mean peripherals they have been using are no longer compatible with the new laptops or require expensive adaptors. She also recognizes the need for more network speed when the laptops are being used for instruction, the need for more probeware for biology labs, and at this point in time, her need for more training on the use of SMART Boards.

Adele was one of the teachers in the sample who had observed new teachers coming into the laptop program. She felt she differed from these teachers because she could no longer imagine teaching without a laptop computer and because of her perception that all teachers, whether in a laptop program or not, should be working with a laptop in the classroom. The fact that she used peripherals more in her teaching was another difference that she identified.

She advises that teachers coming into a laptop program remember that they are biology teachers first, that teaching the curriculum supersedes the use of the laptops, that teachers should continue doing what they do well, and that as they begin integrating the laptops into their instruction they should use the laptops only to their comfort level. She advises that biology classrooms with laptops have to be managed differently; that the teachers control the use of laptops during class time; and that the teachers must be clear on the rules of laptop use they wish the students to follow. However, she does advocate that teachers allow the students to choose whether they use their laptops for tasks such as maintaining notebooks, that the teachers continue to use collaborative learning strategies and small group work in their instruction, and that they should be prepared to develop new teaching materials.

She believes teachers new to a laptop program will be encouraged to integrate the laptops into their instruction as they perceive the positive effects of the laptops on their teaching approaches, and on the students' research skills, learning, and assessments.

### **Keith: Perceptions**

Keith talks of the decisions he makes about how and when the laptops are used for instruction in his classroom. In contrast, he discusses working with members of the IT department and the vice principal, on matters such as the reliability and management of the Lotus Notes platform the school uses for the course databases, but not on pedagogical matters.

Keith finds that change is still happening as he integrates laptop computers into instruction, even after eight years in the laptop program. The time invested in using laptop computers for instruction was high in his first three to four years in the laptop program. In his fifth year in the program, he added about 300 documents to his database. In his sixth year, he added another 200 documents and in his seventh year he added 100 documents. He attributes this slower pace to the fact that he was originally concerned with building the basic structure of the course and he is now enriching the course. He sees this present rate of change as ongoing since it reflects the changing needs of students.

Keith mentions the school's support of the teachers through the implementation process required by a laptop program, including: the original subsidies and interest-free loans which allowed the teachers to become more computer-aware; funds that are available for peripherals needed to teach using the laptops in the laboratory; and, professional development provided at the school. During the initial changes, the teachers had two or three days at the end of the teaching year when they would learn about the new hardware and software for the upcoming year. Now professional development is still available at the school and funds are available for teachers to attend conferences, workshops and courses at other locations. The teachers at the school are encouraged to change by the students in their classes. Keith observes that the teachers learn from the students and the students push the teachers to use the laptops in new and different ways. He is also encouraged by positive feedback from students who have gone on to study biology at post-secondary institutions.

Keith identifies a number of challenges to maintaining the momentum of teaching in a laptop program, including: future upgrades of hardware and software; the time constraints experienced by science teachers; difficulty in finding appropriate professional development; and difficulty in finding opportunities to share with others teaching biology in laptop programs.

If you take a biological example, in order for me to teach biotechnology I shouldn't have to go out and purchase all the different things, and all the chemicals, and all the bits and pieces of equipment necessary, in order for the students to do a lab. I shouldn't have to put it all together on my own, though I'm going to learn a tremendous amount doing that. I should be able to go to someone, get a package, pull it off the shelf and be able to use that package to do meaningful science. Good companies are doing that today, it's costly but I can get those modules and they've been bench tested and I can then work with that material. That's almost how it feels with laptops where you are putting all the bits and pieces together. You're doing all that work from the ground up. The advantage of doing it that way is that you learn a lot and you understand how to do it, so change becomes easy (Keith, III – 249).

Keith feels isolated and talks of the challenges in finding appropriate professional development and appropriate models for instruction.

It's important for groups of individuals that are perhaps using this (laptops) in some fashion, to get together, and share best practices and to discuss things that might be possible. If we could do that, we might be able to take away from that something that would help us (Keith, III – 73).

In the meantime he notes the challenge of not having data which he could use to improve his practice, and not having the tools to collect such data himself. In fact, he expresses doubts that anyone has those research tools at this time.

He believes his experience in teaching with laptops has made him more forward thinking, more willing to deal with change and more willing to consult professional literature to find answers to his questions or to look for new ideas he might implement. Keith has observed a variety of teachers enter a laptop program for the first time. Whether it is an experienced teacher with few computer skills or a less experienced biology teacher with more up to date computer skills he feels the process they must deal with is quite similar.

He advises teachers new to a laptop program to start the integration process by putting their favourite lessons and the most important labs in the course, online. Like Adele, he believes teachers new to teaching with laptops should work from their strengths. He also advises these teachers to take

advantage of the opportunities laptops provide to gather teaching materials to supplement student learning.

He has observed that teachers new to a laptop program can manage to post marks and teaching materials and handle email after one year, but they may not have reached a level of complexity in using laptops for instruction in the classroom. He has noted that the pattern is similar even for experienced science teachers who are new to the laptop program. They find it a different and challenging way to teach.

I mean you see the same trend with new staff coming in because it's a huge undertaking for them to walk in, everything is on the laptop, really. For them to go from wherever they did come from, to this environment must be very difficult. It requires a lot of deep thinking, and a lot of new thinking, and a lot of mentoring, and a lot of time to develop materials and put them in place (Keith, II – 315).

### **Xandra: Perceptions**

Xandra makes the decisions as to how and when the laptops are used for instruction in her courses. She is aware that other teachers in the school use the laptops differently and have different protocols for their use in their classrooms. In retrospect, Xandra is of the opinion that she implemented the laptops because she felt she had no option.

I had to, it was a laptop school. I was given a nice laptop and the IT department head, she is really instrumental in ensuring that teachers are integrating laptops in their teaching. She would always be there around the corner, and asking, and checking up on us, so I think it was because it was necessary. It was what I had to do. I was in a laptop school.

(Xandra, I – 359)

Even so, Xandra said she resisted changes and at first continued to teach as she had been teaching. It took about two years before she started implementing the use of the laptops for instruction.

It probably took a good four years to be as comfortable as I am with a [laptop] and doing everything I am doing with it: using it to teach classes; using it for labs; using it to communicate; reserve rooms; everything. Four years, and I would probably honestly say I resisted in the beginning. I wanted to still hang on and I did. The first year I used the overhead projector because I had all these beautiful overhead transparencies that I had created. I still used them for the first, probably the first two years I was here, and then I slowly started to redevelop my units, scanning the images in, finding images off the web,

so I guess I did change. Probably two years after arriving here I made a concerted effort to prepare my lessons by making my skeletal notes on Word, having a copy posted for the students, having it readily available for me, having them annotate the notes using the SMART Board (Xandra, 1- 311).

She reported that there was no finite time at the school for teachers to change instructional practices to integrate the laptops into their courses.

Xandra says she is encouraged by the more varied biology program she can present, and by the fact that her course is of more interest to the students. When discussing what helps teachers change their instructional practices, Xandra stresses a number of factors: the teacher's attitude; how the teacher deals with the time constraints experienced by science teachers; the support provided by the school; and, the feedback from the students. She believes she is personally motivated to carry out the changes required to use laptops in her instruction and her motivation is sustained by the proficiency she has already developed, and the efficiency the laptops bring to the preparation of her lessons, and, to her teaching in the classroom. She selects the technology which she deems significant for her courses. Some technology available in the school does not meet that criteria and she can choose not to use it. Since time constraints are an important consideration for her, she mentions the positive effect of having time allocated in her schedule to learn about technology, and the importance she

places on having professional development scheduled during the teaching day. Xandra believes that IT support is very important if teachers are to change their instructional practices while integrating laptops into their teaching. She finds the IT department is the one area she can safely and competently consult for assistance. In fact, if she were to choose to teach in another school that supports a laptop program, she would select that school by its IT department, the department's philosophy and its model for using laptop technology. She also notes the importance of the financial support available through the IT department's budget.

I'd emphasize the necessity of having a lot of financial support because the IT in biology, certainly when I think of the money I spent just recently on probes, is sometimes an entire science department budget at certain schools (Xandra, III – 139).

The students are also an important impetus to change.

I could probably say that students who are interested in pursuing the sciences, I can sell them the idea that they get to work with the equipment they might ultimately see at university and that might promote, solidify their interest (Xandra, III – 67).

Xandra identifies challenges to ongoing change in the laptop program, including: the limits to her own knowledge of technology; and, the time constraints experienced by science teachers.

IT, they are more general. I mean they make an effort to bring in math and science, but their support is more general: hardware, software, saving files, Word, Excel, Inspiration. In terms of science-specific technology we're kind of out on our own (Xandra, I – 99)

As a classroom teacher she finds it difficult to be knowledgeable about future technology and can't envision future challenges.

I can't even imagine what technology can provide for me so to have a goal in mind and work back and think how long it would take to get to that goal? With technology, I don't really think that's feasible (Xandra, III – 15).

She experiences real time constraints and believes that time to work with the laptops should be allocated in her schedule if she is to become more proficient at using laptops in her classroom. In addition, she finds teaching the technology to students is time consuming, and, as a science teacher, she needs more assistance in the lab. She observes that co-op university students on work

terms as lab technicians are an uneven resource, requiring ongoing and extensive input from the science teachers.

The previous student we had, he was very competent and willing, but he came from an engineering background, so he was unfamiliar with even how to make agar. So as a result of that I would have to spend the time explaining that to him, but now he knows. The new one we have, I think he has a biochemistry background. It's difficult to hire a lab tech that can be familiar with all the sciences. They have a greater expertise in the physical or the life sciences. We make do with what we have (Xandra, III – 55).

Xandra says she has not observed another biology teacher come into a laptop program for the first time, but she believes that her courses are more entertaining for the students as they learn and easier for her to prepare than courses that are not taught with laptops. She also believes her instructional approaches are more varied and that she, as a teacher, is more up to date on the material she includes in the course.

She advises teachers integrating laptops into their instruction for the first time to remain confident, and not to become discouraged. She believes they need to know that the process requires patience.

I would probably emphasize the amount of time that they need. Learn a piece of software and don't be discouraged if it doesn't work the first time because it takes several tries to understand the equipment and how it is helping you (Xandra, III - 139).

She also believes they should be open to new experiences, willing to learn new skills, and willing to change their thinking to become more of a facilitator of learning in the classroom and less of a director of learning in the classroom. She thinks teachers who begin integrating laptops into their instruction will be encouraged to continue as they become aware of the flexibility the laptops bring to meeting the needs of individual students.

**Darby: Perceptions:**

Darby makes the decisions as to how and when the laptops are used for instruction in her classes.

Well I was just looking for, always searching for ways that I could teach a concept with technology. Sometimes I would look up on the Internet ways to do things. Often I would just come up with something on my own. I mentioned this (to you) last time as well. Originally I was just looking for ways to use technology. I pretty quickly learned not to use technology just to use it. Use it because it enhances learning and don't use it if it doesn't

enhance learning (Darby, II – 267).

Darby has taught biology with laptops for six years. She says there was a steep learning curve in her first year as she started with no laptop experience, but the rate of change has slowed. Every lesson now has some form of integration and she doesn't envision any further integration of laptops into her teaching. Instead, she may be retooling lessons, substituting better labs, or planning better data gathering during experiments.

Darby is encouraged by the convenience the laptops bring to her teaching and to the students' learning. When discussing what helps change instructional practices, Darby stresses the importance of the availability of technology at the school and the standards set for technology use in her courses. She uses the International Baccalaureate Technology Aims as a guide and checks the Ontario Curriculum documents for what is appropriate. She tries to use as much technology as possible and to make the most of the opportunities the technology provides to her.

Darby identifies two challenges to the continuing changes in the laptop program: the availability of better professional development and the opportunity to share with other biology teachers in laptop programs.

How can this be done now? PD? I would say through teachers sharing how to integrate laptops into teaching. It has to be sharing sessions and my idea, which I'd love to see happen

in the future, would be to actually host a technology conference of some sort where teachers share (Darby, II – 39).

Darby doesn't know how she might differ from biology teachers not teaching in a laptop program.

I don't know. I differ in the fact that I am integrating technology, but it doesn't mean I'm covering different things. It doesn't mean that the students aren't coming out with the same end product, with the same knowledge base. *We're still covering the same curriculum* (Darby, III – 85).

She does believe that the laptops make teaching more convenient for her and better for the students and that all teachers should have access to a laptop while they are teaching.

She doesn't think teachers new to a laptop program need to use the laptops every day. She advises that those teachers check the curriculum for what's appropriate, use the laptops when they are worthwhile or enhance student learning, and showcase what technology can bring to the study of biology. She thinks teachers new to a laptop program will be encouraged by having the technology available in their labs and by the flexibility the laptops bring to their teaching.

Because they (the laptops) are there, because it's convenient. Obviously if they weren't right there in the classroom I wouldn't use them, but they are there. Initially I made an effort specifically to use them. Now I use them because it makes life easier (Darby, II – 259).

### **Audrey: Perceptions**

Audrey makes the decisions as to how and when the laptops are used for instruction in the classroom. While she mentions sharing PowerPoint presentations and tracking progress through a course with other teachers, she does not discuss sharing the decision-making for her classes and her students.

Six years ago when Audrey started teaching grade 11, Biology 11 was in the laptop program. She felt there was no expectation at that time that the laptops would be used for instruction.

I think when I started here six years ago, at that point, it was more for attendance or for posting homework sheets. At that point it wasn't even an expectation that a lot of our lectures would be on PowerPoint. To some extent when I started, it was easy to make the transition because I was used to teaching with chalk, talk, and overheads (Audrey, I – 155).

She says that it took her two years at the school to realize what the laptop program meant for students' learning. In that second year she began trying different things, such as helping the students prepare review notes of the course material they had on their laptops.

When discussing what helps them change their instructional practices, Adele stresses the importance of program evaluation and feed back. The school is just beginning a five-year study of science, technology and electronic media which will include a review of the laptop program.

Audrey identifies challenges to ongoing changes in the laptop program in terms of the limits of her own knowledge of technology, future upgrades of hardware and software. She recognizes the benefits of upgraded hardware, faster laptops, and is philosophical about the unintended complications of such upgrades. For example, their new laptops distort the image on the SMART Boards. Similarly she anticipates the benefits of using more probeware for tracking temperature and pH and having tablet laptops which would allow student work to be submitted, marked and returned electronically. She realizes she needs more types of knowledge, such as Prodesktop and GIS software, as well as more software, such as Cobweb, for teaching biology. She identifies a need for skills to vary her teaching style using the laptops and to better meet the learning needs of individual students and different classes.

Audrey did not mention if she had observed other biology teachers come into a laptop program, but feels her teaching would be different because her

laptop is on all the time. She uses the laptop during class time for delivering lessons, but also for attendance and checking marks.

She believes teachers new to using laptops for instruction should accept that it will be a struggle, but should persevere and increase their technical skills. She advises that their focus should be on the content of the course and using the different teaching approaches and learning styles the laptops allow, but warns that they should realize that laptops may not necessarily increase communication between students in a class.

As they integrate the laptops into instruction, Audrey feels they will be encouraged by the new ways they can organize their teaching even if individual class dynamics affect what can be done with the laptops. They may not enjoy their new role in managing student use of laptops during biology classes, and find laptops may not seem like a good idea for students who have difficulty focusing on their studies. While the courses will be more entertaining for the students, she believes the teachers will be encouraged to find that learning with laptops does not diminish their understanding of the concepts, and by the positive effects of the ease with which they and the students can research topics. Eventually they will realize how difficult it would be to go back to teaching without laptops, but in the meantime they should be encouraged by the knowledge that they can always go back to a previous approach to teaching a topic if teaching it with the laptops is not immediately successful.

## **Zoe: Perceptions**

There is a sense of substantial collegial input into pedagogic decisions at Zoe's school. She took over the laptop computer biology program developed by her department head three years ago. Furthermore, lessons in the laptop program are copyrighted by the school.

Over the years Zoe has introduced gradual changes to the course she inherited.

So in my first year, I was probably not as comfortable because I was teaching the course with his program, his teaching style, and I've adapted it more to my program with my teaching style which is a little different. I incorporate different things, different things than he does, like I'll incorporate a video, or a lecture that he wouldn't do (Zoe, III – 781).

At this time, she is the person who picks up ideas for her program and decides if and how she can apply those ideas in her teaching. The changes she has introduced reflect her strengths and interests as a teacher, and the addition of more labs, made possible by the employment of a lab technician to assist the science teachers.

Zoe realizes that the laptop program in biology is organized differently from most other subjects in the school. She is not sure how different even the chemistry and physics programs are from biology. No one tells the teachers how

to use the laptop in a subject area: the use varies with the comfort levels of the teachers and how the subject area fits with the use of laptops.

She is of the opinion that they have already reached full integration of the laptop computers into instruction. The grade 12 Biology students use the laptops every day and cannot cope in the course without them. This is in contrast to the grade 9 science course where the students could still function without the laptops. Her focus now is making sure the labs are updated and current and investigating other labs that they could include in the grade 12 course.

When discussing what helps them as teachers change their instructional practices, Zoe stresses the importance of the support provided at the school, the new, up-to-date technology made available to them, and the positive effect on student learning. The school's direction and commitment to the program is of paramount importance in supporting the implementation of innovation. She anticipates new hardware which is easier to use, such as SMART Boards controlled by touch instead of a keyboard, new laptops that enhance their teaching role by making teaching easier, and new software, also to become available, which will make it easier to manage their course databases. PD is an important form of support during the implementation of innovation: professional development is provided mainly at the school, mainly from the IT department, and from colleagues. For the students she believes the innovations associated with the laptop program have resulted in less student stress and as a result, greater enjoyment of biology. She also finds the output from the students has increased; they get the concepts more easily and more experiences are now

available to them. As a result the students find the courses more enjoyable which makes the courses easier to teach. She is encouraged because her teaching is more efficient. She lectures less, writes on the board less, never photocopies, has less marking after class and no office hours. Grade 12 students make appointments by email for a tutorial. Zoe concludes that biology courses in a laptop program are less labour intensive for students and teachers.

Zoe identifies challenges to ongoing innovations in the laptop program in terms of the nature of the two biology courses, the maturity of the students and the difficulty she finds in accessing appropriate PD. She finds different challenges in integrating laptop computers into grade 11 Biology and grade 12 Biology because of the different nature of the courses.

I think it would just be, just making sure, like any other teacher does, keeping our labs updated and current and always looking for other lab activities that we could include, that we have equipment for and supplies, and that also work within this context (Zoe, III – 143).

The maturity of the students in these courses also provides ongoing challenges. She hasn't found any conferences that provide the specific PD she has in mind, and she has concluded that her needs, and the needs of her colleagues in laptop programs, are quite unique.

I guess for me, what I would like is any information out there on known labs that work well in a laptop environment; just more material that I could incorporate easily. There's an abundance of material on labs out there. I know I can go to a textbook and get a lab from a textbook, but I guess it's anything with other teachers' input (Zoe, III – 689).

Zoe has not seen another biology teacher start the integration of laptops into their teaching, but she is of the opinion that an experienced biology teacher with some computer skills would be functioning reasonably well in about a year. She believes there are a number of ways her teaching is different from those teaching biology without a laptop program: less chalk and talk, no photocopying, less marking after class, and tutorials by appointment rather than office hours.

I definitely lecture less. I definitely write on the board less ... like never. If I told another teacher they'd be like what do you do in there? [laughter] Yes, I don't lecture and I don't write on the board [laughter] (Zoe, III – 163).

