AN INVESTIGATION OF LAPTOP CLASSROOMS AND THE TEACHING AND LEARNING OF MATHEMATICS

by

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A thesis submitted in conformity with the requirements for the degree of Doctor of Philosophy
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Abstract

This research study is an investigation that describes how intermediate mathematics teachers use laptop technology in their classrooms and the influence of this technology on mathematics teaching and learning using the framework of the Ten Dimensions of Mathematics Education (McDougall, 2004). This study was a qualitative analysis of the experiences of six teachers, as well as the classroom environments they created with the use of technology. Data were gathered using a variety of methods including observation, field notes, interviews, and surveys.

Previous research suggests that mathematics teachers have not used laptops frequently, and when they are used, they are used in traditional ways. This study shows that there is potential for mathematics teachers to be effective implementers of laptop technology. The role of the teacher in the studied one-to-one laptop classrooms became one of a facilitator. These teachers were able to be more student-centred in their delivery of the mathematics curriculum. These teachers were also more creative and they were able to use multiple resources to demonstrate mathematical concepts. Because of the wide variety of resources available, these laptop classrooms were more exploratory in nature. These teachers faced barriers such as students being distracted and the extra time it took to plan lessons. The participants indicated that these barriers could be overcome by being patient with their students and by collaborating with their colleagues.
Using the framework of the Ten Dimensions of Mathematics Education, it was found that the presence of a one-to-one laptop environment in these classrooms influenced mathematics teaching and learning in a few key areas. The teachers in this study perceived that meeting individual needs, increased use of manipulatives and technology, and appropriate use of assessment techniques were the aspects that changed the most when laptops were present in the classroom.

One-to-one laptop technology can change the teaching and learning that takes place in schools. The researched classrooms became more student-centred, exploratory, and engaging for students. Thus, this study shows that the presence of laptop technology has the potential to move mathematics classrooms towards a more reform vision of teaching and learning.
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CHAPTER ONE: INTRODUCTION

Introduction

For over two decades, mathematics organizations and researchers have been promoting mathematics reform (Ball, 1996; Kilpatrick, Swafford, & Findell, 2001; Lampert, 1990; National Council of Teachers of Mathematics [NCTM] 1989, 1991, 2000; National Research Council [NRC], 1989; Schoenfeld, 1992; Van de Walle, 2001). A reform classroom is a student-centred environment that encourages thinking, problem solving, and communication. In this type of classroom, the teacher is not the sole voice of expertise. Students are expected to voice their opinions, defend their reasoning, and respectfully challenge the ideas of their peers (Ball, 1993; Ball, Lewis, & Thames, 2008; Lampert, 1990). To offer a theoretical framework for teacher improvement, McDougall (2004) created the Ten Dimensions of Mathematics Education. These dimensions were intended to be used so that teachers could focus on one or more aspect at a time in order to make improvements in their teaching and move to a more reform-oriented practice.

Many studies have provided support that a reform-oriented curriculum has positive outcomes for mathematics teaching and learning. Specifically, evidence has been found that reform methods increase student motivation, improve attitude towards mathematics, improve student achievement, and deepen conceptual understanding of mathematics (Boaler, 1998; Cobb et al., 1991; Fennema et al., 1996; Riordan & Noyce, 2001). Despite the large amount of research in support of the effectiveness of mathematics reform on the teaching and learning of mathematics, this type of learning environment has been slow to be adopted by mathematics teachers (Kajander, 2010; Kajander, Zuke, & Walton, 2008). Most teachers share beliefs similar to those proposed.
by the reform movement, but they overestimate their application of these beliefs to the classroom environment. In their study of reform-oriented teaching practices in primary school teachers, Anderson and Bobis (2005) found through surveys and open-ended responses:

That the majority of these teachers support reform-oriented teaching approaches that promote working mathematically in primary classrooms, particularly in a self-report survey. While most responses were consistent for both sections of the survey, a careful reading of the open-ended responses suggests that this may not be what is implemented in practice. (p. 71)

Ross, McDougall and Hogaboam-Gray (2002) found similar results in their review of research on reform mathematics. “Teachers mostly support the goals of reform but overestimate the extent to which their practices approach these goals” (p. 132). Although progress is being made, it is slow, and reform is still not common place in most mathematics classrooms.

Recently, researchers have been looking at how one-to-one learning environments can affect teaching and learning (Rockman et al., 1998; Silvernail & Lane, 2004, Silvernail et al., 2011; Zucker & McGhee, 2005). With the cost of devices decreasing each day, it is only a matter of time before more classrooms become ubiquitous computing environments. As a result, it is very important that researchers investigate the benefits of this type of environment to teaching and learning. Computers have had a significant influence on many professions, and yet, have not led to significant changes in the education system.

Although education has witnessed a multitude of both technology and innovation over the past fifty years, the educational system has scarcely changed during that time. Few would argue that doctors and dentists of fifty years ago would be competent and capable enough to practice with the technology of today. Yet, a teacher from fifty years ago would probably feel right at home in most of today’s
classrooms, as most technologies and innovations introduced during this time have been discarded. (Hooper & Rieber, 1995, p. 155)

That being said, we know that the potential is there for computers to change education. Computers can be a catalyst for reform (McDougall, 1997). Research has shown that with professional development and support from information technology specialists, change can occur (Dwyer, Ringstaff, & Sandholtz, 1991; Holcomb, 2009; Johnson, Schwab, & Foa, 1999; Rice, Wilson, & Bagley, 2001; Waxman & Huang, 1996). However, one needs to be cautious. “The mere presence of a technology-rich environment is not sufficient for enhanced teaching and learning or added value” (Dunleavy, Dexter, & Heinecke, 2007, p. 442). Teachers who simply view technology as an add-on rather than as a vehicle to transform the classroom environment will not make significant changes (Apple Computer, 1995). Thus, more research needs to be done which looks at how technology can be used as a tool that will inspire teachers to implement more reform teaching methods in their classrooms. More specifically, an examination of what aspects of reform are affected by technology needs to occur. In addition, more research needs to be done that looks at what support teachers need in order to implement computers in their classroom.

We owe it to our students to explore this potential further. Advances in technology and the Internet have enabled today’s students to find anything they want in mere seconds. Growing up in a digital world has profoundly changed them. As Prensky (2001) states, “Our students have changed radically. Today’s students are no longer the people our educational system was designed to teach” (p. 1). So, how do we, as educators, react? We must change our teaching practices in order to meet the needs of the
21st century learner. Technology allows us to do things much more quickly and efficiently and, as a result, conventional skills are less important now than they once were. Adopting reform teaching practices are essential as “problem solving, reasoning, justifying ideas, making sense of complex situations, and learning new ideas independently – not paper and pencil computation – are now critical skills” (Battista, 1999, p. 3). Mathematics educators must be more willing to adopt the ideas proposed by the reform movement, and perhaps technology is the catalyst teachers need to make the idea of reform a reality.

**Purpose of the Study**

The purpose of this study is to document and describe the influence of laptop technology on mathematics teaching and learning in the intermediate mathematics classroom using the framework of the Ten Dimensions of Mathematics Education (McDougall, 2004). Each of the ten dimensions were examined and analyzed as to whether they were enhanced or unchanged as a result of having laptop technology in the classroom. In addition, this study explores how mathematics teachers were able integrate laptop technology in their classrooms. Barriers to integration were also examined, as well as what schools can do to encourage and support teachers to use laptop technology in their classrooms.

**Statement of the Problem**

The problem focuses on how teachers can use laptop technology to assist with the creation of a mathematics classroom that is more reform-oriented and student-centred. This type of classroom encourages differentiated instruction, a collaborative and co-operative learning environment, a focus on problem solving and rich tasks, the use of
manipulates and hands-on activities, an emphasis on mathematical communication, and the use of a variety of assessment methods. My research problem is to contribute to the growing research base surrounding how teachers use computers in the classroom and their bearing on the reform of education.

The research questions are:

1. How does laptop technology influence mathematics teaching and learning in the intermediate classroom?

2. What bearing does the use of laptop technology have on the framework of the Ten Dimensions of Mathematics Education?

3. How do mathematics teachers implement laptop technology?

4. What are the barriers to the implementation of laptop technology?

Significance of the Study

More and more classrooms are integrating technology on a daily basis through the use of laptops or tablets. This study contributes to the existing research on the use of laptop computers in the classroom. There is limited research on how teachers can use the advances in classroom technology to promote mathematics reform. In addition, previous research shows mixed results about the effect of technology on the mathematics classroom. Technology can be the catalyst that makes reform mathematics common place (McDougall, 1997). That being said, some studies report that mathematics teachers are slow to embrace technology in their classrooms (Hitt, 2011; Holcolmb, 2009; Zucker & McGhee, 2005). In addition, there is some evidence that laptop technology does not have a bearing on mathematics reform (Ross, Hogaboam-Gray, McDougall, & Bruce, 2002). The current study explores how teachers can use technology to change the mathematics
classroom to a place that embraces many of the ideals of mathematics reform. Teachers can use technology to have a profound influence on their classrooms and support them in tailoring their teaching to the needs of each individual student, promoting student communication, creating an environment of collaboration and co-operation, and exploring alternate assessment methods. The description of the experiences in these classrooms can help to encourage and inspire other educators to use new technology that may be available to them to promote mathematics reform. As a result of this study, educators will know what bearing technology can have on their teaching, and potentially on the mathematics understanding of their students.

In addition, this case study explores how mathematics teachers are able to implement laptop technology in their classrooms. This case study examines the support that a teacher needs in order to use laptop technology to its fullest potential. Finally, this case study also explores the challenges that teachers have faced when trying to implement laptop technology in the classroom. Many schools who are considering a one-to-one laptop environment can learn from the findings presented in this study.