Yes, it's a totally different way of teaching, I guess, when I think of it that way. But I've never really thought of this like this (Zoe, III – 167).

Yes, I don't photocopy anything. I don't collect papers to mark, it's all emailed. Also with grade 12s, I don't have office hours because the students can email anytime and let me know their spare and we can set up an appointment so they can get one-on-one attention (Zoe, III – 177).

Like Keith, Zoe believes teachers coming into a laptop program should work from their strengths: preparing new teaching materials on their favourite topics, and converting key labs so they can be posted online.

I would say, I would start with the key labs. I would say over the course of the school year you can pull out five to ten labs and that would be your starting point. Get those all written out online and figure out where you can incorporate them (Zoe, III – 184).

During the transition to teaching with laptops, she would advise teachers to vary traditional labs they have used in the past with a number of labs newly designed for student-centred learning during the transition process.

Within those three labs, three or four labs they would, I think, get a feel for the flexibility. The students could

technically be on lab one, another on lab two and another on lab three, and then they could be working in a different spot and that when you can see the pace, the one-on-one time (Zoe, III – 369).

The teachers will be encouraged during the transition by the fact that they can provide more and better learning experiences for the students, and the students' output will increase as will their marks in the course. In the laptop program, the combination of these factors results in a less stressful approach to teaching biology.

### **Ross: Perceptions**

Ross considers that the onus is on him and the other teachers to implement the laptop program, and he makes the decisions as to how and when the laptops are used in his instruction. He mentions the collegial support available in an instructional context, the framework provided for the teachers by the administration and the support provided to the teachers by the IT department when management decisions are being implemented.

However, he prefers not to use the laptops for teaching. He feels few things can be done better on the laptops unless an experiment is dangerous or extremely costly. He prefers traditional science experiments or demonstrations. Occasionally he assigns a handwritten assignment to maintain student skills in

that area. He prints out hardcopies of student homework assignments and collects assignments and tests on paper.

Ross mentioned several times that he did not envision using the laptops, the vision was given to him. He had always used computers and the laptops seemed a logical progression. He has been presented over the years with many examples of what others had been doing with the laptops. He observes that the laptops are used more in science than in some other subject areas and are used differently in other sciences. For example, probes are used more often in physics than in grade 11 Biology. However the approach to implementing innovations was collegial, consensual in nature and given the teachers' busy schedules the laptops make teaching more efficient and effective. They now seem indispensable.

Ross describes a pattern whereby the teachers can change their instructional strategies at their own pace. Three years ago every teacher was to have a webpage daybook for every course. The school had tried this as a pilot project with feedback the previous year, so by the time it was to be implemented many teachers, like him, were already doing it. Every year he tries to implement one more thing. This year it was online grades.

Up until this year, teachers had been free to keep their grades in whatever way they chose: it might have been in a binder, on a spreadsheet, or on a marks manager program. Well, this year the school made the decision to purchase an integrated

software package, and I guess for the first time in twenty years, we were told this is what you're going to keep your marks on. It worked reasonably well [laughter]. People are going to have personal preferences, and there have been some growing pains, and the software's not all it's cracked up to be. For some of them it is probably the first spreadsheet they've ever used for marks, so it's fantastic. They can't believe they never did this before. For others, it's a step back from what they may have been using last year or the year before (Ross, III – 51).

When discussing what helps them as teachers implement innovations in their instructional practices, Ross stresses the importance of the support provided at the school and the positive effect of the laptops on his program and his approach to teaching science. He feels that support from the administration assists the implementation of the innovations as does IT support of the laptop program. In his mind, support also includes financial support of the laptop program and the science equipment to support the use of the laptops in the laboratories. Personally he finds the laptops are more useful and they can do more things with them than they could do with desktops in the past. In addition, in the laptop program, he feels he doesn't have to know everything.

Ross identifies challenges to ongoing innovations in the laptop program in terms of his own teaching and student learning. The challenges, he feels, will be

to find ways to use the laptops that make his teaching even more efficient and the students' learning more effective.

He doesn't know how he might be different from biology teachers not in a laptop program. His laptop is on all the time he is in the classroom and he is of the opinion that biology teachers not in a laptop program should have a personal laptop they can use while they are teaching. He believes laptop programs provide students with better information about the requirements of the course.

He would advise biology teachers coming into a laptop program to increase their technical skills knowing that the time they spend in one year will save time in the next year.

Once you learn the technology, once you learn the applications, it becomes easier. You've got to learn how to use the thing. It's frustrating for the first few hours you're using it, I suppose, but you've got to work out how to run the thing. It's useful technology (Ross, III – 149).

He also believes these teachers should understand that it is not necessary to use the laptops every day. He thinks the teachers will be encouraged to continue as they realize their classroom teaching is more efficient and effective.

### **Samantha: Perceptions**

The laptop program was partially implemented in the Grade 11 Biology course when Samantha was hired. She has continued with a pattern of ongoing innovation and implementation. It is her decision as to how and where laptops are used in her classroom.

Everything I've incorporated, because I was not doing it all at once, I was doing it in small steps so I knew I had a little more control over what the students are producing or giving to me and how they are using their laptops in class (Samantha, I – 163).

As Samantha notes, she was hired to teach at a laptop school where the school and the parents had made a considerable commitment to the laptop program. She is completing her second year of teaching and her second year of a laptop program. She feels it takes one to two years to get a sense of comfort with the hardware and software. Time constraints from her other duties at the school limit the amount of time she can spend on changing her instructional strategies, but implementing innovations is still happening and new ideas are being integrated into her laptop program.

I'm actually happy at the rate I've been going. It could be going a little faster and maybe I could be using it a bit more, but at the same time, with other things in the curriculum that I have to touch

base on, I would have to do a bit more research, maybe during the summer, to know how I could cover that instead of taking time away from other topics (Samantha, I – 163).

She estimates it will require one or two more years to reach the level of integration she wants, but this depends on the PD support available to her.

When discussing what helps them as teachers implement innovation in their instructional practices, Samantha stresses the importance of the support provided by the school and feedback from students. She notes that every August they have five days of PD which includes time to assist them with technology. In addition, they have specific support as science teachers with the provision of sensors and programs appropriate for their teaching.

Samantha also finds a conference, perhaps every one to three months, promotes the implementation of innovations, especially when combined with reminders from colleagues of what can be done with the laptops. She finds a little discomfort with what they are currently doing with the laptops boosts the teachers' progress. She mentions inviting experts to the school to work with science teachers, and students, on technology they might integrate into the courses. She values opportunities to share new knowledge and technology skills with colleagues at monthly staff meetings and values hearing what others are doing through discussions and networking. Positive feedback from students now attending post-secondary institutions also encourages her to integrate the laptop computers into her courses and to continue changing her teaching approaches.

Samantha identifies challenges to ongoing innovation in the laptop program in terms of technology which is prone to failure and time consuming to use, teaching materials which must be double-checked every year before use, finding appropriate PD and time constraints. The laptops are fragile, breakdowns disrupt almost every class and she estimates that 5 percent of the students' laptops are not available at any given time. Marking and returning student work remains a tedious process although she is hopeful that anticipated changes in hardware will allow this to be done electronically. She finds she must double-check teaching materials before use to insure that websites and links are still active. This is time consuming considering her other duties at the school and sometimes the school's firewall programs make this process even more difficult for her. She finds she needs a block of time, such as in the summer, to make significant progress in integrating laptops into her instruction. Finding PD appropriate to her requirements is also a challenge.

Samantha believes that she may be different from other biology teachers in her willingness to adapt to different programs and her open minded approach to teaching with laptops. As a result, she is of the opinion that there is less teaching from the textbook in her program and fewer teacher-centred chalk and talk lessons.

She would advise biology teachers new to a laptop program to be persistent, but not to feel that they had to use laptops in every lesson. Samantha thinks teachers new to using laptops for instruction will be encouraged by the versatility of this innovation. She notes laptops are used differently by different

teachers and by teachers in different subjects. Integrating laptops into instruction is an important innovation they can sustain through the years, through changes in curriculum and through changes in student learning needs.

### **Richard: Perceptions**

Richard makes the decisions as to how and where the laptops are used in his classroom. In fact, he even wonders how other teachers in laptop programs are covering the course with the technology.

He describes the process of integrating the laptop computers into his instruction as evolutionary in nature. He found a pretty seamless interface between the networked desktop program they had in place and the introduction of the laptop computer program. He manages ongoing innovation by renewing his instruction on a unit by unit basis. As far as he is concerned implementing innovation is still happening. As he says, technology changes so rapidly, as a teacher he has to be flexible. He cannot know where change will occur next.

I think part of the rationale for that answer is simply that technology changes so rapidly. I mean we learn about something which happened, and I think technology is already at the next step (Richard, II – 13).

Richard describes the amount of energy he has expended to integrate laptops into his instructional practices as a 'J' curve. He feels his instruction

changed dramatically until his fourth year in the laptop program and his instruction has now had two to three years to evolve more slowly toward the practices he wanted to have in place.

Richard identifies a number of incentives for an ongoing laptop program: convenience for the teacher, better teaching, better student learning, and better results. He found a course in computer moderated conferencing (CMC) which he took as part of his master's degree took his learning to a new level. He is adjusting to more learning styles, using more varied instructional strategies, and his course is more entertaining for the students. As a teacher, he is better prepared, and he finds that it is easier to provide a good learning experience for the students. The students, in turn, encourage him to persevere in the laptop program. Richard sees the students as agents of change, noting that they show him how to do some "amazing stuff".

When discussing what helps them as teachers innovate their instructional practices, Richard stresses the importance of support provided at the school which he describes as phenomenal. This support of innovation is provided by the IT committee and by his professional colleagues.

I think our IT department is excellent. They see your needs and they are there to support you. They've got great, great guys at the help desk. They are amazing. If there is any issue they will solve it. You worry about the teaching, we'll worry about the technical stuff. So that support has been tremendous.

I mean really if you find something you like, you bring it to them and they will do the rest of the work and you just worry about teaching. Or any issues, any problems, anything, they will help out or they will find the answer (Richard, II – 141).

Yes, professional colleagues. You learn a lot from your colleagues. You see that they do something, or they'll present something at a PD session, and you go, OK, let's get more information on that (Richard, II – 161).

Lack of time is an ongoing challenge to pedagogic innovation. Richard is finding the time required is not decreasing over the years as more school functions come online. He also identifies challenges to ongoing innovation in the laptop program in terms of future upgrades of hardware and software, but he recognizes the need for more speed and efficiency as the teachers require more capacity during class time if they are to run interactive programs with their classes. The school's system can get clogged and slow down when classes are in session. He also notes that while they might consider getting more lab probes, it's not a priority for him in the immediate future. He would like to see a study of first year undergraduates studying biology. How much technology are they using? Are they better prepared for the transition to university?

Richard has seen other biology teachers make the transition to teaching with laptops. He feels he differs from biology teachers not in laptop programs: he

is more current, more enthusiastic, and his teaching is more effective and entertaining. His instructional program is more varied and he is meeting more student learning styles.

He advises teachers who are integrating laptops into their instruction to be patient, keep their perspective and not to become discouraged by the process. They should be willing to learn new things. He encourages them to develop new teaching materials, to be willing to alter their role in the classroom and be open to new teaching experiences.

I would say you have to be patient. Don't try to cram.

Technology is just a tool, it's just another teaching tool.

It is not the whole picture. The students still need to go into the hands-on e-type learning. You still need to engage them in the classroom face-to-face, and the fact that we can do both, face-to-face and online conferencing, just really adds to the whole picture. Make sure you find good websites, constantly improve your knowledge of technology and, through PD different tools for use whether it's Excel or whether it's PowerPoint, learn that. A good thing would be to learn how to use PowerPoint properly. Effective use of PowerPoint is useful. Don't be worried, a few pictures, a few words, and that's a good way of getting your message across. I would really encourage them to further their education, whether it is a master's degree

or whatever. Take some courses that use CMC conferencing so you can experience what it's really about and how you can use it (Richard, III – 101).

Richard believes biology teachers new to a laptop program will be encouraged by the resources that they can access and the sense that they are becoming a better teacher as their role changes toward being a facilitator of student learning in the classroom. Richard also believes teachers are encouraged to continue in a laptop program as the learning conditions for students improve, as they perceive the benefits of a 24/7 learning environment, and as they realize students are becoming better critical thinkers with better test results.

### **Kenneth: Perceptions**

Kenneth describes a pattern of collegial input being available for instructional decisions in the laptop program and a pattern of input from the IT department and the administration when management decisions on software generic to all the teachers is being implemented. He mentioned nothing to indicate others make decisions as to how and when the laptops are used in his courses.

The laptop program is a school directive: the school assigns a high priority to this program and Kenneth is of the opinion that there is no turning back since their constituency demands this program and their competition has this program.

Moreover, despite any flaws, he believes the laptop program works and has even more potential for the future. Kenneth has been teaching in the laptop program since its inception eight years ago. He describes the rate of innovation in the laptop program he experienced as high, and says it has remained high as marks reporting, software for attendance, and email have come online. However, he notes the rate of innovation for instructional purposes is now starting to moderate.

Kenneth envisioned the laptops as a tool which would allow students to learn in a more independent, less teacher-directed environment.

I had envisioned and I think I tried to use the laptops more, so that we were all working on our laptops and we were all learning together. I had this vision that they would be doing independent learning and bringing up some of their own discoveries and discussions on particular topics. That sounds great in theory, but it doesn't work in practice, of course. It probably would have with the AP class I was talking about, but before long I sort of moved back to a) not giving them totally unrestricted access to their laptops and b) being a little more discriminating about how I used the laptops (Kenneth, I – 185).

With experience he found his vision was not realistic, so he feels the laptops are still being used below their potential and he grapples with how to use them more effectively. However, he believes they are using the laptops in a

more sophisticated manner over the years and that, as teachers, they are moving in the right direction. He is convinced that the introduction of the laptop program was good for his professional timeline, as the program showed him a whole new way to teach, and invigorated his career.

Support for the laptop program from the IT department is important to Kenneth in a number of ways. This department troubleshoots programs for teachers, solves problems with downloads, and services student needs. He has received a number of peripherals which improve his ability to teach with the laptops, for example: a ceiling mounted projector aligned with the screen with amplifiers and speakers in the ceiling; and, a black-out curtain installed between the teaching area and the lab with its greenhouse windows. When the laptop program was first introduced, the school paid teachers to attend additional professional development during the summer. Now, eight years later, the IT department provides scheduled professional development for the teachers and there are funds available for professional development for individual teachers.

Kenneth identifies challenges to ongoing innovations in the laptop program in terms of his own approach to technology, future upgrades of hardware and software, time constraints experienced by science teachers and the fact that the program is designed for teenagers. Teaching with laptops, he finds, is not necessarily a seamless process at this time.

I try to be as efficient as I can about using the laptop in front of the class, but invariably there is time wasted waiting for links to

open up, or there may be a problem with the network, or my computer cable is not pushed in all the way, or whatever. So it's a bit of a double-edged sword in terms of the laptops saving time and making instruction quicker because there is that downtime (Kenneth, II – 187).

As a classroom teacher, Kenneth says he finds it challenging to anticipate what new innovations he will be facing. He relies on the IT staff and other colleagues to identify upcoming priorities. He recognizes that hardware improvements such as bigger servers would provide speed and increased capacity for of teaching with laptop computers. Similarly, he recognizes wireless access would be an important improvement allowing the laptops to be used in their labs as well as the teaching areas. He would welcome some improvement to the software program used for class databases, as it would make it easier to update and improve instructional material. He also identified the benefits of improvements in software for teaching biology. In his case he mentioned a more sophisticated program for constructing crosswords. Kenneth favours professional development time being allotted to learning how to use the laptops for instruction in the classroom. He recognizes that the technology associated with teaching in a laptop program requires more and more teacher time and sees the provision of a lab technician to assist the science teachers to prepare labs as a way to provide that time. The final challenge to ongoing innovation in the laptop program is that, realistically speaking, the program must meet the needs

of teenagers and take into account their level of maturity and the limits to their attention spans.

Kenneth believes he differs from biology teachers not in laptop programs because he is willing to learn alongside students and from students. He advises that teachers going into laptop programs require patience, perspective, and should not become discouraged because they will find teaching with laptops is a happier and more fulfilling teaching experience. He believes teachers going into laptop programs should be willing to develop new teaching materials and use more real world experiences in their biology courses.

**Question Two: How do senior grade biology teachers perceive and introduce new teaching approaches when integrating laptop computers into high school biology programs?**

For the purposes of this study the term “teaching approaches” has been used to describe a habitual or customary course of action, or way of doing something. The teachers discussed many alterations they had made in teaching practices as a result of integrating laptops into their instruction. The teaching approaches they discussed affected: class preparation, handouts, notebooks, lab activities, active learning, homework, projects, assessment, communications, and, in some cases, backup plans in the event that the laptops could not be used.

### **Adele: New Teaching Approaches**

Adele has concluded that she talks less in class and uses the Socratic method less than before the introduction of the laptop program. On the other hand, she notes these differences in teaching approaches may be due to fact that she has also become a more experienced teacher while she has been integrating the laptops into her instruction. She describes the use of the laptops as a supplement to what she was already doing in the classroom. Her original vision that the laptops should be used 100 per cent of the time has been amended with time and she has cut back on laptop use in the classroom as she found some learning took three times as long with laptops.

She now prepares PowerPoint presentations which can be used as handouts and which students can use to make their own notes. She may develop notes with them during class or she may have them complete their notes for homework. Students do not always use their laptops for taking notes in class. She finds that about half of the students write their notes by hand and about half use their laptops to type their notes, observing that their choice may depend on how well they type.

The laptop program allows her to include more lab activities in her program. There are fewer recipe-oriented student labs and there is more opportunity to use simulations for topics such as dissection. However, the teachers in the school find students want to do the dissections since the teachers believe that hands-on lab activities are important to student learning, the use of

simulations is not extensive. Adele notes that even when student labs have not changed, with laptops there is still the possibility of more creative follow-up, including: a more open-ended format; and, different follow-up questions. Often, she notes, using the laptops and the peripheral technology available for use with the laptops does not speed up labs.

As long as they know how to graph using the computer it's just as easy to use a thermometer as opposed to a temperature probe. So the big thing seems to be time. It just seems to take so much more time, not just in the development, but in actually conducting the lab. It takes more time when using the technology, in some cases (Adele, I - 179).

There had been a recent school wide initiative on inquiry-based learning. Unfortunately, science examples in this professional development initiative were focused on the elementary level, rather than the secondary level. Lacking examples on inquiry-based learning in high school science, the teachers experienced some difficulty deciding how inquiry learning should be implemented in their courses. A search on the Internet, while not informative, reassured them that the changes they were introducing were on the right track.

The laptop program had made homework assignments more meaningful. and the students' ability to research current areas in biology allowed more open ended homework assignments.

So I think as opposed to them just sitting there and me saying read Chapter Three and answer questions 1, 3 and 5, I can just give them a topic and have them research it. So more of an application: for an example when we talk about the endocrine system and we talk about reproductive hormones, I say look up HRT, tell me about HRT, it is in the news a lot. I want you to tell me how it relates to what we've been talking about. So I I kind of let them go with it. It is less prescribed and more open ended. The next class I say, tell me something you found out that you didn't know, that you really found interesting, and tell me how it relates to what we were talking about (Adele, III - 257).

She does this every second lesson or so, believing that what they are learning in biology is more topical and of more interest to them. Similarly the laptop program allows for more independent learning. A large summative project was required, usually at the end of each year. But the school's timing for these summative projects has changed from year to year which meant the topic of the projects has to be changed. The flexibility the laptops brought to planning these projects made it easier for the teachers to accommodate the fluctuating dates.