**Definitions**

*Laptop/One-to-One Classrooms:* for the purpose of this study, laptop (or one-to-one) classrooms describe classrooms in which there is a ratio of one computer (either a laptop or tablet laptop) for one student.

*Reform-Oriented Classrooms:* classrooms in which the student is the centre. In these classrooms, the teacher acts as a guide and a facilitator. A great deal of collaboration, communication, and problem solving takes place in these classrooms. Student work is focused on rich tasks.
Teacher-Led Classrooms: classrooms in which the teacher is the holder and dispenser of knowledge. In these classrooms, knowledge is generally disseminated through lecture. A great deal of drill and practice is also employed (generally from the textbook or worksheets).

Student-Centred Classrooms: classrooms in which the student is at the centre of the learning process. In a student-centred classroom, students are active participants in their own learning and often lessons are more individualized. The teacher is not the sole voice in student-centred classrooms. Instead, students are encouraged to discuss their ideas with one another.

Flipped Classrooms: classrooms in which the traditional lesson structure is flipped. The traditional lesson structure is for students to come to class and be given a lecture and then do practice questions at home for homework. In a flipped classroom, students watch a video of the lesson at home for homework. Class time is reserved for doing practice questions, problem solving, or activities.

Background of the Researcher

I have been a mathematics teacher for ten years. Initially, I was as a secondary school teacher and then made the switch to the elementary panel. I began my career teaching in a very traditional manner, teaching from a textbook, as I had been taught. I loved mathematics and was good at it, so I thought that was a good teaching method. However, it was not long before I started thinking that there must be a more effective and exciting way to teach mathematics that would have relevance to the lives of students and allow them to better understand and question mathematical concepts. Too often I would hear questions such as “When am I ever going to use this again?” and “Why do I have to
learn this?”. As well, many of my students were focused only on memorizing the rules and not on understanding the concepts. I was concerned that my students were reluctant to persist in thinking and problem solving.

Finally, when my students had a problem, they would immediately come running to me for help. They thought that I was the only one that could help them and that I was the only one whose voice mattered. All of these observations distressed me and I began to research current trends in mathematics education. In my research, I came across the reform movement which uses student-centred teaching methods with a focus on problem solving, critical thinking, and communication. I immediately wanted to use these teaching methods in my classroom.

As a result of my desire to change my teaching practices, I began my studies at the University of Nipissing to pursue my Master of Education. As one of the requirements for this degree, I completed a thesis. My research focused on an action research project on problem solving based instructional strategies in my grade six mathematics class and their effects on the mathematical development of my students. The intent was to improve the quality of my mathematics instruction and improve the critical thinking abilities of my students.

Since that time, I have become the math co-ordinator at my school. In this role, I observe and support other teachers in their mathematics classrooms. As I have been doing this job, I have noticed that many of my colleagues teach in a very traditional, teacher-directed manner. Students’ voices are rarely heard in these classrooms, and when they are, it is only to answer a question that the teacher posed. Once again, I became quite distressed. The voice of students should be more prominent. The teacher is not the only
source of knowledge; students have a great deal of knowledge to share with their peers, and they should be encouraged to do so.

As a result of my desire to enact more change in the teaching practices of mathematics teachers, I began my doctoral studies at the Ontario Institute for Studies in Education at the University of Toronto. As I was taking classes, I was further exposed to the ideas of reform mathematics and began to examine some of the barriers to implementation. Around this same time, my school began looking into becoming a one-to-one environment in which each student will bring a laptop to class. As we began the process of investigating the use of technology in the classroom, one large question came to mind.

If we simply give students access to technology, but teachers do not change their practices then we are really not changing the learning of students. With the cost of technology dropping each day, it is only a matter of time before direct access to computers is common place in classrooms. If teachers are not using this technology to change their practices to more student-centred learning environments, then student understanding may not be affected significantly. I began to wonder about how teachers could use technology to enable them to teach in a more reform-oriented way. In addition, as a teacher-leader at my school, I wondered what schools can do to help support teachers to ensure that technology implementation would lead to changes in the teaching and learning that takes place in the classroom, and that the investment would be worth it.

**Format of the Thesis**

The thesis has been organized as follows: this chapter provided an introduction and background to the current study. Chapter Two provides a review of the literature. In
this review, reform mathematics principles will be examined and summarized and
challenges to reform in mathematics will also be discussed. An overview of the Ten
Dimensions for Mathematics Education (McDougall, 2004) will also be provided. In this
summary, each dimension will be discussed. In addition, Chapter Two will include an
overview of technology in the classroom. Here, the effects of technology on the
classroom environment will be discussed, as well as barriers to effective integration and
some potential challenges teachers may face with integration of technology. I will also
explore how technology can be used to promote constructivism. Finally, I will examine
previous research on one-to-one classrooms, as well as research done specifically in
mathematics classrooms.

Chapter Three provides details of the research design of the study as well as a
description of the research context. The various data collection instruments are also
outlined. In addition, this chapter provides an explanation of the data analysis procedures.
Finally, Chapter Three includes a discussion on some of the ethical considerations in this
project.

The fourth chapter presents the findings of this study. I will provide an overview
of each of the cases, as well as present the results of the surveys on attitudes and practices
to teaching math. The main themes of the qualitative data, such as the interviews and
field notes, will be presented and summarized.

Chapter Five provides conclusions made from the analyzed data. Major themes
will be discussed, and a clear picture of how laptop computers have influenced the
intermediate mathematics classroom will be detailed. Recommendations for schools on
implementation of laptop computers will also be presented. Finally, recommendations for future research will be outlined.
CHAPTER TWO: LITERATURE REVIEW

Introduction

The objective of the proposed research study is to contribute to the existing body of knowledge surrounding the effects of technology on the teaching and learning of mathematics. More specifically, this research will look at the effect of laptop technology on the teaching and learning of mathematics using the Ten Dimensions of Mathematics Education (McDougall, 2004) as a framework. To do this, I will examine ways in which intermediate mathematics teachers are using laptop technology and describe the effects of these strategies on the ten dimensions.

In this chapter, I provide an overview of reform mathematics, its connection to current trends in mathematics education, and where educators currently stand with the implementation of reform. In addition, I present a summary of some of the challenges that educators face when implementing reform mathematics teaching methods. I also provide an overview of the Ten Dimensions of Mathematics Education (McDougall, 2004). I describe each of the ten dimensions and how they can be used to form a framework for teacher change towards more reform-oriented practices.

Next, I describe some of the effects of technology in the classroom and link the role of technology in the creation of a reform oriented classroom. Research related to one-to-one teaching environments will also be presented. I describe how technology has been used in the past by educators and what can be done to help teachers frequently implement technology in schools. I will also describe some of the challenges of and barriers to effective implementation. Finally, I provide a summary of some previous
research that has been done on the use of technology in the mathematics classrooms and its effects on the ten dimensions.

**Reform Mathematics**

Learning is an active process for students in which they need to construct their own understandings. Active learning is commonly based on the theory of constructivism (Dewey, 1902; Piaget, 1952). Constructivism is based on the idea that students learn by constructing and developing their own knowledge. “The main proposition of constructivism is that learning means constructing, creating, inventing, developing our own knowledge….Each of us constructs our own meaning and learning about issues, problems, and topics” (Marlowe & Page, 1998, p. 10). Students are placed in the centre of the learning environment, and knowledge is co-constructed through investigation and exploration. NCTM (2000) states that “students must learn mathematics with understanding, actively building new knowledge from experience and prior knowledge” (p. 20).

Traditionally, a mathematics class has the following structure: begin by reviewing the previous day’s work, introduce a new topic (teacher led) with a note on the board and a few examples, assign seatwork to the students (traditionally textbook based), and assign homework. The teacher-led method relies on direct instruction and skill and drill and is transmission based. In other words, the teacher is the centre of the learning environment, and knowledge is transmitted from the teacher to the student. Battista (1999) states “according to the traditional view, students acquire mathematical skills by imitating demonstrations by the teacher and the textbook. They acquire mathematical concepts by absorbing teacher and textbook communications” (p. 4).
There are some educators who believe very strongly in the benefits of traditional teaching using direct instruction (Hattie, 2009; Przychodzin-Havis, Marchand-Martella, Martella & Azim, 2004; Stockard, 2010). In mathematics, there has been considerable debate about traditional versus reform teaching (Laterell & Copes, 2003; Reys, 2001). In addition, many parents are upset with some of the changes that have been made in the mathematics curriculum and do not believe that their children have a solid foundation of mathematical skills (Reynolds, 2012). There are other educators who understand that there is a time and a place for both methods of teaching mathematics (Daro, 2003; Schoenfeld, 2004) and that what is best for students must be placed at the forefront of all decisions. The key, however, is to understand the need to go beyond solely using traditional methods of teaching and introduce methods of teaching in which the student voice can be heard and in which students are given the opportunity to construct their own understanding of mathematics.

Brooks and Brooks (1993) report that “student thinking is devalued in most classrooms. When asking students questions, most teachers seek not to enable students to think through intricate issues, but to discover whether students know the right answer” (p. 7). Such practices are disheartening as there is considerable research which supports active learning in a classroom. Perkins (1999) states “active engagement in learning may lead to better retention, understanding, and active use of knowledge” (p. 8). Thus, although there can be a time and a place for traditional teaching methods, this cannot be the only method used. It is very important that teachers put an emphasis on problem solving and communication in their classes, and they need to develop critical thinking skills in their students. The challenge, however, is to give teachers support and
development to make these changes. That being said, the process of teacher change can be overwhelming. McDougall (2004) created the Ten Dimensions of Mathematics Education so that teachers had a framework that could be used to break down some of the key features of a reform classroom. These dimensions make it easier for teachers to focus on a few aspects at a time in order to slowly change their practices.