She has not changed her approach to assessment with the integration of laptops. She finds assessment is not efficient on the laptops and that paper and pencil quizzes are faster than quizzes on the laptops.

With email, Adele finds there is now more communications with students she teaches and with their parents. She is not aware of students communicating with students in other schools about biology. She has observed that whether there is increased communication between students in study groups depends on the individual students involved, and notes that electronic communication may not have increased communication between students, just replaced face-to-face communication.

Adele found that she had to be ready for those times when the school's technology does not work, such as during power outages. She uses as alternative approaches, the teaching approaches she would have been using before the laptop program was introduced, but with one difference. The increased communication capability of the laptops makes it easier to deal with the instructional after-effects of such power outages.

### **Keith: New Teaching Approaches**

Keith begins to discuss changes in teaching approaches by noting that prior to the laptop program he rarely chose to use the desktops to teach science. He lists changes in teaching approaches, including: media and other sources which result in more depth to the course; more challenges for the students; and, a more immediate process for answering student questions. He finds a student can Google the answer to a question and he can adjust the learning in the classroom right away.

Now, Keith provides handouts in paper and electronic form prior to

classes. The outlines he distributes are used as a prompt for learning during classes and for preparing notes. Keith states that note taking was never a big feature of his instruction, but there is far less note taking in his classes with the laptop program since information is always available electronically.

They couldn't lose anything anymore [laughter]. I mean you can't lose the notes, the binder can't get stolen. So I was thinking, there is no longer the excuse that I don't have that, or I can't get access to that. I can give it to them in paper form, I have that capability. I can give it to them in electronic form and they can access it on their desktops at home, from anywhere around the world on their laptops, and on their laptops around the school. If our system goes down I can give them a piece of paper and back it up in electronic form. No excuses, you know. I think as a teacher I was getting bored with "I don't have it", or "I lost it, sorry sir" (Keith, II – 123).

Biology, he notes, is a messy subject to teach. It is important to provide a program with hands-on experience and deal with students' expectations that results should be obtained the first time an experiment is carried out. It is difficult to convey in high school science courses that an experiment may need to be done ten times, and to give students an experience more comparable to a practicing scientist. Keith remembers designing labs earlier in the laptop

program which he later decided were above the level of high school students and discarding them. However the laptop program has successfully extended the students' hands-on experience in the lab. One example, he cites, is an online simulation called Fish Farm which requires a biologist to determine the best environment for raising a species of fish. Students work with data, follow a testing process to determine optimum factors, and write a report. Keith feels this is a successful simulation experience which teaches students how to use vast amounts of data on a number of parameters such as oxygen concentration, flow rates, and the availability of proteins. The simulation gives the students the experience of conducting repetitive tests to determine best results, (make the most money in this simulation), without requiring them to do vast amounts of busy work. Since it gives the students a sense of the richness of this type of experience, he would like to provide more of this type of simulation. This is not teacher-centred learning.

Keith appreciates the active learning opportunities the laptops provide for students. He noted the benefits of having students post their progress for their peers and for him during independent study. In addition, the students may be required to prepare a half hour presentation which involves posting the topic, the resources to be used, a rough draft and the final project. The laptops make it easy for him to ascertain if different stages of the study have been completed and submitted on time. Since he becomes just one of the observers of the independent study process, he finds it easier to involve the entire class in other students' work.

Keith does not use the laptops to adjust course content for students of varying abilities, but he does find it easier to cue students' prior knowledge on concepts they had studied earlier in the year or in previous years. Depending on the readiness of the students, he reorganizes and repackages his instructional materials. He believes his lessons are less rigid, more relevant to the students and he does find it easier in the laptop program to help individual students who have missed class time or to provide enrichment. In addition to providing enrichment, he finds he is able to get the students to think at a higher-level. He finds their responses are more thoughtful which makes it easier to clarify concepts.

Students tend, in part, to form informal groups with others they feel comfortable working with. While groups are not always formed this way he has found such groups can be very efficient. When he tried to create electronic teams and to introduce a study-buddy process of four students, he found these practices were not that successful, and the groups operated quite differently from the groups the students self-selected.

The teachers can count the number of visits to the class website. Keith finds good students visit the website more often, they read more, and spend time browsing the course material and the Internet sites he provides. He believes that students spend more time out of class working on the course than before the laptop program was introduced, and that for some students, day-to-day work replaces cramming for tests.

Keith now provides many links for enrichment, but it is not his practice to test on this enrichment material. His testing remains straightforward and involves pen and paper tests. Keith knows of an effort to use the laptops for multiple choice type testing.

I don't feel comfortable yet testing the biology curriculum electronically. I mean I've got that capability, I could use the tools that exist. I just don't feel I want to (Keith, II – 437).

One thing he appreciates in the laptop program is that he can post work completed in previous years as a guide to the students and to show how the work was evaluated. Another benefit for assessment in the laptop program is that he can be very firm about deadlines. He can request that homework, like progress on independent study projects, be posted on the class site by a specific hour. It is now very clear if the assignment was done and whether it was submitted to the class site on time.

Although students use laptops in unproductive ways such as gaming and other distractions, Keith believes the laptops have also resulted in more communication and more immediate communication within the school community. As an example, he notes that a student queried one of the objectives posted for a test. He agreed that the objective could be removed and all the students received updated objectives immediately. Similarly he can post important clarifications or expand a point of discussion after a class has finished.

### **Xandra: New Teaching Approaches**

Xandra has changed her teaching approaches although she still uses a combination of Socratic teaching and active learning approaches using the laptops. Nothing comes to her mind as being more effective than what she was doing before the laptop program.

Xandra posts skeletal notes for the students, unit by unit, and uses them as handouts. She teaches by projecting skeletal notes consisting of headings, subheadings, and drawings which she can annotate, onto a SMART Board. She has observed that it is easier for the students to annotate the drawings by hand than with the draw function of the Word software. She can include clips, such as a clip on muscle contraction, or an animation of a biological process, which result in better student comprehension of particular concepts. She appreciates that she can then save a version of the lesson for her records and that the information given to the students during class is available to them on Blackboard.

Despite the organization built into instructing in a laptop program, she perceives that she still has a role ensuring that students have unit summaries and notebooks.

The super organized, they're now super-duper-organized. It (the laptop program) enhances their organization, but even if they didn't have a laptop they would find another way. They'd find sticky notes, highlighters, there would be another way.

I think the group in the middle does benefit. It definitely helps solidify their organization, that structure that I give them when I use the laptops. So probably the middle group.

Those stragglers who could benefit from more organization and are not quite there yet? Definitely not. They're just as disorganized (Xandra, I – 461).

Xandra has bought an updated version of the biotech equipment she used at the board high school before she went overseas. She describes using Vernier probes for the students to collect data during their labs, including: temperature; pH; and, pressure. She finds using the probes with the laptops is time effective since students can use two or three probes to collect data at the same time and the data are accurate. She thinks these labs, using laptops and peripherals are more interesting for the students, and that students who plan to study science in post-secondary institutions are positive that they are seeing such equipment ahead of time. The science department uses a series of university co-op students on internships to assist with lab activities.

In the laptop program she has projected rubrics and exemplars simultaneously, allowing the students to solidify what they need to know about an assignment, how to proceed with an assignment, or how to plan their own lab reports. She finds showing exemplars at the beginning of the year, and at the mid point in the course, has been an effective instructional strategy. She obtains

permission from previous students to display their work with the comments she made when she marked it. She has also found it effective to put up a project, or a completed lab report, with the rubric, so she and the class mark it together.

Xandra has used the laptops for multiple choice tests but she doesn't enjoy using this type of assessment. Although students could download tests and complete them on their laptops, she finds students don't seem to like this type of testing either, preferring to scribble on paper tests as they think.

She has found that with the laptops the students take less time to find information than they would using books and journals, but that their search may not have been carried out effectively. Although the librarian teaches research skills, Xandra believes she has a role to play in how the students search for biology information. She directs them to databases for which the school has licences or to websites when they are researching for projects and assignments.

She still plans for some group learning in the laptop program and has used discussion boards where comments are posted and groups of three or four students dialogue with one another.

### **Darby: New Teaching Approaches**

In biology classes Darby works from PowerPoint presentations, perhaps twelve slides, with headings, pictures and the homework assignment filled in. She writes notes on the SMART Board as she teaches and the students type notes on a copy of the PowerPoint which they have downloaded. Having the diagrams on the PowerPoint presentations avoids errors between what the

students were supposed to observe and what they saw. Students also have the advantage of seeing what is happening during the class and what is going to happen before the end of the class.

Not that many teachers teach the way I do with the PowerPoint where I put up a blank PowerPoint using the SMART Board ... but the students have always said they like it. I've asked multiple times and they say they like it. I think it's because they wouldn't like it if I just put the notes up and they had to copy them out even if it was on their computers. I like the interaction where, if we're brainstorming, I can still write down their ideas. It's not something already written out for them (Darby, II – 415).

Darby thinks the students like the PowerPoint approach to lessons since it is interactive, it organizes them and their notebooks, and takes less time than writing out notes in class.

Lab probes are used in field studies and during lab activities for real time data collection, proving to students the graphs in the text really happen. Students still need graphing skills, and data can be collected without using the laptops, but Darby finds it is easier to use probes with the laptop computers and leaves more time to analyze what is being graphed.

Darby is certain that using PowerPoint lessons makes it easier for students who have been ill, or missed classes for a school activity, to catch up

the work that they missed and helps the students avoid many of the second generation mistakes inherent in the catch up process.

### **Audrey: New Teaching Approaches**

Audrey finds there is now more time to deal with content in Biology 12 since the students are skilled in the use of laptops. Since the grade 12s dislike too many PowerPoint presentations, she is not planning to increase the number of PowerPoint presentations she now uses. She has concerns that PowerPoint presentations focus the students on words and they miss a lot of what they should be learning in biology. In response to this concern, she adds references for drawings in their text on the PowerPoint presentations and she has learned to use SMART Boards and other tools so that she can insert photos, animations and illustrations from the Internet as she prepares lessons.

Compared to her experience prior to the laptop program, she found the students did not have drawings in notes they made on their laptops. She became concerned that although they had links to animations and illustrations in their notes they weren't using them, and they lacked drawings they were to do by hand. Now, whether they use laptops for their notes, or not, may be decided on the number of drawings in the lesson. Audrey doubts that the laptops have improved the students' organization. She still deals with students who cannot organize their notebooks to those students who could organize anything.

With Excel she has been able to introduce mathematics and graphing into biology much more than she could before the laptop program. She particularly

appreciates being able to generate a graph with the students when they are studying population growth.

In the past few years she has introduced simulations online to augment lab experiences on running a gel and action potentials. Generally she has found the results of the simulations are disappointing. The simulations on action potentials are good provided students have seen a nerve lab. If the students have not had that experience, she felt it seemed more like a computer game to them and did not have the same impact. Similarly, if students have not had the experience of running a gel, cutting the DNA at the same sites and looking for fingerprints in three sequences, she found most could not visualize the online simulation. On the other hand, a link to a histology site where they could point and click to identify the types of cells and platelets they were seeing on a blood smear through their microscopes was very successful. She was impressed with the quality of the lab reports they completed in this instance.

Audrey notes that they had been through a number of PD opportunities to encourage active learning. In the research phase all the teachers learned about teaching the students how to find pertinent information on the Internet. She found despite their expertise with mainstream media, students didn't have the same level of capability for researching information. Once they had been taught those skills, she found it easier to meet individual student needs or the needs of groups of students in the laptop program. She mentioned specifically: students who will not choose to study maths and science at the post-secondary level, students whose multiple intelligences are not a good match for mainstream

biology courses and are not being reached in traditional lessons, and enrichment for students who are not being challenged. She finds the laptops can enhance learning at every level.

Despite these advantages, she learned that it is more challenging to keep the students focused during collaborative work in the laptop program.

My favourite previous strategy was to unplug their Internet  
(Audrey, I – 301).

Yes, a few years ago, before the wireless, it was one of my favourite things to walk around and unplug (the Internet cable) so that if they were working on some co-operative project together, a lab report or something like that, I could be sure they were not distracted (Audrey, I – 305).

Since the school went wireless in most areas two or three years ago. It is now more difficult to ensure the students are on task.

She now uses their new skills to plan more interesting homework assignments on topics such as hormones. She plans the assignments, they do the research. Or she may ask them to research a word, find a diagram and put it in their notes, or take a quiz. She finds this type of assignment increases student interest in the course and the students learn that everyone has to look things up. She does have a concern about the fact that the laptops feed a student

assumption that they can multitask. Some can, many can't, yet homework may be completed amid the distractions provided by a laptop, telephone and television, resulting in a lack of focus on the work being completed.

Audrey has found that the laptops provide a welcome degree of accountability during shared projects as it is easy to track each student's contribution. One year, the school scheduled the grade 12 summative projects for just before the end of year exams. The teachers decided to change the topic they had used in the past and have the students prepare a study guide for the final exams: thirty topics, one per student, with a view to everyone sharing the study guide for their topic with the rest of the class. All the students were active participants in this project since they had their own topic. Her role was to verify the usefulness of each study guide before it was distributed for the other students to use.

Audrey prints any work submitted electronically and marks the paper copy. She is interested in the idea of tablet laptops where work can be submitted, marked and returned to the student electronically. She is unsure of the cost of these tablet laptops or whether they will be introduced at the school in the future. She observes how students write answers by hand when they are used to working on laptops. The organization of their written answers appears less linear than she would expect, with more evidence of the equivalent of cut and paste, attempts at rewrites, and having to actually start over again.

### **Zoe: New Teaching Approaches**

As a result of the laptop program, Zoe is now teaching one-on-one in her classes. She may end up saying the same thing to each student, but says she has their attention and they are focused. Or, she may choose to do a quick lecture and then concentrate on the one third to one half of the students who might have difficulty with the topic. She makes PowerPoint presentations which she can then use from year to year. She finds this is useful, efficient and less repetitious for her since she is not writing on the blackboard. She plans PowerPoint presentations so that students have to develop part of their learning for themselves. She considers it would be ineffective to prepare everything for them.

All documents and assignments are on Word and posted on Blackboard. Since students don't need time to develop notes, the pace of the class is quicker. As students have the information to refer to at all times and nothing can be lost, the students can apply concepts and develop higher-level thinking skills. Next year she understands the students will have One Note and they will be able to take a file and build on previous notes to produce an electronic binder. The students would then have the option of printing out the binder before tests and exams depending on their learning preferences. She thinks most students do not print out notes, but knows some do.

The course is a series of student-directed labs which students can work through independently or with another student. Students use their own laptop and a series of labs with supplies prepared for them and available in the lab.

This is the third year that they have had a lab technician in the science department and she finds it makes a massive difference. With this assistance, she has been able to add more labs to the program.

During classes she works as a facilitator with each student and they have a due date for completing each lab. She finds this pattern of instruction is effective with students in grade 12, but is not always appropriate for younger students. This is an efficient model for enrichment, for dealing with absent students, and if a student they have been collaborating with is absent.

If she is using a group activity, such as a jigsaw, she can prepare information and post it on the website or provide supplies for each group. She finds the laptop program makes it easier to provide materials for different groups to work with, and there is no photocopying which saves her time and paper.

Zoe identifies homework as one of the key changes in the laptop program. She can post homework, email the class with homework reminders, or anything else she forgot to say in class. Since parents have access to the course website, she can copy her emails to parents and student advisors if a student has work that needs to be caught up.

The nature of the homework has changed since she can design more interesting assignments for them. Rather than have students read the text and answer questions, she can assign a greater variety of tasks and create more goal oriented assignments for them.

Zoe monitors student progress in grade 12 from day to day. When students are ready to have their work assessed at the end of a lab, they ask for

an interview. They explain their lab to her orally plus she looks at their lab work online. Her laptop has tablet and stylus capability so she can mark an electronic copy of their work and email it back to them. As a result of this process, she is marking more during class time and less outside the classroom.

If there is an assignment due that day, their assignment must be in her inbox before they leave the classroom. She checks to make sure the assignment is there and that it is satisfactory. If the work is not satisfactory, she sends an email right away and the student is in detention that afternoon. This process insures work is completed and submitted in a timely manner.

Scheduled paper and pencil tests throughout the year establish the minimum pace for completion of labs and student progress through the course. There are two secure pencil and paper exams each year scheduled by the school.

Since power losses during school hours have not been a problem, Zoe has no backup plans in the event classes are disrupted. She believes that the laptop program will make it easier to recover from such an event should it ever occur.

### **Ross: New Teaching Approaches**

Ross describes taking less time to prepare for individual classes in the laptop program and finds there is more time to prepare work for the course. He prepares PowerPoint notes explaining, for example, that teaching Mendel's Second Law without the PowerPoint is less efficient and takes more class time to

explain. He can now have a more interactive discussion with the students because the PowerPoint is online, they don't have to take notes and they can print the lesson after class if they wish. Some students choose to annotate the PowerPoint on their laptop, but he finds with less note taking, classes tend to be more truly Socratic than before the laptop program.

Lab work is done in a lab adjoining the classroom. He does not use the laptops during biology labs although he knows another biology teacher does use the laptops for one series of experiments.

Yes, I think in the early stages I tried to do a little more on the computer than I think the computer was capable of doing. Doing simulations where there really was no reason to simulate something you can demonstrate better or they can do better (Ross, I – 477).

Ross continues to use traditional science experiments carried out by the students, or demonstrations. At one point he was using simulations but decided they were not necessary for student learning and cut back on their use.

I guess the bottom line is I'm not really going out of my way to find applications. If I stumble across one and I think its better, I'll use it, but I'm not trying to reinvent the wheel. Again, we had a fabulous unit a month ago, dissection. I'm not going to stop

using dissection (Ross, I – 539).

The students use digital cameras in place of detailed drawings in dissection labs and a digital microscope, which augments their work with optical microscopes. He would use the laptops if he had appropriate software for the students and he thought the software provided better student learning. Some software he has seen support labs he would not choose to do anyway and in other labs (lab probe software) it would take longer to teach the students to use the software than to just do the lab. Time is a factor and applications which are retained must be efficient and effective in improving student learning.

Students who miss class for hockey games, other school activities, or who are ill, can catch up by accessing the class website and Ross finds they need less time to catch up than before the laptop program.

Gone are the days of, I've lost the assignment, or I couldn't do it, or I was away at a hockey game so I didn't know what I was supposed to do, or I was sick. It doesn't take them, or the parents, long to realize all those excuses are out the door.

Their assignments have been posted, the due dates are posted.

They don't have to worry about calling their friends to find out what homework to do. Certainly there is an efficiency there.

The students are not spending as much time getting caught up on their work. They can, if they choose to, stay on top of the

work much, much more easily than in the past (Ross, I – 575).

He thinks that good students spend more time on homework in the laptop program. If asked to read five pages in the text, they would do that. If directed to the Internet, these students read for a longer time. Other students, he believes, read for less time in the laptop program as they focus on finding the right answer. He has to stress that the journey is the important part of the assignment, not just getting the right answer.

Major assignments are handed in electronically and in hardcopy. The teachers at the school use turnitin.com to check student work for plagiarism. Ross prints out hardcopies of student assignments submitted electronically and collects other assignments and tests on paper. He prefers marking hardcopies because he can add comments to their work. Testing is largely pencil and paper in his class, like the external testing and biology competitions the students write.