Over the past twenty years, mathematics educators have realized that there is a need to better prepare students for a rapidly changing and complex world. Students need to be trained to think, understand, and make sense of their learning. In addition, questioning, thinking critically, and problem solving are important skills for students to learn. Reform in mathematics has been a particular focus in much of the recent mathematics education research. Organizations such as the National Council of Teachers of Mathematics (NCTM, 2000) and the National Research Council (NRC, 1989), as well as the Ontario Mathematics Curriculum (Ontario Ministry of Education (OME), 2005), and the reports of the expert panels in Ontario (OME, 2003; OME, 2004a; OME, 2004b) all note how important it is to teach mathematics for understanding. As was mentioned, however, despite the push for reform in mathematics, there has been much resistance to its implementation and there has been debate surrounding reform (Laterell & Copes, 2003; Reynolds, 2012; Reys, 2001). The following section will provide a brief description of some of the features of reform mathematics, an introduction to the Ten Dimensions of Mathematics Education, and a short discussion on the challenges of implementing a reform curriculum.
Principles and Standards for School Mathematics

In 1989, NCTM published *Curriculum and Evaluation Standards for School Mathematics*. This was an extremely important document that was focused on getting educators to shift their view away from mathematics content and towards how children could most effectively learn mathematics. In the late nineties, the NCTM began revising these Standards, and in 2000, they published *Principles and Standards for School Mathematics*. It is the belief of NCTM that “students should have frequent opportunities to formulate, grapple with, and solve complex problems that require a significant amount of effort and should then be required to reflect on their thinking” (NCTM, 2000, p. 52). In order to do this, classrooms must be created in which students are encouraged to explore, share their understandings with one another, and question the ideas of others.

Within the recommendations in the *Principles and Standards for School Mathematics*, the NCTM proposes five process standards for school mathematics. These principles, problem solving, reasoning and proof, communication, connections, and representation, are directly linked to what students learn to do in a reform-oriented classroom. In addition, all of these standards are an integral part in helping children understand the mathematics they are learning. As the NCTM (2000) states:

When students are challenged to think and reason about mathematics and to communicate the results of their thinking to others orally or in writing, they learn to be clear and convincing. Listening to others’ explanations gives students opportunities to develop their own understandings. Conversations in which mathematical ideas are explored from multiple perspectives help the participants sharpen their thinking and make connections. Students who are involved in discussions in which they justify solutions – especially in the face of disagreement – will gain better mathematical understanding. (p. 60)
Of course, creating classrooms in which processes such as problem solving, communicating, reasoning and justifying are the norm begins with teachers. Teachers play an important role in the development of students’ problem-solving dispositions by creating and maintaining classroom environments, from prekindergarten on, in which students are encouraged to explore, take risks, share failures and successes, and question one another. In such supportive environments, students develop confidence in their abilities and a willingness to engage in and explore problems, and they will be more likely to pose problems and to persist with challenging problems. (NCTM, 2000, p. 53)

Also in 1989, the National Research Council (NRC) published *Everybody Counts: A Report to the Nation on the Future of Mathematics Education*. This was an important document to assist educators to create classrooms in which reform mathematics principles were the norm. “Seeking solutions, not just memorizing procedures; exploring patterns, not just learning formulas; formulating conjectures, not just doing exercises” (NRC, 1989, p. 84) became focal points for teachers. The NRC supported these teaching changes so that students would have “opportunities to study mathematics as an exploratory, dynamic, evolving discipline rather than as a rigid, absolute, closed body of laws to be memorized” (p. 84).

In 2001, the NRC published another document called *Adding It Up: Helping Children Learn Mathematics*. In this publication, the term “mathematical proficiency” (Kilpatrick, Swafford, & Findell, 2001, p. 116) was introduced. Mathematical proficiency is comprised of five intertwined strands which summarize what it means to learn mathematics successfully. Conceptual understanding is the first strand. This strand is about the comprehension of concepts and operations. The second strand is procedural fluency. This strand is about students being skilled in carrying out procedures accurately and efficiently. Procedural fluency is what most people who have been taught
traditionally believe mathematics is all about, the ability to do math correctly and quickly. Strategic competence, the third strand, is the ability to solve mathematical problems. The fourth strand, adaptive reasoning, is the ability to reflect, explain, and justify answers. The final strand, procedural disposition is the ability to see the mathematics as useful and worthwhile (Kilpatrick et al., 2001, p. 116). All five of these strands are directly linked to what students learn to do in a more student-centred classroom. Thus, learning mathematics with understanding relies heavily on problem solving, communicating, reasoning and justifying, which are all at the heart of mathematics reform.

In 1995, a standards-based curriculum, formed from the NCTM standards, that was intended to be student-centred was developed in Ontario, Canada. This curriculum was revised in 2005, but many of the principles remain the same. The beliefs presented in the Ontario curriculum are similar to those in the reform movement in mathematics:

Learning mathematics results in more than a mastery of basic skills. It equips students with a concise and powerful means of communication. Mathematical structures, operations, processes, and language provide students with a framework and tools for reasoning, justifying conclusions, and expressing ideas clearly. Through mathematical activities that are practical and relevant to their lives, students develop mathematical understanding, problem-solving skills, and related technological skills that they can apply in their daily lives and, eventually, in the workplace. (OME, 2005, p. 3)

Like the Principles and Standards, this document includes mathematical processes that students need to learn as they work through the five content strands. These processes are: problem solving, reasoning and proving, reflecting, selecting tools and computational strategies, connecting, representing, and communicating. This document also stresses the importance of teaching for understanding. Students are asked to reason and justify
answers, and this document encourages teachers to provide activities which will allow students to investigate and explore mathematics and to connect mathematics to their world.

**The Current State of Reform Mathematics**

The ideas presented in the section entitled “Principles and Standards for School Mathematics” have been around for over two decades. Some mathematics educators have been quick to make changes in their practice, while others have been slower to adopt some of the ideas described in the reform movement. Thus, the question to consider is where does the mathematics education community currently stand with reform mathematics?

One of the critiques that teachers had about some of the ideas of reform were that they were great in theory, but not as easy to implement in practice. For example, opening up one’s classroom in the way that Ball (1993) and Lampert (1990) describe takes a great deal of time. This type of classroom has been recently termed a math talk learning community. A math talk learning community is “a classroom community in which the teachers and students use discourse to support the mathematical learning of all participants” (Hufferd-Ackles, Fuson, & Sherin, 2004, p. 82). Creating such a classroom community is a huge undertaking. Students need time to learn how to talk to each other respectfully, how to express their ideas and opinions, and how to listen to the ideas of their peers. Teaching a concept in the traditional manner, where the teacher directly tells the students a procedure and then gets them to practice it, might take one class, perhaps two. Allowing students the freedom to explore a concept, consider all viewpoints, and present all ideas before coming to a conclusion, can take much longer. Many teachers
indicate that they would love to teach in this manner, but they simply do not have the
time because the curriculum has so many expectations to get through. Teachers feel that
they must “cover” all the expectations in the curriculum documents. As a result, some
students do not gain a deep understanding of what they are doing, and for them,
mathematics continues to be a mysterious subject with many rules to follow.

The NCTM realized that mathematics teachers were becoming too focused on
getting through all the content and were not able to focus on the things that were most
important. Students could not develop deep understandings and connections because they
were expected to become familiar with such a wide range of topics in a relatively short
period of time. The NCTM realized that students were being expected to do a lot, but that
it was never truly clear what the key idea or focus was. In order to get teachers to focus
on larger, bigger topics in mathematics rather than a bunch of small expectations, the
NCTM created the Curriculum Focal Points in 2006.

The NCTM felt that the Curriculum Focal Points would provide a consistent set
of key mathematical concepts for each grade level. The hope is that educators will use
these focal points to facilitate deep understanding, mathematical fluency, and coherence
among mathematical topics. As NCTM (2006) states:

Organizing a curriculum around these described focal points, with a clear
emphasis on the processes that Principles and Standards addresses in the Process
Standards—communication, reasoning, representation, connections, and,
particularly, problem solving—can provide students with a connected, coherent,
ever expanding body of mathematical knowledge and ways of thinking. Such a
comprehensive mathematics experience can prepare students for whatever career
or professional path they may choose as well as equip them to solve many
problems that they will face in the future. (p. 1)
The NCTM believes that the Curriculum Focal Points are vital elements in developing a mathematics program that emphasizes problem solving, critical thinking, and communication. In addition, the NCTM believes that getting teachers to focus on the most important aspects of mathematics will enable them to better achieve the goal of reform. As NCTM (2006) states, “students would have opportunities to explore these topics in depth, in the context of related content and connected applications, thus developing more robust mathematical understandings” (p. 4). The NCTM also hopes that these Curriculum Focal Points will become the launching point for future discussions about curriculum standards, assessment, and the content of textbooks.

This work may assist in the creation and eventual development of new models for defining curriculum, organizing instruction, developing materials, and creating meaningful assessments that can help students learn critical mathematical skills, processes, and ways of thinking and can measure and communicate what students know about the mathematics that we expect them to learn. (NCTM, 2006, p. 2)

Other mathematics education experts have recognized the importance of teaching teachers to focus on the big ideas. One of the most well known educators promoting the notion of focusing on larger, key concepts in mathematics is Marian Small. Small (2009) wrote Big Ideas from Dr. Small: Creating a Comfort Zone for Teaching Mathematics in order to help teachers focus on what was most important in mathematics. She created the big ideas to help teachers understand the purpose behind a lesson and to see the connections between various topics in mathematics. As she states:

One of the many gaps in many teachers’ mathematical backgrounds is an internal map of the subject. They lack a fundamental understanding of how various mathematical topics interconnect, which topics are more important in the long term than others, and which aspects of those topics are most important. As they teach, many teachers often feel like they are going through a checklist, checking off whether students have learned each new discrete concept or skill listed in the curriculum. This is in stark contrast to what we know from research about how
much more effective it is for students to learn when connections are explicitly made between new knowledge and ideas that students already know. Big ideas help teachers and students make these connections. (Small, 2009, p. xii)

In addition, Small teaches the importance of making these big ideas explicit to students. Finally, teachers should make sure that they plan both their instruction and assessment by considering the big ideas. As Small (2009) states, “too often our assessment focuses on the details and often less important aspects of the mathematics when it is the big picture that really matters” (p. xiv).