### **Samantha: New Teaching Approaches**

In Samantha's classes students use their laptops, in class, once or twice a week to take notes or to see a diagram she is using. They use their laptops after class to make notes and prepare review notes. They may run their review notes past her to make sure they have the relevant focus. She know some students who maintain more traditional notebooks, but thinks the students are more engaged if they use their laptop computers rather than notebooks. With their notes on the laptops, other students can help a student who has lost their work or

hasn't backed up their work. She does not encourage this practice except under exceptional circumstances.

Even in a laptop program, Samantha believes in a more hands-on approach to experiments in the lab, and a hands-on approach to the constructing of models during lab activities. This is how she prefers to approach teaching biology despite the fact that there is no lab technician to assist the science teachers with experimental work.

She has found that using laptops takes time which reduces the lab time available for the course. However, she is aware that the laptops can augment the hands-on program where experiments or chemicals are too dangerous for a high school setting, or too expensive. Their labs are tight on space when the laptops are out, especially in chemistry and physics, but a virtual pig dissection is an option she can provide in biology.

This year I had five or six students that opted not to do the actual dissection so I give them the option of searching on the Internet for an appropriate virtual dissection site. Then they checked in with me and I would say whether it was a legitimate site. Then they just went ahead and studied it, and that worked out quite well. Last year I gave them the option as well, but everyone took part in the dissection. Some of them said they didn't want to do it, but they were the ones who eventually dived in (Samantha, I – 117).

To encourage active learning she uses webquests on mitosis/meiosis instead of teaching these processes in the traditional way. She doesn't usually have them do Internet searches in class on the laptops and if she wants them to do the search for homework she will normally have them close the laptops until the end of class. She gave another example:

I'm relating this to the mitosis class when I used the mitosis simulation and it was online. It would go through the steps and there would be someone talking in the background explaining what's happening in the diagrams, when I told the students, to just close their computers, they were all focused and after they were all interested and wanted to know what the website was. I got it out to them later (Samantha, I -175).

If she does assign individual work in the lab using computers, the students will sometimes listen to music as they work and she allows them to do that. Usually the students work in small groups, but she asks them at the end of a unit what they liked and didn't like. They may give her feedback such as too many presentations or too much group work. If they do, she cuts back on presentations or the amount of group work in the next unit. She finds their feedback is very constructive.

Samantha thought last year that the students rarely had a lot of homework in biology. They seemed to be able to complete it in class or in tutorial, where

they might get questions answered as they worked. A year later in the laptop program, she still thinks they spend less time on biology outside the classroom and they seem to need less time to prepare for tests and quizzes.

Samantha redesigned how booklets on a plant unit are used. Last year it was a collaborative project and students could go to the library to look up sources. This year they are working with the units in class, as an individual laptop project. They don't take the booklets out of the lab. The students are finding it harder as they must focus during class time. As they work, she reinforces finding reliable sources and understanding what makes those sources reliable. They can also use books, but must not rely on their text. She encourages them to use university sites, the Environment Canada site, and science journals

She has students develop rubrics and attach them to assignments they are handing in to be marked. More of their assessments are laptop-based than written by hand. She found she needed professional development to use the marks gathering program used at the school, but now she calls students up to the front of the room so they can see their marks on her laptop and discuss their progress with her.

She is excited about the possible introduction of tablet laptops for every teacher in the school. Two teachers have had tablet laptops for a year, as pilot project, and they report back at every staff meeting on what they have been able to do with them. With tablet laptops, assignments can be marked with a stylus and returned to the students electronically with the teacher's corrections. She

now marks on paper so the students can see her comments, but using tablet laptops will save paper and students always have the option of printing out corrected work if they wish.

Samantha is of the opinion that the laptops increase communications between students and with students in other schools. The laptop has also increased her communication with other teachers. Teachers exchange lists of email addresses at conferences and she actually had another teacher who wanted to network with her, but unfortunately it wasn't another science teacher.

### **Richard: New Teaching Approaches**

Richard prepares PowerPoint presentations for lessons and the students also prepare PowerPoint presentations for their classmates. He has included the service of the librarian to assist the students prepare effective PowerPoint presentations.

Lab activities remain largely hands-on, but Richard welcomes the opportunities the laptops provide. He can actually demonstrate many aspects of biology, for example, online labs on fruit flies, instead of hands-on labs which are difficult to do well in a high school setting. The emphasis remains on hands-on labs, and lab activities which engage the students, such as a camouflage lab done in the Evolution Unit using what Richard referred to as M&M s.

There are more opportunities for active learning, although reading the students in class, he is concerned that in the laptop program it may be possible to do too much and to overwhelm the students. He feels more time is now spent

teaching students how to find information and answer questions and the students have an increased opportunity to learn collectively. They have the opportunity to learn through computer-mediated conferencing (CMC) which he finds Improves the quality of interaction between students and reduces their reliance on him for information. For example, if other duties at the school delay him from getting on the class website, they answer one another's questions in First Class conferences.

We have this class conference. Any confusion, any questions, anything they don't understand they are to post there. The theory behind that is I may not get on until the next morning, who knows where I am as a house master or whatever? Someone else will get on and answer that question, probably before I will, and that's what happens all the time. Students answer their own questions and that's great (Richard, III – 21).

The students do more work out of class in the laptop program. Home work assignments can be different, more specific, and there is much more information available to the students now.

It sort of shifted the way I do things now. I'm really a facilitator. I keep saying, I'm nothing more than a facilitator. You're going to be teaching me things and students like that. They like to challenge you, as in there's something he doesn't know. They

can find a recent research article, and post it, and they do.

That's great, I love that. (Richard, II – 119).

As an example, he assigned three questions in the physiology unit: childhood obesity, fitness, and food. The students have to be online every night, and there are criteria and guidelines to guide their participation. While there is a limit on the amount of written work they contribute to the discussion, they must reference their contributions, and build on others comments without repetition. This takes work on their part.

Similarly, he finds these new teaching practices have carried over to projects. Learning anytime, anywhere is a reality. A 24 hour test assigned from 3:30 Thursday to 3:30 on a Friday holiday is not a problem. Tests, labs, assignments which are emailed are date and time stamped, a much easier way of receiving and keeping track of student work.

He has found that grade 12 averages have definitely gone up over the last eight years. While he cannot be sure this increase results from the laptop program, he feels there is evidence from the students' results in the University of Toronto Biology Competition and the results of the students who write AP biology papers of the benefits of laptop technology.

As mentioned above, Richard finds there is more and improved communication between students, especially as they gain experience with computer-mediated conferencing.

## **Kenneth: New Teaching Approaches**

Kenneth doesn't know if his perceptions are typical or atypical of other biology teachers, but he doesn't feel using laptops makes a lot of difference for instruction, other than the use of PowerPoint notes and the inclusion of digital images. He gives the example of using PowerPoint notes to teach Mendel's Second Law and notes the time the students save making notes can be used for an interactive discussion and classes tend to be more truly Socratic than before the laptop program since the students know they can print out the notes that night. Some choose to annotate the PowerPoint notes on their laptops, others annotate their PowerPoint notes by hand.

The daybook is a web-based diary of what the class has done. When the daybook concept was to be adopted, a number of teachers were concerned, but the school ran a pilot project to provide the staff with feedback. Two teachers were used during the pilot study since they had already been using the concept. Most of the teachers use FrontPage for their daybook. Kenneth notes that he edits and updates the daybook in front of the class so that the students can see there is some flexibility in the class's progress through the course. Students can check the daybook if they missed a class and parents can check to see what the students are studying.

Students receive the course manual in a binder and online. It contains the notes, handouts, review materials, practice tests, corrected practice tests, and vocabulary review. He finds this saves an enormous amount of time which would be spent photocopying and passing out notes in class over the year. Students

are asked to bring the binder with the year's "notes" to class, along with their textbook. Although the students already have the notes for a class, sometimes he designates students to take notes for the other students on their laptops and generally, he allows students to use their laptops to take notes as long as the laptops are not connected to the Internet.

He has just located a great simulation for dissecting the foetal pig which he finds helpful for students who are initially reluctant about dissecting, or for those students who opt out entirely. He is preparing a taxonomy unit for Grade 11 and would like to set up a field investigation on insects using a dichotomous key he has located on the Internet. He is also hoping to establish a project for his grade 11s with Bird Study Canada. There are bald eagles nesting nearby and the students have been providing information they gathered using a digital camera and a telescope. If Bird Study Canada could band the young eagles with transmitters, the students could track them over the Internet when they fledge.

He has an ongoing concern with labs that he feels is correlated with laptop use. He thinks the students tend to skim the vast amounts of reading material the laptops provide for them and as a result they do not read well. He has noticed their skill at reading lab instructions has been declining since the laptops were introduced. He has had to focus on having them read lab instructions carefully, but notes that the more experiments they carry out, the better they get at reading for details.

Kenneth has found that having the course manual online has been a real boon to his work and has made it easier for students who must miss class, or for

those students who are not particularly well organized. He does assign active learning activities for the students to complete on the laptops. One example, called Cell Decathlon, focuses on cell structure and function and involves ten interactive websites. Students work in pairs with a scorecard which gets stamped at each of the ten stages and there is a prize at the end. He finds the students enjoy the competition and have fun. Students preparing to write the Advanced Placement exam in biology prepare an independent study as part of the plant unit. They then get a chance to teach their unit to the class using the laptops and the LCD projector. Kenneth says the students are amazed at how difficult it is to teach using the laptops.

The students now have PowerPoint notes with interactive links to the best slides for review, but Kenneth finds a minority of the students take full advantage of these additional resources. He estimates that 80 per cent of the students read the daybook to check the homework assignment, 50 per cent might read the entire log for the day and 10 per cent, the most motivated students, read the log, open the links, and complete the assignments.

Kenneth had been able in the past to assign an active learning project on the cloning of Tasmanian wolves. He found this simulation a great independent activity until the Australian Museum decided they didn't have the resources to continue the project.

The students went to the Australian Museum Online and looked at the whole controversy around trying to bring back the extinct Tasmanian wolf from DNA that was preserved in the 1890s.

That was great activity for about two or three years, but then the Australian Museum decided they didn't have the resources and they shelved the project. In the old system I would never have heard about this project. I would have been working from the textbook. So I mean there is a whole lot more societal, real world applications (Kenneth, II – 229).

Kenneth does not think that the laptops have increased student-to-student communication. Rather, he feels communication on the laptops has replaced the telephone for day students, and face-to-face interactions for students in residences. He thinks the laptops have probably increased the interaction between students in different residences, but he hasn't heard that the students are using the laptops to communicate with students in other schools.

As a teacher, he finds he has more communication with the students since they got laptops, although he still maintains office hours every day.

Computers don't save you time. I'm one example of that. I have many more contacts with students outside of class now with email than I ever had when I was teaching and going home at the end of the day before laptops (Kenneth, I – 241).

He deals with about half a dozen emails per evening, some of which may involve multiple emails if there is a request for help. He knows other colleagues

are more disciplined about electronic contact than he has felt he needs to be, but he thinks the communications are a real help to the students and notes that the emails tend to be from the more conscientious students.

**Question Three: What new teaching materials do senior grade biology teachers use when integrating laptop computers into high school biology programs?**

For the purpose of this study, “teaching materials” refer to objects that are created by the teacher. This section examines the evolution in the materials the teachers used to teach biology before and during the laptop program. The changes the teachers discussed centred on their use of hardware, peripherals, software, the Internet and textbooks. More concise lists of the teaching materials the teachers in the sample used to use and now use are available in Appendix F. The teachers were not asked to prepare these lists. The lists were compiled from answers they provided during the interviews.

**Adele: New Teaching Materials**

Adele describes a busy program of preparing new materials as the teachers rework biology units, individual lessons, and projects, for use with the laptops. PowerPoint presentations are posted online in preparation for lessons and for use as handouts. The primary form of the PowerPoint is used for teaching purposes and a secondary form is used by the students for taking notes. The teachers are now reworking lessons for Biology 11.

She describes a previous teaching approach which had involved hardcopy handouts, overheads, overhead projectors and lab equipment appropriate to the experiment. These teaching materials have now been replaced with laptop computers, liquid crystal display (LCD) projectors, lab equipment appropriate to the experiment, SMART Boards and digital cameras.

As in most schools, the teachers use software to enter their marks, prepare report cards and to use the school's email system. Adele also mentions using a British software program which not only makes preparing PowerPoint presentations faster, but also makes them interactive; publishing software such as ProDesktop; Excel, Wizard for graphing; and Windows Office 2007. In the labs the teachers use Vernier probes (such as temperature probes), Data Studio to run the probes, Pasco, and a multimedia package from the textbook publisher, Campbell, which she uses with grade 12 students preparing to write AP Biology. The school has acquired online databases and online journals for the teachers and students to use in their research. The teachers have located simulations on the Internet and now have the option of inserting simulations in some topics in biology. Frog dissection, pig dissection, fruit fly labs in genetics, gel electrophoresis, and mitosis were all mentioned as areas where simulations augmented hands-on student labs and improved student learning.

### **Keith: New Teaching Materials**

Prior to the introduction of the laptop computer program, Keith described having Individual desktop computers and networked desktops in the computer

labs. There were several desktops in the biology lab at that time, but they were not used for instructional purposes.

I didn't use them very much because it was hard  
(Keith, III – 409).

The school had cameras and TV equipment which could be used to videoconference with other schools. He kept his course notes in a binder and the students maintained their notebooks in binders and used a textbook.

As the school started into the laptop computer program they used Lotus Notes to provide information for courses and after they got an Internet connection at the school he was able to add some electronic enhancement to the information about courses. The school also acquired a scanner at that time which helped the teachers as they reorganized their courses and teaching materials for the laptop program.

In the laptop program, both teachers and students have laptops and there are LCD projectors in the classrooms. Under these circumstances, the teachers have decided that having SMART Boards would be redundant. This decision has been reinforced by their opinion that SMART Boards are not problem-free at this time. The teachers have obtained a number of other peripherals to use with the laptops, including: a class set of micro pipettes; and, three spectrophotometers with laptop connectors. They are examining the possibility of getting electrophoresis apparatus.

The teachers continue to use Lotus Notes for their course databases and to use the Internet to find suitable teaching materials from a variety of sources, such as: university biology department sites: Canadian Broadcast Corporation's (CBC) Quirks and Quarks website; non-governmental organization (NGO) sites; and, private sources such as the Howard Hughes Medical Institute (HHMI). Teachers maintain contact with other teachers, students, and parents by email. The students continue to use a textbook, but now they have a textbook with a disk.

I use the text as a reference book, so that's the start point for everything because it's such a comprehensive source to begin with. From there, we draw stuff in, so my database, over time, has taken on more of an integration with the textbook in many respects. That's why I feel very comfortable, as opposed to ... I'm creating my own sort of textbook and we just use whatever we can to do that. I've never seen anything that works quite as well as having the electronic support of the material in place, enhanced with a textbook (Keith, II – 273).

### **Xandra: New Teaching Materials**

Xandra used desktops at her previous school in the local board to prepare handouts, instructions for labs, tests, and to prepare her own notes. Desktops were available on movable carts at that school, and for a time carts were shared by two departments. Later, one desktop was provided in the science office for

four science teachers. There were no desktop computers or LCD projectors in the classrooms at that time, although she did have access to VHS which she could use to show animations such as muscle contraction. In her first international school, one or two desktops were available in the science department, but they could use any desktop in the school, in any department. It was at that time that she started using a scanner to help prepare handouts for classes. She scanned images which she photocopied on transparencies for an overhead projector. She provided a package of her skeletal notes and the scanned images to the students. The pattern was very much the same at her second international school, until in her last year an agreement was negotiated whereby the teachers could get financial assistance from the school and a substantial subsidy, to purchase an Apple laptop computer. This was the beginning of another learning curve for her since she had always used PCs. This international school didn't have money for the software and equipment (e.g. electrophoresis equipment) to use with the laptops, or a support network of schools where she could borrow equipment. In the board she had taught for in Ontario, the high schools shared expensive science equipment. As a result, she had a laptop computer, but wasn't able to use the technology in the classroom.

She now uses a laptop and a SMART Board for instruction. She uses many of the Blackboard functions to organize her teaching, including: posting course materials; announcements; test dates; exemplars; rubrics; and, test questions. She uses the discussion board function in some of her courses, but not in biology as she prefers to be part of any discussion to insure erroneous

information is not introduced. She uses Excel for marks gathering and to display, process, and graph data.

I have used technology for the students in their laboratory experiments to collect data. That is definitely one thing I've added. It is called Vernier, that's the company, and they have all these different types of probes which students can use to collect various forms of data from temperature, pH, to pressure. You name it, they probably have a probe for it. So I use that from time to time in my teaching. As well, I've been able to purchase all that biotechnical equipment, in an updated form, which I learned years ago and I employ that in the laboratory component of the courses that I teach (Xandra, 1-161).

From the Internet she selects animations of biological processes for lessons and movie clips of concepts such as muscle contractions. Depending on the copyright provisions the school has arranged, this information can be posted on Blackboard for the students to use. Other times, the material can only be displayed on her laptop. She uses email within the school community and continues to use textbooks in her courses. One of the textbooks she is using has an accompanying CD-ROM.

### **Darby: New Teaching Materials**

Darby worked for a period of time after university graduation and before attending a Faculty of Education. During this work period she used a desktop computer with access to PowerPoint software and databases. During her practice teaching there was probeware available in the lab which the associate teacher was not using and textbooks with CD-ROMS.

She now teaches using one binder and a laptop which the school upgrades most years, if not every year. This is her second tablet laptop and she is pleased that the tablet function is now faster and easier to use. She writes on a SMART Board as she teaches, or when giving notes, and uses probes for real time data collection during experiments. She uses software to prepare PowerPoint presentations, a program for drawing organic molecules which she describes as not being user friendly, and a program, Chime, to view molecules in three dimensions.

Darby uses the Internet to prepare webquests for the students, to select websites for students to visit, to locate freeware she can install on First Class and Java applets on pertinent topics which they can install on their laptops. She describes email as increasing different types of communication, including: student-to-student, student to her as a teacher, and teacher-to-teacher. She estimates she is in contact with ten students a day. As a result, she knows if students are away, how they are catching up on work they have missed, and she can follow-up on assignments with individual students. She still uses a textbook

with a CD-ROM but finds the students prefer to read the textbook over using the CD-ROM on their laptops.

They have a CD-ROM that goes with their textbook, but pretty much every student says they can't read off the CD-ROM and they say they still need their textbook. So, they still need that hardcopy in front of them (Darby, II – 131).

### **Audrey: New Teaching Materials**

Audrey used a desktop at home to prepare lessons and handouts. She now has a laptop computer which is replaced from time to time by the school and she teaches with probeware for temperature, and pH, and SMART Board. The teachers at the school were provided with professional development on the use of SMART Boards and are encouraged to use them. The school is wireless, but the teachers and students still use cables for laptops sometimes and in some parts of the building.

In theory the school is wireless, but in one science classroom the reception is terrible. The old building has very thick stone walls. The building is good, but ... (Audrey, I – 163).

She mentions using software for attendance, PowerPoint for lessons, Excel for graphing, Microsoft Office for drawing and Cobweb for predator/prey

relationships. At the time of the interviews the teachers were about to receive professional development on the use of Wikis, a computer application which she expects to implement next year.

Audrey selects animations and illustrations from the Internet for her lessons and online simulations for gel electrophoresis and action potentials. She has located specialized sites such as a histology site for blood smears, and special programs such as the PBS program, *The Brain*. She finds worksheets which require the students to consult websites are more popular than the homework she could assign before the laptop program was implemented. She uses email for communication and mentions exchanging emails with students in the evening.

She continues to use textbooks with CD-ROMs in her courses. However, she notes, the CD-ROMs were never popular and frequently got lost.