While the NCTM’s (2006) Focal Points and Small’s (2009) Big Ideas are important additions to the efforts of educators to promote a more constructivist view of learning, they can also be questioned in terms of placing too much of an emphasis on focusing on content and mathematical processes. As opposed to viewing mathematics as more open-ended and dynamic, the focal points and big ideas can be viewed as more fixed on particular concepts of mathematics. Although this might help students master the content more easily, one must wonder if focusing on the focal points and big ideas will help students become better critical thinkers and problem solvers.

Those in the mathematics education community are also realizing that properly training pre-service teachers about the ideas in reform mathematics can facilitate more frequent implementation of mathematics reform methods in schools. The more people who are given training to the ideas and vision presented in mathematics reform, the more likely it is to spread into more schools. As younger teachers enter the profession, they bring enthusiasm and new ideas. Older teachers may see what some of the newer teachers are trying and may be more likely to enact change in their own classrooms. Teacher education is not an easy undertaking, however. Many teacher education programs have
limited time to devote to instruction on mathematics teaching and learning. For example, Ontario is a one-year teacher certification program and elementary teachers are required to take one mathematics methods course that is 36 hours in length, but in reality ends up closer to 24 hours (Kajander, 2010, p. 230). In this time, however, instructors cannot just focus on mathematics pedagogy; they must also focus on classroom management, assessment, and mathematics content. Thus, although teacher education programs are attempting to teach new teachers about reform-oriented mathematics, it is a challenge. Kajander (2010) recommends that “more time in such programs appears to be required for conceptual understandings as needed for teaching to more fully develop” (p. 249).

There is recent evidence that teachers in Ontario are making progress in the attempt to change to a more reform-oriented teaching method (Annable, 2006; Jao, 2009; LeSage, 2005). That being said, widespread adoption of reform methods has still not occurred. In my role as a curriculum leader of mathematics, I can report first hand on the challenge it has been to get some of my colleagues to move towards a more student-centred way of teaching. In addition, Kajander (2010) and Kajander, Zuke and Walton (2008) indicate that many pre-service teachers find it a challenge to implement the reform methods they learn about in their methods class because many of their teacher supervisors do not employ these methods. In addition, there is evidence that although teachers believe in the main tenets of the reform movement they are not implementing these ideas in practice (Anderson & Bobis, 2005; Ross, McDougall, & Hogaboam-Gray, 2002).

Thus, currently in the mathematics education community, and particularly in Ontario, the ideas first presented by the NCTM, NRC, and others in the 1980s are still
being promoted today. The ideas have been adapted to reflect a new focus on big ideas or focal points and also on promoting a math talk learning community, but the basic tenets remain the same. Mathematics coaches, facilitators, consultants, and researchers and instructors at the faculties of education are still working very hard to teach teachers how to move away from solely using traditional methods and toward using more reform, student-centred methods of teaching. As was outlined in the section describing the current state of mathematics reform, progress is being made, but it is very slow. There are still many teachers who have not yet begun to make significant changes in their classroom practice. Some of the reasons for this lack of adoption are described in the next section.

**The Challenges of Reform**

Despite the research that supports reform teaching in mathematics classrooms, change in mathematics teaching has been slow. One must ask, then, why are classrooms not changing? There are a few obstacles to overcome for teachers who wish to offer a more reformed mode of instruction. One of the main challenges to reform is the resistance from teachers. Change is difficult. Teachers are hesitant to change for three reasons. To begin, in education there can be frequent curriculum changes. Just as teachers are becoming accustomed to one idea, another one comes along. Lortie (1975) pointed out, “teachers have a built-in resistance to change because they believe that their work environment has never permitted them to show what they can really do” (p. 235). Thus, teachers can be hesitant to try something new because it may not last very long or they may not be given a chance to see what they can really do with the new idea.
Second, some teachers, especially those of younger students, may not have a solid background in mathematics (Ball, 1996; Clarke, 1997). These teachers do not have confidence in their own mathematical abilities, so opening up the classroom to the ideas of their students can be daunting. Prior experiences with mathematics can also play a large role in shaping beliefs about teaching. Another concern that is related to Clarke’s research is that teachers today are being asked to teach using a method that is very different from how they themselves were taught. So, they revert to a more teacher-led approach which is more comforting because they know what to expect. Ball (1996) writes:

Elementary teachers are themselves the products of the very system they are now trying to reform. An overwhelming proportion of them are women, and the majority did not pursue mathematics coursework beyond what was minimally required. Many report their own feelings of inadequacy and incompetence with regard to mathematics, and some can even recall experiences that became turning points that caused them to stop taking mathematics. Rather than look critically at the way we handle mathematics in school, they often assume that their negative experiences reflect their own mathematical inadequacies or stem from the inherently useless content of mathematics. Those same experiences have equipped them with ideas about the teacher’s role, about who can learn mathematics, and about what it takes to learn and know mathematics. (p. 504)

Even educators who want to teach in a reform-oriented way and believe in the ideas presented by the reform movement face challenges if they lack subject knowledge.