### **Zoe: New Teaching Materials**

Zoe worked in medical and scientific settings and for a software company where she received training in database tracking tools. She is grateful that as a graduate student she had the opportunity to learn Internet Explorer, as well as *Word* and all its functions. The university she attended as an undergraduate provided all the students with email accounts when they were in third year.

After attending teachers college, in her first year at this school, she used a laptop with cable access to the Internet, a SMART Board, and a textbook with a

CD-ROM. She found the students lost the CD-ROMS and ended up using the textbook for their studies.

Zoe now has her second laptop with tablet and stylus capability. This hardware is easier to use and much of her day-to-day marking is now done electronically. The labs in which she teaches are now wireless, but cables are still routinely used, as they are more reliable. She now uses a SMART Board controlled by touch instead of a keyboard while she teaches and peripherals for collecting data during labwork.

Blackboard is used for in-house functions at the school and storing course sites, PowerPoint presentations, word documents, homework assignments and other assignments. All the labs the students are to complete are online, the materials they will require are prepared in advance and available for the students to use at their own pace. Next year she hopes the students will have One Note to assist them maintain electronic notebooks. In the meantime, she teaches with no paper, no photocopying, and she no longer has teaching materials in binders.

Zoe locates images on the Internet with the content she needs for use in classes, interactive websites, and websites for topics such as for food chains, for the students to use. The students routinely use search engines and databases. Email is used for communications: homework reminders to the class, follow-up emails to parents and student advisors at the school, and to schedule individual tutorials which have replaced the office hours she used to post. When tutoring, or even when teaching, she can post specific documents for an individual student who is having difficulty with a concept or a topic. This is the first year she has

started using an online text and she expects it will be more fully integrated into her course next year.

This is one of their labs. They go through and get the information ... it has activities built in. There is this diagram to review, so they review it, and then this has to be updated. This is from last year when we used to have a CD-ROM. Now we refer them to their e-text and we just go through the activities, what they do. Then they would start, either summarizing the results, or whatever they need to do: modular models, guess this chemical, or whatever we're working on. Everything is outlined here (Zoe, III – 611).

### **Ross: New Teaching Materials**

As Ross describes it, he had desktop computers at home, and in his office at school, which he used mainly for word processing. There was a computer lab with 25 networked computers which he never used for teaching biology and a desktop computer with a projector in the biology classroom. He was using spreadsheets, a webpage for the course, and email to advise parents that there was a course webpage, which they could access. The class used a textbook.

He now uses his laptop. Since they have LCD projectors, the science department decided it was redundant to have SMART Boards. They have made the transition from cable to wireless Internet access. Ross uses his laptop as a management tool: for marks gathering and for attendance records. He mentions

using his laptop for correspondence functions: correspondence with parents, and keeping notes from staff meetings and committee meetings.

All teachers now have websites for their courses. He uses his laptop as a prompt while teaching, for homework assignments and tests. He mentions using PowerPoint, Excel, and turnitin.com to check assignments students have submitted.

In labs, he prefers to continue using demonstrations and experiments carried out by the students. They now use digital cameras and a digital microscope in their labs to augment work done with optical microscopes. He cannot predict yet whether he will begin to use lab probes in his biology course.

Ross uses the Internet to locate information for his classes. In particular, he mentions the Howard Hughes Medical Institute (HHMI) site and the University of Ottawa Biology Department website. He collects assignments and tests on paper. Major assignments are handed in electronically and on paper; the paper copy is marked. The laptops, and the information that can be retrieved using the laptops, have replaced the textbooks he used to use.

There are very few things, I've found, that I can do better with a laptop. There are some exceptions. We don't have a textbook in grade 11 any more. It suddenly dawned on us a couple of years ago that the students have a \$100 textbook which they never opened because they can easily find the answer on the Internet much quicker than looking through the index of the

textbook (Ross, I – 377).

More and more I'm sold on the idea, because right now we're doing a research project on a genetic disorder. Rather than take them over to the library and pulling out a textbook which might be ten years old, they can get on the Mayo Clinic website and find the most up-to-date research on any research paper they're dealing with. We tend to use sources like that (Ross, I – 383).

### **Samantha: New Teaching Materials**

As a pre-service teacher, Samantha taught with transparencies, an overhead projector and a textbook. In one science course during her teacher education program they used laptops on a cart to demonstrate how to implement laptops in a school and she learned how to make PowerPoint presentations and movies. During that pre-service year, and as an undergraduate, she was able to use desktop computers in a computer lab for projects and assignments.

She now uses a laptop to teach and PD for using tablet laptops has been scheduled. There is an LCD projector and whiteboard at the front of the room. She has not used sensors to collect real time data in biology labs although she thinks she may implement them next year. She has already used them in other science course she teaches. Samantha uses software as part of the assessment procedures and Excel for spreadsheets and graphing. A colleague has

presented PD on Imovie and Moodle training has been scheduled for the teachers.

Next year we are going to be introducing tablets. The faculty are going to be getting tablets as a pilot project to see how effective they will be. I'm excited about that because then if I'm taking notes in biology with them, I can write it on the tablet, it will be projected, instead of using an overhead projector, and I can automatically put it online for them. It's going to be much easier when it's already on my computer. For us right now, if I've got a handwritten note, I'll scan it from the photocopier and put it on my email, then take it from my email and put it onto Moodle where the students can access it. This way I can do a straight transfer onto Moodle and I'll have that resource right there. I think it will be great in terms of drawing diagrams and having the students more engaged. They can come to the front of the class, draw, add, label a diagram. I'm looking forward to it. You could do it with an overhead projector and a transparency, but I would love to have it all online (Samantha, I – 229).

Samantha uses the Internet to prepare webquests for the students. Both she and the students locate websites, virtual lab experiences and animations for the course. She encourages the students to use university websites, the Environment Canada website and science journals for their research. She

continues to use a textbook in each of her biology courses. Email is a communications tool: within the school she mentions, student-to-student, student-to-teacher and teacher-to-teacher, but she also mentions email communication with some students in other schools.

### **Richard: New Teaching Materials**

Richard described a previous teaching approach, which involved using software on small floppy disks to investigate water quality and making good ecological decisions. He also had some simple dissection programs for frogs and pigs. He noted that the school had assisted teachers in getting their first computers, but also observed that he used his first computer for keeping marks, and printing out assignments, not for instruction. Eventually teachers progressed to networked desktops in the laboratory, and he could use a desktop at the front of the room for instruction. The textbooks remained an important teaching tool at that time.

These arrangements have now been replaced by the laptops, and programs such as PowerPoint, Excel, and First Class for their daybook and computer-mediated conferencing. The website, Biology Place, is a source of labs and review exercises.

Richard has peripherals such as lab probes for use, although labs remain hands-on to a great extent as he feels the students need the experience of manually using pipettes. He may use more probes in the future, but, in fact, right now he's cutting back on the use of probes.

Through the school, he and the students have access to the latest papers, websites such as Biology Place, the National Association of Biology Teachers (NABT) website. He searches widely for interactive sites and finds even with lists of links from other teachers there are no shortcuts, half the links do not function after a year.

Now everything's for free and it's good. So really I'm not looking to pay for anything now (Richard, II – 179).

I was going through a whole lot of stuff yesterday, actually just getting ready for biology class for the rest of the year, just finding good websites. I looked at the ones we used last year, half of them are gone now. I can't find the page, so ... (Richard, II – 69).

Email is used to hand in assignments such as homework, labs and projects, an enormous improvement on prior practices, but Richard says possibly the biggest change in teaching materials has been in the area of textbooks. They do not have a textbook. In addition to the information students can access on their laptops, he has some resource books and he is aware of the possibility of an electronic text in the future. In the meantime he mentions finding a book at a local bookstore which is a good review book for students preparing for the AP exams. He finds the students like the detailed notes he provides for the course which they can annotate over the year. Although he sees his course notes as being different from a textbook, he thinks the students don't see that difference.

### **Kenneth: New Teaching Materials**

Prior to the laptop program, Kenneth mentions having access to desktops, blackboards and whiteboards in the school, but notes he did not use the desktops for teaching in the classroom. He did use PowerPoint and eventually Internet access was provided in the classroom. There was a laser disc player available with a catalogue of thousands of images and videoclips, and a video microscope projector, a camera connected to a microscope used with microscope slides. The images could be projected on a television monitor for the entire class to see.

He now describes teaching with the laptops and a LCD projector in his classroom. The teachers use Lotus Notes for their course databases, class logs and course manuals. They now have an attendance database, a marks database, and an online reporting system. He mentions continues to use PowerPoint, Inspiration for concept mapping, and Mind, as well as a digital camera.

One of the things I've found as a useful tool is a digital camera to document the results of labs. Students always seem to get a kick out of seeing themselves and their actual lab results. It's worked really well (Kenneth, I – 95).

Kenneth searches the Internet for animations, video clips and interactive links he can add to his lessons. He specifically mentions finding online tutorials,

and simulated dissections to augment the students' in-class experiences and a dichotomous key for field studies. In addition, he accesses: university websites for graphics and photomicrographs; government websites for information on such topics as the human genome; medical sites, such as the Huntington's Foundation; simulations such as the Wolves of Yellowstone; and he has found he can access interviews on the Internet with actual scientists.

He uses email to post messages for the entire class and to answer student inquiries. In addition to the electronic copy of the course manual, a hardcopy is given to the students in a binder and includes notes, handouts, review materials, practice test materials, corrected practice tests, and vocabulary review for the year.

## **Appendix B: DETAILED DESCRIPTION OF THE ANALYSIS**

### **Introduction**

This appendix presents an analysis of the data presented in Appendix A. As described in Seidman (2006), analysis is an opportunity for the researcher to begin addressing what was not understood before the interviews, what has been learned, and what was not anticipated. Specifically, this appendix addresses what the teacher participants shared with us regarding the themes identified in Appendix A.

### **Analyzing the Data**

Inductive analysis involves discovering patterns, categories and themes in the data. This study was designed to collect data describing biology teachers' perceptions of integrating laptop computers into their courses. It was not designed to test hypotheses, nor was it designed to develop theory (Seidman, 2006). The analysis was guided by the research questions and the themes and categories established in Chapter Four. In this appendix, findings common to teachers from all level of experience are presented first. Then, the findings from experienced teachers, mid-career teachers and early-career teachers are presented when appropriate.

### **Question One: How do senior grade biology teachers perceive the integration of laptop computers into high school biology programs?**

The teachers' perceptions as they integrated the laptop computers into their instruction dealt with three themes: the type of innovation the teachers were introducing in their classroom; what the teachers perceived supported their ability to modify their instruction; and, what challenges the teachers perceived they faced, and still face, in changing their instruction.

#### **Type of Innovation**

All of the teachers in the sample indicated that they decided how to integrate the laptops into instruction and that they recognized that how they chose to integrate the laptop computers was possibly unique among their colleagues. Teachers in all categories, experienced, mid-career and early-career teachers, reported some collaboration with colleagues on academic matters or content, but they made the decisions as to what the laptops were used for and how the laptops were used in their classrooms. Even fewer teachers mentioned having shared lesson plans and planning with teaching partners. In addition, only occasionally was it mentioned that the IT department assisted with software the teachers wished to use for teaching in biology. All the teachers described a gradual or evolutionary pattern of integrating laptop computers into their instruction.

The decision-making pattern for pedagogical matters described above was very different from the process the teachers described for the integration of

hardware and software to be used throughout the school by teachers in all subjects. In this latter instance, where the laptops were used for administrative or non-pedagogical purposes, although the teachers did not make the decisions as to what or when an innovation would be implemented, a few mentioned having had some input into the decision making process, including: collaboration with the IT department; participation on IT committees; participation in pilot projects; the provision of a teacher who had some release time to work with teachers on the integration of the generic aspects of using the laptops; and, occasionally, collaboration with the vice-principal.

Experienced teachers reported that it had taken two or three years to integrate laptops into their instruction; however, they acknowledged that the innovations would be ongoing for a number of reasons, including: they might be teaching different courses; changes in curriculum guidelines; and, innovations they would introduce to reflect student needs. One experienced teacher observed that the level of maturity required for adolescents to learn in a laptop program is, in itself, an endpoint to what can be accomplished in high school classrooms. Mid-career teachers gave a range of one or two years to integrate laptops into their teaching, but realized that integrating laptops into their instruction would be an ongoing innovation. These teachers described the innovations they expected to be dealing with in the future, such as: advances in technology; changes in teaching assignments; and, changes in teaching partners.

Early-career teachers reported a wide time range for integrating laptops into instruction, including: one or two years; four years; and, as high as five to six years. Early-career teachers noted that they might have new software programs they want to introduce into their classrooms. These early-career teachers envisioned the endpoint of the integration process as every lesson having some integration of the laptops. Most report that they had reached the point in the integration process where they were now substituting better labs and better data gathering experiences for the students.

### **Supports During Innovation**

*When asked what had supported their efforts through the challenges associated with integrating laptop computers into their instruction, a number of themes emerged from the teachers in this study, involving the students, the schools, professional development, instruction, and themselves as teachers. I will deal with each of these themes in more detail.*

Teachers from all levels of experience cited positive, if anecdotal, feedback from students and alumnae/i that encouraged them in their efforts to integrate laptops into their instruction, including: students felt they were better prepared for post-secondary studies; and, alumnae/i felt they were better prepared to succeed at the post-secondary level through participation in the laptop program. Teachers at all levels of experience stressed the importance of the role played by the school, sometimes identified as “the administration” or “the IT department”, in supporting the integration of the laptop computers in their

classrooms. For most of these teachers, evidence of this support is the provision of the peripherals needed to teach biology with laptop computers, and the provision of up-to-date technology. Teachers at all levels of experience stressed the importance of the professional development provided by the IT department. Having professional development at the school was seen as a great advantage, preferably at times scheduled into their timetables, and preferably to address the needs they as teachers identified. These teachers mentioned that they were encouraged by the fact that the school had designated funds available for them to attend conferences, workshops, and/or courses. Teachers at all three stages of their careers mentioned that innovations they had already made in instructional approaches encouraged them to continue the process of integrating laptops into their biology programs although the reasons, described in the following paragraphs, were variable.

The most experienced teachers mentioned learning from the students as they integrated the laptops into their instruction and being stimulated by the students' interest in the biology course, as well as by the increase they perceived in student learning and student motivation. An experienced teacher said he had been encouraged to continue since the integration of the laptops could be fitted into his approach to teaching biology. These experienced teachers also mentioned the importance of the financial support they had received from the school in the initial stages of implementing the laptop program, including: loans and subsidies to purchase laptop computers, and additional professional development opportunities. Experienced teachers mentioned that receiving the

professional development with colleagues assisted the mentoring process within the science department. One experienced teacher noted that once a school is in a laptop program, there is no going back since observing that all the schools most comparable to the school where he was teaching had introduced laptop programs.

The most experienced and mid-career teachers spoke in terms of the *importance of financial support from the IT department for the peripherals* needed in biology labs. As one mid-career teacher explained, the cost of these peripherals could exceed a science department's budget for the entire year. Another mid-career teacher observed that it just wouldn't be worth the effort of integrating laptop computers into instruction for out-of-date technology.

Experienced and mid-career teachers observed that personal characteristics, perhaps unique to them as individuals, encouraged them to continue the process of integrating laptop computers into their instruction, including: a positive attitude to implementing innovations; the ability to deal with the time constraints of teaching a laboratory subject; and, their increasing proficiency within the laptop program which encouraged them to continue the process. Other comments ranged from: the laptop program had a positive influence on their personal learning; the laptop program had a positive effect on their personal organization; and, they had been allowed to manage a gradual modification in their teaching approaches.

Mid-career teachers reported that they were encouraged by seeing new ideas they could adapt for their laptop programs and by seeing what other

teachers in laptop programs were doing in other schools. These teachers mentioned that they were encouraged because they became more efficient with regard to preparing lessons and classroom teaching. One mid-career teacher said she was encouraged to continue the integration in her classroom because she could select her own peripherals and decide how the technology was to be used in her classroom.

Early-career teachers described improvements in the instruction of their biology courses, including: more learning experiences for the students; the students' output had increased in the laptop program; students liked the coursework more; and, students were less stressed by the requirements of the course. These teachers noted the importance they placed on having the software they required to teach biology, and the importance of acquiring new software and hardware which they anticipated would make the instruction process easier. Early-career teachers outlined a number of professional development activities which they considered to be important, including: hearing about integrating laptops into instruction from colleagues during staff meetings; the support provided when technology "experts" were invited to the school to demonstrate new equipment to the teachers (and in one school, to the students as well); and, having colleagues present during professional development opportunities. This is seen as an advantage for follow-up after the professional development experience. Some of the early-career teachers said they were encouraged to continue integrating laptop computers into their instruction by standards for technology use in biology courses issued by the Ontario Ministry of

Education and the International Baccalaureate, by program evaluations carried out at their school, and by the feedback they received from such program evaluations.

### **Challenges to Innovation**

When asked about the integration of laptops in their instruction, the teachers in this study identified a number of challenges, including: the ongoing nature of technological innovations; instructional issues; their role as a biology teacher in the school; finding appropriate professional development; and, issues associated with the maturity of students in a laptop program.

Challenges the teachers in the sample associated with technology included issues with hardware, software, and the peripherals used with the laptops to teach biology. Surprisingly however, many of the observations about hardware are positive in nature, including: upgrades such as laptops with tablet and stylus capability will make it easier to teach; and, more network speed and capacity and wireless capability will make it easier to use the laptops for instruction. The unintended, sometimes negative, consequences of hardware updates, which result from the acquisition of new laptops, are noted with *philosophical resignation*, as the *price of progress*. Similarly, it is thought that improvements in software and upgrades in peripherals, such as probeware and SMART Boards which can be controlled by touch, will make teaching in the laptop program easier or more efficient in the future. Dealing with the inevitable

incompatibility between existing resources and newly acquired resources, although challenging, was again viewed as the price of progress.

Teachers at all levels of experience raised concerns regarding their personal level of knowledge and what they still need to learn if they are to teach more effectively in a laptop program. They noted that teaching with laptops in a laboratory subject resulted in increased time constraints and presented additional challenges in teaching their biology program. They observed that teaching a laboratory subject made it more difficult to schedule the blocks of time they needed in order to master and integrate hardware, software and peripherals into their instruction than if they had been teaching another subject in the school. Most of the teachers who participated in this study either had no assistance in the laboratory or technical support that changed frequently (such as university co-op students on work terms), which consistently, year after year, requires input of additional time and energy from the teachers.

Similarly, teachers at all levels of experience considered accessing appropriate professional development a challenge. Most teachers articulated a need for more training on the technology they used to teach biology, a wish to find appropriate teaching models to observe, and opportunities to share with other teachers in other laptop biology programs. The need to provide students with more effective learning opportunities is mentioned by teachers at all levels of experience, as are the associated challenges of providing a laptop program to teenagers. The teachers acknowledged that learning experiences needed to be tailored to a realistic level of maturity for adolescent students. One experienced

teacher identified the need for feedback on his teaching approaches in the laptop program and noted that he is of the opinion that no one even has the tools to provide that type of feedback to teachers like him.

Generally, experienced and mid-career teachers did not express concerns about instruction. The early-career teachers most often noted instructional challenges. Their concerns included: varying the delivery of classes; varying their teaching approaches; individualizing instruction for different classes and different students; the time and energy required to double-check teaching resources each year before they can be used in the classroom; the tedious and cumbersome process for receiving, marking, and returning student work; and, the fact that the different nature of the Biology 11 and Biology 12 courses presented different instructional challenges for them.

### **Diffusion of the Innovation**

In order to gather the teachers' perceptions of the diffusion of this innovation, biology instruction in a laptop program, the teachers were asked three questions: 1) How might you differ from biology teachers not teaching in a laptop program?; 2) What advice would you give biology teachers entering a laptop program?; 3) What would encourage biology teachers to integrate laptops into their instruction? About half the teachers in the sample said they had observed "new colleagues" go through the process of integrating laptop computers into their instruction. As before, the perceptions of experienced, mid-career and early-career teachers have been analyzed.

When asked how they might differ from biology teachers entering a laptop program for the first time, teachers at all levels of experience mentioned a number of differences, including: their laptop was on all the time during every class; there was less chalk and talk during their classes; and, their program and instructional approaches were more varied.

Experienced teachers in this study said they can no longer imagine teaching without a laptop and that as a result of their involvement in the laptop program they might be different from other biology teachers in a number of ways, including: more forward thinking; more willing to modify their practices; more current; more effective; more enthusiastic; more willing to learn from their students; and, more willing to consult the literature while teaching. These experienced teachers used their laptops as an organizational tool and believed the structure built in to a course being taught with laptops resulted in students being better informed about the course requirements. They observed their biology courses might also be different in a number of ways: the courses had become more entertaining for the students; instruction and teaching approaches had become more varied; and, the learning styles of a wider variety of students were being met.

Mid-career teachers also observed that they could no longer imagine teaching without a laptop, noting that teachers should have a laptop, if only a personal laptop, for their use in the classroom. They believed that their courses and lessons in the laptop program were easier for them to prepare and more interesting for the students.

Early-career teachers were of the opinion that while they might not have known how they were different from new colleagues entering a laptop program, they thought that all teachers should be using a personal laptop in their classrooms. The early-career teachers in this study observed that they and their courses might have been different in a number of ways: as teachers, they were more open minded and more willing to adapt to a program that was different from the norm; the courses they were able to present were better for the students; and, the laptops have changed how they organized individual student help. The early-career teachers believed that the laptop program was a more convenient way for them to teach, and they cited a number of differences, including: the lack of photocopying; how they delivered their lessons in the classroom; a less teacher-centred approach to learning; less teaching from the textbook; and, the use of email for communication within the school community.

When asked what advice they would give new colleagues entering a laptop program, teachers from all levels of experience observed that new colleagues should: ask more experienced teachers for help; have a patient optimistic outlook; be open to new experiences; and, be willing to learn new skills. The teachers in the sample also mentioned the importance of a supportive administration as new colleagues begin to integrate laptop computers into their instruction.

The experienced teachers in the sample advised that new colleagues be patient with themselves, that they maintain their perspective as they begin to integrate the laptops into their teaching and not allow themselves to become

discouraged during the process. Both experienced and mid-career teachers advised that teachers new to a laptop program should be willing to modify their thinking about their teaching in the classroom, adopting more of a facilitator role in the classroom and less of a teacher-centred role. These teachers advised that new colleagues should plan to integrate the laptops only to their personal comfort level and they should continue to use the teaching approaches, techniques and teaching materials that worked for them in the past as they begin the process of integrating laptops into their instruction.

Mid-career teachers believed that new teachers' confidence has to be maintained throughout the process of integrating the laptops into their courses and advised that the curriculum requirements of the courses supersede the requirement to use the laptops. The mid-career teachers provided advice on managing the laptops in the classroom, including: new teachers should realize that managing student learning in biology classrooms with laptops is different; that teachers should control the use of the laptops during class; that teachers need to make their rules for laptop use in the classroom very clear to the students; that students should be given some option as to whether tasks are accomplished on laptops or by hand; and, that teachers continue to use small group and collaborative learning approaches while increasing the active learning opportunities possible in a laptop program.

Mid-career and early-career teachers mentioned the importance of focusing on content and presentation during the transition to using laptops in biology instruction, and advised new teachers to vary their teaching approaches

and develop new teaching materials. These teachers recommended alternating traditional laboratory experiments the teachers would have used in other schools with laboratory experiences that have been redesigned for use with laptops.

While advising that new teachers should introduce more student-centered activities and decrease the time spent on teacher-centered activities, mid-career and early-career teachers observed that new teachers might find that the laptops do not increase academic communication between students.

Early-career teachers in this study felt it is important that new colleagues accept that the process of integrating laptop computers is a struggle. These teachers provided advice on how to start reorganizing courses and lessons and how to start using the laptops, including: check the curriculum to find concrete ways to show students what technology can contribute to the learning of biology; realize that laptop use will vary with the content of the biology course being taught; use a variety of teaching approaches in the classroom; realize the laptops do not have to be used every day; and, start the conversion to teaching with the laptops with their favourite topics and the key labs in the course. The early-career teachers also advise that since the maturity level of the students will influence what can be done with the laptops, it might be wise to start with grade twelve students rather than grade nine or ten students.

When asked what would encourage biology teachers to integrate laptops into their instruction, teachers at all levels of experience noted that the realization that students were learning better and more successfully will encourage new colleagues. They felt that new teachers are encouraged if the school identifies

the laptop program as a priority and has high expectations for the teachers and students in the program. The teachers in this study observed that new colleagues will also be encouraged as they begin to understand that integrating laptops into their instruction is an innovation that works and, despite its flaws, has enormous potential for future teaching.

Experienced teachers believed that a number of factors would encourage new colleagues, including: their teaching will become more effective and efficient as they adjust to their role as a facilitator in the classroom; they will realize they can become happier, more fulfilled teachers in a laptop program; it is easier to supplement student learning; and, that time spent implementing the laptops in one year saves time in future years. These experienced teachers also observed that new colleagues will be encouraged to continue integrating laptop computers by all the new teaching resources they can access. Both experienced and mid-career teachers said that new colleagues would be encouraged by the growing realization that it would be hard to go back to teaching their biology courses without laptops.

Mid-career teachers believed that new colleagues would be encouraged by the positive effects of modifying their teaching approaches in a laptop program, including; a more truly Socratic teaching experience when these types of lessons are used; a more flexible approach to meeting individual student needs; having the newest and most efficient technology available for teaching purposes; and, by trying to use as much of the technology as was feasible.

Early-career teachers observed that new colleagues would be encouraged by the perception that teaching with laptop computers is an innovation that is sustainable through changes in curriculum and student learning. These teachers also believed that new colleagues would be encouraged by possessing a realistic understanding of teaching in a laptop program, including: laptops are being used differently by other science teachers; laptops are being used differently by teachers in other subject areas; teaching will become less stressful despite their initial misgivings about having less available class time in a laptop program; laptops are not a good tool for students who have difficulty focusing; they may have misgivings about their new supervisory role if the laptops are to be used appropriately during class time; and, they can expect to have concerns about matching laptop use with differing class profiles. Early-career teachers also felt that new colleagues would be encouraged to integrate the laptops into instruction by the fact that: students find the biology courses more interesting; there will be an improved learning experience for the students; the students' output will increase; and, that using laptops will not diminish the students' understanding of the concepts presented in the course. Early-career teachers also cite the following as being encouraging: the benefits of teaching the students how to use the research tools available to them; the ease with which students can find information in the laptop program; and, the benefit of having the students realize that everyone, including teachers, use these research skills. They felt that new colleagues would also be encouraged by the knowledge that they can always go back to a previous teaching approach, if necessary.

**Question Two: How do senior biology teachers perceive and introduce new teaching approaches when integrating laptop computers into high school biology programs?**

The teachers described new teaching approaches resulting from the integration of laptop computers into their instruction, including: lesson preparation and lessons; notebooks; lab activities; active learning opportunities, homework, and, assessment procedures. There was a high degree of congruency in the new teaching approaches introduced by the teachers in my sample and a few differences in the emphasis they placed on these teaching approaches according to their years of experience in the classroom.

Teachers from all levels of experience in this study believed that using PowerPoint presentations reduced the time that had been used in science classes for taking notes prior to the introduction of the laptop program, but observed that when PowerPoint presentations were being annotated in class, the students did not always use their laptops, sometimes choosing to annotate the PowerPoint presentations by hand. The teachers in this sample observed that with laptops in the classroom, whole class instruction was decreased and Socratic lessons, when used, became more truly Socratic since the students had access to all the information they would need after class and were not dependent on taking notes during discussions. Most teachers in the sample were of the opinion that developing notes and annotating diagrams on a SMART Board was a convenient way to teach a class.

Despite the Guidelines from the Ministry of Education which state that students should have a hands-on laboratory program, teachers from all levels of

experience in this study reported using a number of different simulations to augment the experimental work students completed in labs in order to supplement experimental work which is normally not successful given the time and facilities available in most high schools, and to replace experiments that teachers believe are too dangerous or too expensive in a high school setting. In addition, teachers from all levels of experience in this study noted that the assistance of a lab technician improved the quantity and quality of the labs they could provide in their courses. Unfortunately, not all the arrangements that schools made for technical assistance for science labs allowed the teachers to transfer time and energy into integrating the laptops into their biology programs. Some arrangements, such as hiring co-op university students, required ongoing and continual input from the science teachers.

Teachers from all levels of experience in this study were of the opinion that there was more independent learning in the laptop program and that part of their new role in the classroom was to teach the students to research biology information in a credible fashion using a laptop. Some teachers believed it was easier in a laptop program to plan for groups of students and for students with different needs and all the teachers agreed that the PowerPoint presentations were a valuable tool to help students catch up on work they had missed. I am taken aback by the difference the teachers felt the laptop program had made to this latter aspect of their teaching. Clearly, from their responses, helping students catch up on missing work was an area which used to consume a great deal of their time and energy.

The teachers stated that since the laptops had been integrated into instruction they could design homework assignments that were of more interest to the students and were more meaningful for the students' learning. The experienced teachers were of the opinion that high-achieving students spent more time on homework in the laptop program. Other teachers expressed the opinion that the students were spending the same amount of time on homework, and some teachers observed that students appeared to need less time to prepare and study for tests in the laptop program.

An exception to the introduction of new teaching approaches is that most of the teachers did not alter their assessment practices. Most continued to assess student progress using pen-and-paper tests and examinations, and they continued to mark and return paper copies of student assignments. One early-career teacher, in a student-centred program, marked student work electronically during class.

Textbooks, which prior to the introduction of the laptop program had been an important, but expensive teaching resource, are in some cases no longer used. Where textbooks are no longer used, they have been replaced by a combination of course notes prepared by the teachers, resource booklets, and resources which can be accessed using the laptops. Other teachers have retained a text, sometimes with an accompanying CD-ROM. Electronic texts were being considered by some teachers in the sample, and an electronic text had been chosen for implementation in one school.

I noted some differences in new teaching approaches that tend to be described by teachers with different levels of teaching experience. Experienced teachers in the sample most often noted changes in lesson preparation, changes in active learning opportunities for students less often, and are of the opinion that high achieving students spent more time on homework in the laptop program. Mid-career teachers most often tended to describe changes in lesson preparation, maintaining science notebooks, laboratory experiences for students, and comment that making notes and annotating diagrams on a SMART Board was a convenient way to teach. Early-career teachers most often appeared to describe active learning opportunities for students and put less emphasis on different approaches to lesson preparation, notebooks, labs and homework, while observing that it was easier to plan for groups of students with different needs in a laptop program.

**Question Three: What new teaching materials do senior biology teachers use when integrating laptop computers into high school biology programs?**

The teachers' perceptions of new teaching materials as they integrated laptop computers into instruction dealt with four themes: hardware, peripherals, software and the Internet. I will first deal with the teaching materials the teachers described using prior to the introduction of laptop computers into their instruction, and then with the teaching materials they described using with the laptop computers.

## **Materials Used Prior to the Laptop Computer Program**

Teachers from all levels of experience in this sample had, by and large, not chosen to use the desktops, the multiple desktops, or the networked desktops for instruction.

The peripheral used most frequently by the teachers in the past was the scanner. Otherwise, no one peripheral was mentioned by all the teachers in the study. Certain individuals cited access to different peripherals, such as: biotech capability in the lab; a video microscope projector with a TV monitor; a laser disk player with disks; VHS players and tapes; cameras; overhead projectors; and, whiteboards.

Some teachers in the sample mentioned that they had used software to keep track of marks on their computers. Otherwise the use of software in the past among the teachers was variable, including: a software platform used for organizing class materials; a simple dissection program; the use of PowerPoint for lessons; the use of spreadsheets; and the use of word processing programs. Some of the experienced teachers mentioned having Internet access at the school prior to the introduction of the laptop program. One mentioned that he had developed a course webpage and that he was using email capability at the school before the laptops were introduced. In all cases, textbooks were mentioned among the teaching materials they used. In summary, the experienced and mid-career teachers described using from four to eleven of the applications mentioned in this section. The average number of applications described was seven.

## **New Teaching Materials Used in the Laptop Computer Program**

When asked about the use of teaching materials in the laptop program, the teachers who participated in the study described using up to thirty different applications. The average number of applications described was twenty. The early-career teachers tended to use the most applications, followed by the experienced teachers, and the mid-career teachers. All mentioned their use of laptops, peripherals, software, the Internet; email for communicating within the school community, and textbooks, (often accompanied by a CD ROM), or an equivalent. One teacher described using a multimedia package available with the text, and another started to use an electronic text.

Laptop computers replaced the desktops, the multiple desktops and the networked desktops the teachers used prior to the introduction of the laptop program. Since the laptops were being used for instruction, it appeared that hardware became less of an issue for the teachers. Wireless capability in the labs, the fragility of the laptops in the hands of students, and the new capability of tablet laptops in the instruction process were mentioned.

This study found that peripherals, the additional technology associated with teaching in a laptop program, were widely available in the classrooms. The use of whiteboards and LCD projectors was widespread, and SMART Boards were frequently available in the labs, some controlled by touch which was seen to be more convenient than SMART Boards controlled by a laptop. The use of peripherals such as probes to gather data during experiments, although

widespread, was by no means universal. Other peripherals such as biotech equipment and micropipettes were mentioned by a few teachers, as were digital microscopes, cameras, and spectrophotometers.

The use of software has become widespread in their teaching. The most frequently used platform for their teaching activities was Blackboard, although First Class and Lotus Notes were also used. In addition to learning the platform software, PowerPoint was the most frequently mentioned software, followed by Excel for graphing and Microsoft Office for drawing. The teachers in the sample learned and used a number of different programs for recording attendance and reporting marks, and they anticipated learning a number of new programs in the upcoming year to improve assessment practices. The teachers also learned to use a range of software, from desktop publishing programs to programs designed to draw organic molecules. I noted that the teachers were learning a wide range of software programs and there was little similarity as to what software was being used to carry out the same function in different schools. I also noted that although many software programs were being used, few were specifically designed for teaching biology and many were being used to for management of marks, attendance, and reporting student progress.

The teachers who participated in the study, however, talked mostly about the instructional materials they accessed on the Internet. They mentioned searching for and incorporating some thirty different types of teaching materials. The materials mentioned most often were animations to illustrate concepts. Locating simulations was mentioned slightly less frequently, followed by the

creation of webquests for students' use. Often, schools had purchased databases and access to scientific journals, but the teachers said that increasingly they were finding free material that they preferred to use on websites posted by universities, non-governmental organizations, medical institutes, and government departments. Again, there was considerable variation and little similarity among the teachers in this sample with respect to the sites they chose and how the materials were incorporated into instruction. The teachers described a personal search and selection process which took a great deal of their time and was carried out with considerable care. The teachers indicated increasing satisfaction with the stability of the sites they could now access on the Internet. While they still had to double check these teaching materials before starting a lesson, they said discovering the material was no longer available was much less of a problem than it had been a few years ago.

### **CBAM: Contribution to the Analysis**

The rubric for the six Stages of Concern (SoC) indicated that all the teachers in the sample were focusing on concerns at the highest three levels:

6-Refocusing

5-Collaboration

4-Consequences

Only one early-career teacher, who was finishing her second year in a laptop program at the time of the interviews, was deemed to be still focusing on concerns at the third level:

### 3-Management.

None of the teachers in the sample expressed concerns at the lowest three levels:

2-Personal, level

1-Informational

0-Awareness

Other than the one teacher who expressed some Level 3 (Management) concerns, there were no other differences in the nature of their concerns by years of experience. Interpreting the results for Level 5 (Collaboration) proved difficult, since all of the teachers were isolated in the sense that they were either the only teacher in their schools teaching their biology course, or the only teacher in the school teaching biology.

The results were similar for the six Levels of Use (LoU) rubric. All of the teachers' patterns of use of the laptop computers were focused at the three highest levels:

VI-Renewal

V-Integration

IVB-Refinement,

None of the teachers were focusing on use of the laptop computers at the lower levels:

IV-Routine

III-Mechanical Use

II-Preparation

I-Orientation

0-Non-Use

Again, the results for Level V (Integration) were difficult to interpret using this rubric since there were experienced, mid-career and early-career teachers who were the only biology teacher in their school, or the only biology teacher teaching their course.

The rubric for Innovation Configuration (IC) indicated teachers from all levels of experience were in the top category in eight of ten characteristics of a laptop program.

- 6 Access to computers
- 7 Student use of computers in subject area
- 8 Classroom organization
- 9 Learning activities
- 10 Nature of task environment
- 11 Technological literacy

The exceptions were Categories 4 and 5:

- 9 Independent learning
- 10 Teacher-student relationship

These two categories differentiated between the classroom of one teacher in the sample, an early-career teacher in a student-centred program, and the other nine teachers who had introduced student-centred activities, but the programs remained more teacher-directed than the student-centred program. The

descriptors for Levels 4 and 5 in the IC made it difficult to place these nine teachers on the rubric.

In conclusion, teachers at all levels of experience in this sample were overwhelmingly operating at the highest levels of CBAM, whether Stages of Concern, Levels of Use, or Innovation Configuration. At some levels and in some categories the context of their teaching made using the rubrics developed from CBAM difficult to interpret.

Appendix C1

Table 1. Percentage Frequencies by Decade of 12 Emerging Patterns in Science Education Literature

Pattern	1955-64	1965-74	1975-84	1985-
1. Call for reform	26.8	30.8	31.6	30.
2. Better teachers'	18.8	24.3	25.7	27.
3. Instructional methods				
lab exercise	24.8	19.4	14.6	14.
lecture	8.8	9.4	6.5	7.
discussion	6.3	7.9	6.5	11.
activity	5.4	6.6	9.7	11.
teacher demo	12.5	4.0	3.5	5.
audio-visual aids	6.3	7.0	5.0	3.
individualized instruction	2.2	8.6	8.9	1.
4. Science literacy	10.8	16.4	18.2	12.
5. More students	14.8	3.7	9.5	7.
6. Real-life/societal issues	25.4	25.7	37.8	31.
7. Conceptual understanding	26.6	30.1	35.8	26.
8. Student interest	20.7	16.8	15.7	17.
9. Subject emphasis				
biology	25.4	27.1	33.3	23.
chemistry	29.0	25.8	25.8	28.
physics	21.9	17.8	21.2	24.
10. Problem solving	17.3	19.1	18.8	18.
11. Teaching strategy				
direct	49.2	54.2	48.2	51.
inquiry	50.8	45.8	49.4	32.
constructivist	N/A	N/A	2.4	15.
12. Integrated science	44.6	13.0	21.0	24.

(Ponder & Kelly 1997)

Appendix C2

Despite the discourse on better teaching, including the use of better instructional strategies and methodologies in classroom/laboratories, instructional methods recommended for use have changed little.

Table 2. Percentage Frequencies of Top-Ranked Instructional Methodologies by Decade

1955-1964	
Laboratory exercise	24.8
Teacher demonstration	12.5
Lecture	8.8
Textbook	6.7
Discussion	6.3
Audio-visual aids	6.3

1965-1974	
Laboratory exercise	19.4
Lecture	9.4
Individualized instruction	8.6
Discussion	7.9
Audio-visual aids	7.0

1975-1984	
Laboratory exercise	14.6
Hands-on activity	9.7
Individualized instruction	8.9
Discussion	6.5
Lecture	6.5
Field trips	6.0

1985-1994	
Laboratory exercise	14.8
Hands-on activity	11.9
Discussion	11.0
Teacher demonstration	5.5
Teacher demonstration	5.5
Group work	5.5

(Ponder & Kelly 1997)



# Université d'Ottawa University of Ottawa

Société de la recherche en éducation et en sciences humaines / Society of Educational and Human Sciences

## **SOCIAL SCIENCES AND HUMANITIES RESEARCH ETHICS BOARD**

### **CERTIFICATION OF ETHICAL APPROVAL**

This is to certify that the University of Ottawa Social Sciences and Humanities Research Ethics Board (REB) has examined the application for ethical approval for the research project **Teacher Perceptions of Changes in High School Biology Programs Using Laptop Computers (Dossier # 12-06-03)** submitted by Morag S. Gundy and supervised by Marie-Josée Berger of the Faculty of Education. The members of the REB found that the research project met appropriate ethical standards as outlined in the Tri-Council Policy Statement and in the Procedures of the University of Ottawa Research Ethics Boards, and accordingly gave the research project a Category Ia (Approval).

This certification is valid for one year from the date indicated below.

\_\_\_\_\_  
Catherine Paquet  
Protocol Officer for Ethics in Research  
For the Chair of the Social Sciences and Humanities REB  
Richard Clément

March 30, 2007  
Date



uOttawa

Université d'Ottawa  
Faculté d'éducation

University of Ottawa  
Faculty of Education

## Formulaire de consentement à l'intention du conseil scolaire

Date :

Adresse du conseil scolaire :

Madame,  
Monsieur,

Je suis étudiante au doctorat à l'Université d'Ottawa et je mène actuellement une recherche ayant pour but de déterminer de quelles manières les pratiques d'enseignement évoluent au sein d'une classe ou d'un laboratoire de biologie lorsqu'on y intègre de nouvelles technologies, plus précisément lorsqu'il s'agit d'ordinateurs portables. Il est possible de rejoindre ma directrice de thèse, Madame Marie Josée Berger.

J'aimerais communiquer avec des enseignant(e)s de biologie de 11<sup>e</sup> et/ou de 12<sup>e</sup> année utilisant des ordinateurs portables dans leurs salles de classe afin de leur proposer de participer à ma recherche. Les données recueillies auprès des enseignant(e)s seront utilisées afin de rédiger une étude de cas et fourniront une description des perceptions et expériences des enseignant(e)s par rapport à l'intégration des ordinateurs portables en salle de classe. Ces données pourront également nous renseigner sur la façon dont les enseignant(e)s se sont adapté(e)s à cette intégration. Les données seront recueillies au cours de trois entrevues individuelles avec les enseignant(e)s d'une durée d'une heure. Le matériel pédagogique utilisé par les enseignant(e)s sera également recueilli. Ces entrevues pourraient leur fournir l'occasion de partager leurs expériences professionnelles et de faire le point en ce qui a trait à l'intégration de nouvelles technologies et à leur impact sur leurs pratiques pédagogiques.

Les entrevues se dérouleront à l'école et au moment qui convient le mieux aux enseignant(e)s. Ayant moi-même enseigné les sciences au secondaire pendant plusieurs années, je m'intéresse particulièrement aux perceptions des enseignant(e)s par rapport à l'impact des nouvelles technologies sur leurs stratégies d'enseignement. Cette recherche n'engendrera aucune interruption sur le plan de l'enseignement ou des activités en salle de classe ou en laboratoire. En outre, la recherche ne requiert aucune participation de la part des étudiants.

Seule la chercheuse aura accès aux données recueillies. Celles-ci seront conservées dans un classeur fermé à clé dans la résidence de la chercheuse. Les enregistrements des entrevues seront effacés une fois que les données auront été transcrites électroniquement et vérifiées par les enseignant(e)s participant à l'étude. Au fur et à mesure que les données sont enregistrées à l'ordinateur, toute caractéristique permettant d'identifier les participants seront effacées et les fichiers informatiques seront protégés au moyen d'un mot de passe. Les données seront conservées pendant cinq ans après la fin du programme de doctorat. Par la suite, les transcriptions seront déchiquetées et les fichiers électroniques seront effacés.

Vous trouverez ci-joint une copie des lettres destinées aux directions d'école ainsi qu'une copie de la lettre d'information destinée aux enseignant(e)s, laquelle est accompagnée d'un formulaire de consentement pour ceux et celles qui seraient intéressés. La participation à cette recherche est volontaire. Les participants sont libres de refuser de participer ou de se retirer de l'étude en tout temps sans subir de conséquences négatives. Tel que mentionné précédemment, ni le conseil scolaire, ni les écoles, ni les participants ne pourront être identifiés tout au long du processus de recherche, que ce soit dans le rapport ou dans les données recueillies pendant les entrevues. Aucun étudiant ne sera identifié et aucune information ne sera recueillie au sujet des étudiants.

J'aimerais donc obtenir l'autorisation d'entreprendre des démarches auprès des directions d'écoles de votre conseil scolaire, de mener une recherche dans les écoles qui auront accepté de participer et d'utiliser les données recueillies pendant les entrevues dans le cadre du programme de doctorat auquel je suis inscrite à la Faculté d'éducation de l'Université d'Ottawa, lors de la rédaction de la thèse ainsi que pour toute publication où présentation à caractère savant.

**Autorisation :**

Je, soussigné(e), donne l'autorisation à Morag Gundy d'entreprendre des démarches auprès des directions d'école du conseil scolaire afin de pouvoir mener sa recherche. Je consens également à ce que les données recueillies auprès des enseignant(e)s soient utilisées dans le cadre du programme de doctorat auquel elle est inscrite à la Faculté d'éducation de l'Université d'Ottawa, lors de la rédaction de la thèse ainsi que pour toute publication ou présentation à caractère savant.

Nom du responsable du conseil scolaire : \_\_\_\_\_

Signature du responsable du conseil scolaire : \_\_\_\_\_

Date : \_\_\_\_\_

Merci.

Morag S. Gundy



uOttawa

Université d'Ottawa  
Faculté d'éducation

University of Ottawa  
Faculty of Education

**Board Consent Form**

Date

Board Address

Dear (Board Official)

I am doing research for a PhD degree at the University of Ottawa. The purpose of my research is to ascertain how instructional practices change in a biology classroom/laboratory with the introduction of technology, specifically the integration of laptop computers. My thesis supervisor is Dr Marie Josée Berger at the University of Ottawa. She can be reached at

I would plan to approach members of the teaching staff teaching biology in grades 11 and/or grade 12 in the laptop program with a request to participate in a case study. It is expected that the case study would result in a description of the teachers' perceptions and experiences of integrating laptops into instruction and how they went about the integration. Information would be gathered from each teacher during three one-hour interviews and the collection of material the teachers would have already prepared. For the teachers this should be an interesting professional growth experience and an opportunity to reflect on changes in instructional strategies.

The interviews would be scheduled at the school at a convenient time for the teachers. I have taught high school science for many years and I am interested in the teachers' perceptions of changes in teaching strategies. There would be no interruption of program or of regular laboratory or classroom activity. This study does not involve the classroom or the progress of any student or students.

The data will be available only to the researcher and will be kept in a locked filing cabinet in the researcher's home. Recordings of interviews will be erased after the electronic transcript has been completed and verified by the teacher participant. As data are entered in to the computer, all identifying characteristics will be removed and computer files will be password protected. Five years after the thesis process has been completed, the data gathered from the teacher participants will be shredded and electronic files erased.

145 Jean-Jacques Lussier  
Ottawa ON K1N 6N5 Canada

I have enclosed a letter to principals and a detailed letter with a consent form which would be sent to teachers who might be included in the sample. Participation in this research project is voluntary. There are no negative consequences attached to either choosing not to participate, or to withdrawing from participation in the study at any time. As stated, the board, school and the teacher will not be identified in the study, in any part of the report or recorded on interview notes. No students will be identified and no information will be collected about the students.

I am requesting your permission to approach principals in your board, proceed with the research at the school and to use the information collected from the interviews in the process of completing a PhD (Education) degree including a dissertation, any further publication(s) and scholarly presentations..

**Permission:**

I, the undersigned, give Morag S. Gundy permission to approach principals in the board's schools and to conduct the research, and grant permission for the data collected from the teachers to be used in the process of completing a PhD (Education) degree, a dissertation, any further publications, and scholarly presentations.

Name of Board Official: \_\_\_\_\_  
 Signature of Board Official: \_\_\_\_\_  
 Date of Signature: \_\_\_\_\_

Thank you

Morag S. Gundy



uOttawa

Université d'Ottawa  
Faculté d'éducation

University of Ottawa  
Faculty of Education

## Formulaire de consentement à l'intention de la direction

Date

Adresse de la directrice ou du directeur

Chère Madame ...

Cher Monsieur ...

Je suis étudiante au doctorat à l'Université d'Ottawa et je mène actuellement une recherche ayant pour but de déterminer de quelles manières les pratiques d'enseignement évoluent au sein d'une classe ou d'un laboratoire de biologie lorsqu'on y intègre de nouvelles technologies, plus précisément lorsqu'il s'agit d'ordinateurs portables. Il est possible de rejoindre ma directrice de thèse, Madame Marie Josée Berger,

J'aimerais communiquer avec des enseignant(e)s de biologie de 11<sup>e</sup> et/ou de 12<sup>e</sup> année utilisant des ordinateurs portables dans leurs salles de classe afin de leur proposer de participer à ma recherche. Les données recueillies auprès des enseignant(e)s seront utilisées afin de rédiger une étude de cas et fourniront une description des perceptions et expériences des enseignant(e)s par rapport à l'intégration des ordinateurs portables en salle de classe. Ces données pourront également nous renseigner sur la façon dont les enseignant(e)s se sont adapté(e)s à cette intégration. Les données seront recueillies au cours de trois entrevues individuelles avec les enseignant(e)s d'une durée d'une heure. Le matériel pédagogique utilisé par les enseignant(e)s sera également recueilli. Ces entrevues pourraient leur fournir l'occasion de partager leurs expériences professionnelles et de faire le point en ce qui a trait à l'intégration de nouvelles technologies et à leur impact sur leurs pratiques pédagogiques.

Les entrevues se dérouleront à l'école et au moment qui convient le mieux aux enseignant(e)s. Je m'intéresse particulièrement aux perceptions des enseignant(e)s par rapport à l'impact des nouvelles technologies sur leurs stratégies d'enseignement. Cette recherche n'engendrera aucune interruption sur le plan de l'enseignement ou des activités en salle de classe ou en laboratoire. En outre, la recherche ne requiert aucune participation de la part des étudiants.

Seule la chercheuse aura accès aux données recueillies. Celles-ci seront conservées dans un classeur fermé à clé dans la résidence de la chercheuse. Les enregistrements des entrevues seront effacés une fois que les données auront été transcrites électroniquement et vérifiées par les enseignant(e)s participant à l'étude. Au fur et à mesure que les données sont enregistrées à l'ordinateur, toute caractéristique permettant d'identifier les participants sera effacée et les fichiers informatiques seront protégés au moyen d'un mot de passe. Les données seront conservées pendant cinq ans après la fin du programme de doctorat. Par la suite, les transcriptions seront déchetées et les fichiers électroniques seront effacés.

Vous trouverez ci-joint une lettre détaillée destinée aux enseignant(e)s qui voudraient éventuellement participer à l'étude. La participation des enseignant(e)s à la recherche est volontaire. Les participants sont libres de refuser de participer ou de se retirer de l'étude en tout temps sans subir de conséquences négatives. Tel que mentionné précédemment, ni les écoles, ni les participants ne pourront être identifiés tout au long du processus de recherche, que ce soit dans le rapport ou dans les données recueillies pendant les entrevues. Aucun étudiant ne sera identifié et aucune information ne sera recueillie au sujet des étudiants.

J'aimerais donc obtenir la permission de mener cette recherche dans l'école et d'utiliser les renseignements obtenus au moyen des entrevues pour la rédaction de la thèse de doctorat à la Faculté d'éducation ainsi que pour toute autre publication ou présentation à caractère savant.

Autorisation :

Je, soussigné(e), \_\_\_\_\_, donne l'autorisation à Morag S. Gundy, de mener cette recherche et de recueillir les données nécessaires au moyen d'entrevues, lesquelles seront utilisées pour la rédaction de la thèse de doctorat à la Faculté d'éducation ainsi que pour toute autre publication ou présentation à caractère savant.

Je comprends que je peux communiquer avec la chercheuse au [ ] avec sa directrice de thèse, Madame Marie Josée Berger, Ph.D.,

Je comprends que pour tout renseignement sur les aspects déontologiques de cette recherche, je peux m'adresser au responsable de l'éthique en recherche de l'Université d'Ottawa, soit par écrit, au Pavillon Tabaret, 550, rue Cumberland, salle 159, Ottawa, ON, K1N 6N5, soit par téléphone au (613) 562-5841 ou par courriel au [ethics@uottawa.ca](mailto:ethics@uottawa.ca).

Je comprends qu'il y a deux copies du formulaire de consentement, dont une que je peux conserver.

École :

Nom de la directrice/du directeur :

Signature de la directrice/du directeur :

Merci beaucoup.  
Morag S. Gundy



uOttawa

Université d'Ottawa  
Faculté d'éducation

University of Ottawa  
Faculty of Education

## Principal Consent Form

Date

Principal address

Dear (Principal)

I am doing research for a PhD degree at the University of Ottawa. The purpose of my research is to ascertain how instructional practices change in a biology classroom/laboratory with the introduction of technology, specifically the integration of laptop computers. My thesis supervisor is Dr Marie Josée Berger for the University of Ottawa. She can be reached at:

I would plan to approach members of the teaching staff teaching biology in grades 11 and/or grade 12 in the laptop program with a request to participate in a case study. It is expected that the case study would result in a description of the teachers' perceptions and experiences of integrating laptops into instruction and how they went about the integration. Information would be gathered from each teacher during three one-hour interviews and the collection of material the teachers would have already prepared. For the teachers this should be an interesting professional growth experience and an opportunity to reflect on changes in instructional strategies.

The interviews would be scheduled at the school at convenient time for the teachers. I am interested in the teachers' perceptions of changes in teaching strategies. There would be no interruption of the program or of regular laboratory/classroom activity. This study does not involve the classroom or the progress of any student or students.

The data will be available only to the researcher and will be kept in a locked filing cabinet in the researcher's home. Recordings of interviews will be erased after the electronic transcript has been completed and verified by the teacher participant. As data are entered in to the computer, all identifying characteristics will be removed and computer files will be password protected. Five years after the thesis process has been completed, the data gathered from the teacher participants will be shredded and electronic files erased.

I have enclosed a detailed letter which would be sent to teachers who might be included in the sample. Participation in this research project is

voluntary. There are no negative consequences attached to either choosing not to participate, or to withdrawing from participation in the study at any time. As stated, the school and the teacher will not be identified in the study, in any part of the report, or recorded on interview notes. No students will be identified and no information will be collected about the students.

I am requesting your permission to proceed with the research at the school and to use the information collected from the interviews in the process of completing a PhD (Education) degree including a dissertation, any further publication(s), and scholarly presentations.

Permission:

I, the undersigned, give Morag S. Gundy permission to conduct the research and grant permission for the data collected from the interviews to be used in the process of completing a PhD (Education) degree including a dissertation, any further publication(s) and scholarly presentations.

I understand that I may contact the researcher or her supervisor, Dr. Marie-Josée Berger, I have any questions about the study.

I understand if I have any ethical concerns regarding my participation in this study, I may contact the Protocol Officer for Ethics in Research, University of Ottawa, 550 Cumberland Street, Room 159, (613) 562-5841 or [ethics@uottawa.ca](mailto:ethics@uottawa.ca)

I understand that there are two copies of the Consent Form, one of which I may keep.

School: \_\_\_\_\_  
 Name of Principal: \_\_\_\_\_  
 Signature of Principal: \_\_\_\_\_  
 Date of Signature: \_\_\_\_\_

Thank you

Morag S. Gundy



uOttawa

Université d'Ottawa  
Faculté d'éducation

University of Ottawa  
Faculty of Education

**Lettre d'invitation et formulaire de consentement à l'intention de l'enseignant(e)**

Date

Adresse de l'enseignant(e)

Chère (enseignante)

Cher (enseignant)

Je suis étudiante au doctorat à l'Université d'Ottawa et je mène actuellement une recherche ayant pour but de déterminer de quelles manières les pratiques d'enseignement évoluent au sein d'une classe ou d'un laboratoire de biologie lorsqu'on y intègre de nouvelles technologies, plus précisément lorsqu'il s'agit d'ordinateurs portables. Les informations recueillies serviront à la rédaction de ma thèse dans le cadre du programme de doctorat de la Faculté d'éducation. Il est possible de rejoindre ma directrice de thèse, Madame Marie Josée Berger, :

La présente lettre vise à vous inviter à participer à cette étude. Les renseignements que vous nous fournirez seront utilisés afin de rédiger une étude de cas et fourniront une description de vos perceptions et de vos expériences par rapport à l'intégration des ordinateurs portables en salle de classe. Ces données pourront également nous renseigner sur la façon dont vous vous êtes adapté(e) à cette intégration. Les données seront recueillies au cours de trois entrevues individuelles d'une durée d'une heure. Nous recueillerons également le matériel pédagogique que vous aurez utilisé. Ces entrevues auront lieu au moment qui vous convient le mieux. Ces entrevues pourraient vous fournir l'occasion de partager vos expériences professionnelles et de faire le point en ce qui a trait à l'intégration de nouvelles technologies et à leur impact sur vos pratiques pédagogiques. Vous aurez accès aux transcriptions des entrevues afin que vous puissiez vérifier l'exactitude de vos propos. Nous vous remettrons également un résumé des principaux résultats de la recherche.

Les écoles et les enseignant(e)s participant à l'étude ne seront identifiés en aucun temps, que ce soit dans l'étude, dans le rapport ou dans les transcriptions d'entrevues. L'anonymat et la confidentialité des données seront respectés en tout temps. Ayant moi-même été enseignante de sciences à l'école secondaire, je peux vous assurer que cette étude ne vise pas à vous évaluer, vous ou votre école. Cette recherche n'engendrera aucune interruption sur le plan de l'enseignement ou des activités en salle de classe ou en laboratoire. En outre, la recherche ne

145 Jean-Jacques-Lussier  
Ottawa ON K1N 6N5 Canada

www.uOttawa.ca

requiert aucune participation de la part des étudiants et aucun de ceux-ci ne sera identifié.

Votre participation est tout à fait volontaire. Vous êtes libre de participer ou de refuser de participer sans subir de conséquences négatives. Vous êtes également libre de vous retirer de l'étude en tout temps, et ce, sans avoir à motiver vos raisons.

Seule la chercheuse aura accès aux données recueillies. Celles-ci seront conservées dans un classeur fermé à clé dans la résidence de la chercheuse. Au fur et à mesure que les données sont enregistrées à l'ordinateur, toute caractéristique permettant d'identifier les participants sera effacée et les fichiers informatiques seront protégés au moyen d'un mot de passe. Les enregistrements des entrevues seront effacés une fois que les données auront été transcrites électroniquement et que vous les aurez vérifiées. Les données seront conservées pendant cinq ans après la fin du programme de doctorat. Par la suite, les transcriptions seront déchiquetées et les fichiers électroniques seront effacés.

Si vous êtes intéressé(e) à participer à cette étude, veuillez remplir le formulaire intitulé *Formulaire de consentement du participant* qui accompagne la présente lettre et le retourner dans l'enveloppe pré-affranchie ci-jointe avant le (date). N'hésitez pas à communiquer avec moi pour toute question au sujet de l'étude. Je serai heureuse d'y répondre.

Je vous prie d'agréer, Madame, Monsieur, mes sincères salutations.

Morag S. Gundy

### **Formulaire de consentement du participant**

Je, \_\_\_\_\_, accepte de participer à l'étude intitulée *Perceptions des enseignant(e)s par rapport aux changements associés à l'intégration des ordinateurs portables en classe de biologie au secondaire* menée par Morag Gundy, de l'Université d'Ottawa, Faculté d'éducation, dans le cadre des exigences partielles du programme de doctorat.

Veillez apposer vos initiales pour chacun des énoncés suivants afin d'indiquer que vous en acceptez les termes :

Je comprends que ma participation à cette étude est volontaire et que je peux me retirer de celle-ci en tout temps sans avoir à motiver mes raisons auprès de la chercheure.

Je comprends que ma participation consiste à prendre part aux entrevues ainsi qu'à être consulté(e), le cas échéant, à d'autres moments.

Je donne l'autorisation à la chercheure de me rencontrer afin de mener trois entrevues individuelles d'une durée d'environ une heure, lesquelles auront lieu lors de trois journées différentes au moment et à l'endroit qui me conviennent le mieux, soit à l'école ou ailleurs, dans le but fournir les données nécessaires.

Je donne l'autorisation à la chercheure d'enregistrer les entrevues et d'en faire la transcription. Je comprends que je peux demander à la chercheure d'arrêter l'enregistrement à tout moment pendant l'entrevue.

Je comprends que les fichiers informatiques seront protégés au moyen d'un mot de passe et que les données recueillies seront considérées comme étant de nature confidentielle en tout temps et que tout enregistrement, transcription et fichier informatique seront conservés dans un classeur fermé à clé dans la résidence de la chercheure lorsqu'ils ne seront pas utilisés.

Je comprends que mon nom, le nom de mon école ainsi que toute information supplémentaire susceptible de nous identifier ne sera pas utilisée dans les données ou les résultats. Des pseudonymes seront utilisés afin de conserver l'anonymat et la confidentialité tout au long de l'étude.

Je comprends que les enregistrements des entrevues seront effacés une fois que les transcriptions seront terminées et que j'en aurai assuré l'exactitude.

Je comprends que les transcriptions seront échangées entre la chercheure et moi au moyen de courrier postal. Toutefois, si je désire les recevoir par courrier électronique, il demeure néanmoins possible que ceux-ci soient interceptés et que la confidentialité des données ne puissent être assurée.

Je comprends que, selon les directives du comité de déontologie de l'Université d'Ottawa, toutes les transcriptions relatives à la recherche, à savoir les transcriptions sur lesquelles les noms de personnes ou de lieux ont été effacés, seront conservées à l'Université d'Ottawa, au bureau de la directrice de thèse, pendant les cinq années suivant la publication de la thèse.

Je permets que les données recueillies à partir des entrevues soient utilisées tout au long du programme de doctorat poursuivi par Morag Gundy à la Faculté d'éducation, y compris la rédaction de la thèse ainsi que toute publication ou présentation à caractère savant.

Je comprends que je peux communiquer avec la chercheure \_\_\_\_\_<sup>1</sup> ou sa directrice de thèse, Madame Marie Josée Berger, \_\_\_\_\_ pour toute question au sujet de l'étude.

Je comprends que pour tout renseignement sur les aspects déontologiques de cette recherche, je peux m'adresser au responsable de l'éthique en recherche de l'Université d'Ottawa, soit par écrit, au Pavillon Tabaret, 550, rue Cumberland, salle 159, Ottawa, ON, K1N 6N5, soit par téléphone au (613) 562-5841 ou par courriel au [ethics@uottawa.ca](mailto:ethics@uottawa.ca).

Je comprends qu'il y a deux copies du formulaire de consentement, dont une que je peux conserver.

J'aimerais recevoir une copie des résultats de la recherche. Veuillez la faire parvenir à l'adresse suivante :

\_\_\_\_\_  
 \_\_\_\_\_  
 \_\_\_\_\_  
 \_\_\_\_\_

Signature de la participante/du participant : \_\_\_\_\_ Date : \_\_\_\_\_

Signature de la chercheure : \_\_\_\_\_ Date : \_\_\_\_\_



uOttawa

Université d'Ottawa  
Faculté d'éducation

University of Ottawa  
Faculty of Education

## Teacher Letter of Invitation and Informed Consent Form

Date

Teacher Address

Dear (Teacher)

I am conducting a research study at the University of Ottawa. The purpose of my research is to ascertain how instructional practices change in a biology classroom/laboratory with the introduction of technology, specifically the integration of laptop computers. I plan to use the information collected to write a thesis for a PhD. degree in Educational Studies. My thesis supervisor is Dr Marie Josée Berger at the University of Ottawa.

I am inviting you to participate in a case study. It is expected that the case study would result in a description of your perceptions and experiences as you integrated laptops into your instruction and how you went about the integration. Information would be gathered through three one-hour interviews, and the collection of some written materials which you have already prepared. The interviews with you would be scheduled for a convenient time and place. For you, this would be an interesting professional growth experience and an opportunity to reflect on changes in instructional strategies. Transcribed data from interviews will be made available to you to ensure that I have accurately captured what you have said or intended to say. You will also be provided with a summary of the main research findings.

The schools and the teachers participating will not be identified in the study, in any part of the report, or recorded in interview notes. At all times your privacy and confidentiality will be protected. I have taught high school science and want to assure you that this study is not designed to judge or evaluate you or your school. This study does not involve the progress of any student or students and no students will be identified in any way. There would be no interruption of program or to regular laboratory or classroom activity.

Participation in this research project is voluntary. There are no negative consequences attached to either not choosing or choosing to participate. You may, of course, withdraw from participation in the study, at any time, without reason.

The data will be available only to the researcher and will be kept in a locked filing cabinet in the researcher's home. As data are transcribed into the computer, all identifying characteristics will be removed and computer files will be password protected. Recordings of interviews will be erased after the electronic transcript has been completed and you have verified it. Five years after the thesis process has been completed, the data gathered from the teacher participants will be shredded and electronic files erased.

If you would like to be involved in this case study, please complete the "Agreement and Consent Form" attached to this letter and return it in the stamped addressed envelope by (give date). If you have any questions, I would be glad to answer them.

Yours sincerely,

Morag S. Gundy

### **Participant Consent Form**

I \_\_\_\_\_ agree to take part in the study entitled Teacher Perception of Change in High School Biology Programs using Laptop Computers being conducted by Morag Gundy through the Faculty of Education, University of Ottawa, in partial fulfilment of her doctoral thesis.

Please initial each of the following to indicate your agreement to the terms:

I understand that participation in this study is voluntary and that I may withdraw from the study at any time without having to provide the researcher with justification for the withdrawal.

I understand that this study will involve my being interviewed and consulted with outside of the interview situation.

I grant the researcher permission to meet with me for approximately 60 minutes each time on three separate days at a convenient time and place in the school, or outside of the school, for the purpose of gathering data for the study.

I grant permission for the interview session to be recorded and the recording to be transcribed. I understand that I may request the researcher to stop the recording at any time during the interview.

I understand that computer files will be password protected; data collected will be considered confidential at all times, and that all recordings, transcripts, and

computer files will be kept in a locked filing cabinet in the researcher's home office when they are not being used.

I understand that my real name, my school's name, or any other information that may be personally identifying will not be used in the data or results. Pseudonyms will be used to protect my privacy and confidentiality as well as that of the school.

I understand that the recordings of my interviews will be erased once the researcher has completed the transcripts and I have verified their accuracy.

I understand that transcripts for verification will normally be exchanged by mail, but if I request that transcripts be sent by e-mail, there is a risk of interception and the confidentiality of the data could therefore be at risk.

I understand that in keeping with the University of Ottawa's Ethical Guidelines, all transcripts from the research (i.e. that have identifying names and places removed) will be conserved in the thesis supervisor's office at the university for a period of 5 years following the publication of the thesis.

I grant permission for the data collected from the interview to be used in the process of Morag Gundy completing a PhD (Education) degree including a dissertation, any further publication(s) and scholarly presentations.

I understand that I may contact the researcher \_\_\_\_\_ or her supervisor, Dr. Marie-Josée Berger, \_\_\_\_\_ should I have any questions about the study.

I understand if I have any ethical concerns regarding my participation in this study, I may contact the Protocol Officer for Ethics in Research, University of Ottawa, 550 Cumberland Street, Room 159, (613) 562-5841 or ethics@uottawa.ca

I understand that there are two copies of the Consent Form, one of which I may keep.

I would like a copy of the research findings from this study. Please send it to this address:

\_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_

Participant's signature: \_\_\_\_\_ Date: \_\_\_\_\_

Researcher's signature: \_\_\_\_\_ Date: \_\_\_\_\_

### **Main Research Questions**

- How do senior biology teachers perceive the integration of laptop computers into their instruction?
- How did they implement this change with respect to the introduction of new teaching approaches and the use of new materials?

### **Interview Questions**

#### **Teacher Background**

What is your academic background?

What is your professional background?

Describe your teaching career.

What biology/science courses have you taught?

What was your technology background prior to teaching? How did you learn those skills?

What was your previous use of technology as a teacher? How did you learn those skills?

How have you participated in the laptop program? How did you learn the necessary skills?

What do you think laptops bring to your teaching?

It has been suggested that teachers learn about technology as it happens (just-in-time learning) rather than through instructed learning. Do you agree or disagree with this statement and why?

**Interview 1**

How are the laptops changing the way you teach biology?

What changes did you make in course organization and in preparation for teaching? Why did you decide to make these changes? What changes did you decide were effective/ ineffective?

What types of teaching strategies appear to be most effective when you are teaching with laptops?

Explain how you decide whether an instructional strategy using laptops was effective or not.

What is your role in the classroom when teaching with laptops? Is that a change for you? Is the change still happening?

What changes have you noticed in how time is used during class/laboratory periods?

What changes did you deem to be effective/ ineffective in how time is used in the laboratory/classroom?

How has the use of time outside the classroom/laboratory been changed or restructured?

What changes did you deem to be effective/ ineffective in how time is used outside classroom/laboratory time?

Did you notice a change in how time is used immediately, or over time?

**Interview 2**

What factors or influences encourage you to use laptop computers in your teaching?

What types of support would help you to continue your progress in using laptop computers in your classroom?

How do you think further upgrades of hardware and software will affect lesson planning and your teaching?

How do you feel about the time investment that you are making to learn and incorporate technology into your teaching?

What are your best hopes for this process of incorporating laptop computers into your teaching of biology?

**Interview 3**

How long do you think it will take to integrate laptop computers into your teaching of biology in the way you envision it? What would be important to your progress?

How might you differ from biology teachers who are not integrating technology into their instruction at this time?

Identify the most important factor or factors that will determine whether you continue to plan for and use laptop computers in your laboratory/classroom.

What advice would you give to biology teachers who have a desire to begin the process of integrating laptop computers into their instruction?

## **APPENDIX F: Teaching Materials**

### **Mid - career teacher**

#### **Used to use**

- hardware
- software
- peripherals
- Internet

### **Classroom materials and textbook**

#### **Now use**

##### **Hardware:**

- Laptops
- Projectors
- Smartboards

##### **Software:**

- PowerPoints
- UK program to make PowerPoints faster and interactive
- Academic Search Elite
- Online databases with scientific journals
- Front Page (grade 10's)
- Excel: Wizard for graphing
- Wiki, next year
- Windows 2007
- Datastudio (grade 10's)
- Pro desktop for CAD (grade 7&8)

##### **Peripherals:**

- Probes
- Digital camera

##### **Internet:**

- Genetic fly labs
- Simulations: gel electrophoresis
- Dissections
- E-mail
  - Student e-mails to her in the evening
  - Student to student e-mails

##### **Classroom materials:**

- Textbooks with CD ROMS
- Multi media package for one text

## **Experienced teacher**

### **Used to Use**

#### **Hardware**

- Networked desktops
- Desktop in lab
- Desktops, not used for instruction

#### **Software**

#### **Peripherals**

- Cameras
- TV equipment

#### **Internet**

### **Now Use**

#### **Hardware**

- Laptops

#### **Software**

- Lotus Notes
- WebCT
- Concept mapping software

#### **Peripherals**

- LCD projector
- Scanner
- Micropipettes
- Spectrophotometers

#### **Internet**

- Internet access
- University websites
- CBC sites
- NGO sites
- Medical sites
- Virtual labs: Fish Farm

#### **Email**

Textbook with disk

## **Mid - career teacher**

### **Used to use:**

#### **Hardware:**

Desktop at home to prepare handouts, instructions for labs, tests, her own notes. Had desktop on cart shared with another department, then a desktop in science office  
Scanner for handouts and overheads  
Overhead projectors  
Transparencies

#### **Software:**

Had software in one school

#### **Peripherals:**

Had electrophoresis equipment in one school  
Was able to borrow equipment from other schools in the board  
VHS to show e.g. muscle contractions

#### **Internet:**

#### **Classroom materials:**

Student packages with skeletal notes plus scanned images

### **Now use:**

#### **Hardware:**

Laptops  
SMART Boards

#### **Software:**

Excel: graphing, marks gathering  
Blackboard: discussion boards, post announcements, course materials, test dates, post exemplars, rubrics, test questions

#### **Peripherals:**

Vernier probes for the students in their labs  
Probes to measure temperature, pressure, pH plus the biotech equipment

#### **Internet:**

Movie clips of muscle contractions (on teachers' laptops only)  
Animations of biological processes  
E-mail

#### **Classroom materials:**

Textbooks, one with CDROM

## **Early - career teacher**

### **Used to use**

Hardware:

Software:

Internet:

Classroom materials:

Text book with CDROM

### **Now use**

Hardware:

Laptops

Smartboards

Software:

First Class

PowerPoint

For drawing organic compounds (not user friendly)

United Screening: school subscription

Peripherals:

Probes for real time data collection

Internet:

Website: Chime to view molecules in 3D

Freeware she can install on First Class

Java applets

E-mail:

Student to student

Student to teacher

Classroom materials:

Uses the laptop and one binder for teaching materials

Students prefer textbook over the CDROM

## **Early - career teacher**

### **Used to use**

#### **Hardware:**

Desktop computer at home to prepare lessons, handouts

#### **Software:**

#### **Internet:**

#### **Classroom materials:**

### **Now use**

#### **Hardware:**

Laptops

Smart Boards

Wireless

#### **Peripherals:**

Probeware: temperature, pH

#### **Software:**

PowerPoint

Excel for graphing

Wiki expected next year

Microsoft Office drawing

Cobweb for predator prey interactions

Academic Search Elite

Infotrack

#### **Internet:**

Animations, illustrations:

Simulations on line: gel electrophoresis and action potentials

Histology site for blood smears

PBS program, The Brain .

Attendance

E-mail

Communication with students in evening

#### **Classroom materials:**

Worksheets with websites to be consulted are a more popular home work assignment

Textbooks with CD's. CD's were never popular, got lost

## **Early - career teacher**

### **Used to use**

Hardware:

Software:

Internet:

Classroom materials:

Text with CDROM

### **Now use**

Hardware:

Laptops with cables

Laptops with tablet and stylus capability, wireless or cables

SMART Boards controlled by keyboard

SMART Boards controlled by touch

Software:

Blackboard used in house

Course site

Gradebook used for marks

Attendance

Outlook used to schedule meetings

Word document: assignments posted here

Expect to have One Note next year

Peripherals:

probes

Internet:

Search engines

Databases

Websites for food chains, interactive websites, images with content

E-mail

Homework reminders to the class

Cc parents and student advisors if work is behind

Classroom materials:

She can post a document in response to a student's need

Labs are on line and are prepared in advance in the lab, students work through them as individuals using their laptops

She posts notes or PowerPoint presentations on Blackboard ... no paper, no binder

Homework posted

No photocopying

Started using an online text (Alters and Alters)

## **Experienced teacher**

### **Used to use**

#### **Hardware:**

Desktop computers at home and in his office at school, used mainly for word processing

Computer lab with 25 networked computers

Stand alone desktop and projector in the biology lab

#### **Software:**

Had a webpage for the course

Spreadsheets

#### **Internet:**

E-mail - advised parents of webpage they could access

#### **Classroom materials:**

Textbook

### **Now use**

#### **Hardware:**

Laptops

Wireless system

#### **Software:**

##### **Management tool:**

Blackboard for marks, Attendance records

##### **Communication tool:**

Correspondence with parents, Notes from meetings

##### **Instructional tool:**

All teachers have websites for their courses with "Daybook"

Front Page

Demonstrations

Homework assignments

tests

turnitin.com used to check student work

Excel

PowerPoint

#### **Peripherals:**

Digital camera

Digital microscope

Lab probes in some other science subjects

#### **Internet:**

HHMI site for stem cell research

University of Ottawa Biology Department website

#### **Classroom materials:**

Prints out hard copies of homework assignments

Collects assignments and tests on paper

Major assignments are handed in electronically and on paper

Laptops replace the textbook

## **Early - career teacher**

### **Used to use**

#### **Hardware:**

Desktops in computer labs as an undergraduate, preservice teacher

#### **Software:**

Had made PowerPoints as a preservice teacher

#### **Internet:**

#### **Classroom materials:**

Acetates and overhead projector as a preservice teacher

Had made movies as a preservice teacher

Textbook

### **Now uses**

#### **Hardware:**

Laptop

Tablet laptop training scheduled

Whiteboard in classroom

LCD projectors

#### **Software:**

Excel for graphing

Excel for spreadsheets

Colleague presented PD on Imovie

Moodle training scheduled

For assessment

#### **Peripherals:**

Sensors : will implement them maybe next year in biology. She has used them in other science courses

#### **Internet:**

She prepares webquests

Websites

Virtual lab experiences

Animations

University sites

Environment Canada site

Science journals

E-mail

#### **Classroom materials:**

Textbooks: Grade 11 Nelson Thomas

Grade 12 Nelson Thomas

## **Experienced teacher**

### **Used to Use**

#### **Hardware**

Desktops, not used for instruction

#### **Software**

Power Point

#### **Peripherals**

Whiteboard

Laser Disk Player with images

Video Microscope with TV monitor

#### **Internet**

Internet access

### **Now Use**

#### **Hardware**

Laptops

#### **Software**

Lotus Notes

PowerPoint

Inspiration

Mind

Crossword Puzzle

#### **Peripherals**

LCD projector

Digital camera

#### **Internet**

Internet access

Animations

Videoclips

Interactive links

Tutorials

Simulated dissections

Dichotomous keys

University websites

Museum sites: Tasmanian Wolves

Simulations: Wolves of Yellowstone

Interviews (taped) with scientists

Email

## Experienced teacher

### Used to Use

#### Hardware

- Networked desktops
- Desktop in lab
- Desktops, not used for instruction

#### Software

#### Peripherals

- Cameras
- TV equipment

#### Internet

### Now Use

#### Hardware

- Laptops

#### Software

- Lotus Notes
- WebCT
- Concept mapping software

#### Peripherals

- LCD projector
- Scanner
- Micropipettes
- Spectrophotometers

#### Internet

- Internet access
- University websites
- CBC sites
- NGO sites
- Medical sites
- Virtual labs: Fish Farm

#### Email

### Textbook with disk