Limited subject matter knowledge restricts a teacher’s capacity to promote conceptual learning among students. Even a strong belief of “teaching mathematics for understanding” cannot remedy or supplement a teacher’s disadvantage in subject matter knowledge….Because of their own deficiency in subject matter knowledge, their conception of teaching could not be realized. (Ma, 1999, p. 36)

A great deal of professional development must be offered in order to assist educators with changing their practice. As Ball (1996) states, “to learn to teach mathematics as we were
taught is hard enough. To learn to teach in the ways envisioned in the new math standards is harder still” (p. 505). There are documents in Ontario that offer strategies to help mathematics educators plan and implement the required curriculum, and they offer many examples and references to help those who are unsure feel more confident with teaching mathematics (Ontario Ministry of Education, 2003; Ontario Ministry of Education, 2004b). In addition, the ten dimensions framework was created as a guide to help teachers change. Finally, the implementation of peer coaching and math coaches in schools can also have a positive effect.

Third, teachers can be resistant to change due to a feeling of isolation from one another. There is not a great deal of time set aside for teachers to discuss teaching methods with their colleagues or observe the teaching of others. Without exposure to the ideas of others, teachers will often revert back to what is comfortable to them. Stigler and Hiebert (1999) state:

The isolation of U.S. teachers has greatly hindered our discussions about teaching and hence our ability to improve it. U.S. teachers rarely have the opportunity to observe other teachers in action and are rarely observed by other teachers. For whatever reason, teaching in the United States is considered a private, not a public, activity. (p. 123)

Although this quote refers specifically to the United States, the situation is similar in Canadian schools. Canadian teachers are expected to do all their preparation, marking, and conferencing in a relatively small amount of release time. As a result, Canadian teachers can become isolated from one another, which can lead to less collaboration with their peers.

Fullan (1982) lists three criteria that teachers use to measure change. Each of these criteria requires teachers to ask themselves a question. To start, does the change
address a need? Will the students be interested, and will they learn? Second, how clear is the change in terms of what the teacher will have to do? Finally, how will the change affect the teacher personally in terms of time, energy, new skill, sense of excitement and competence, and interference with existing priorities? Change can be overwhelming and uncomfortable, as the answers to these questions are all unknown to a teacher, especially when making a change as large as changing the way they teach mathematics.

In addition to resistance from teachers, there is some debate among parents and others surrounding the issue of reform methods versus traditional methods of teaching. In the United States, this debate is described as the “Math Wars” (Laterell & Copes, 2003; Reys, 2001). On one side of this “war” are educators who believe in a more traditional approach to mathematics which emphasizes skill and drill. There are others who believe in a more student-centred, reform approach to teaching. A recent article in Macleans (Reynolds, 2012) outlines some of the concerns that parents have as mathematics classrooms move away from the traditional, teacher-led environment that they remember. We must make sure, however, that the needs of the students do not get forgotten. As Marshall (2003) states, “children in school today – and tomorrow – will need more mathematics than their parents did yesterday, and they will need to be taught in a far better way” (p. 194).

The Ten Dimensions of Mathematics Education

One way to make mathematics reform more commonplace is to provide a theoretical framework for teachers and leaders. A framework can be used to help make professional development more effective as it gives teachers specific areas to focus on. As has already been mentioned, one framework that has been used in elementary and
secondary classrooms is the Ten Dimensions of Mathematics Education (McDougall, 2004). This framework was created after researchers identified common areas of teaching which could be focused on in order to improve mathematics instruction and make it more aligned with the reform standards. Many current research studies have used the Ten Dimensions of Mathematics Education as part of their research framework (Egodawatte, McDougall, & Stoilescu, 2011; Jao, 2009; McDougall, 2009; McDougall et al., 2010; McDougall, Ross, & Ben Jaafar, 2006). The Ten Dimensions of Mathematics Education (McDougall, 2004) are depicted in Figure 1.

Figure 1 The Ten Dimensions of Mathematics Education (McDougall, 2004)
The first dimension is focused on planning and implementing the curriculum. This dimension is called Program Scope and Planning. Within this dimension, it is important that teachers focus on the key ideas in mathematics, as was also described previously with the NCTM’s Curriculum Focal Points (2006), and Marian Small’s Big Ideas (2009). In addition, teachers should include all strands of mathematics in the classroom, often looking to connect two or more of these in one unit or lesson. Teachers should also consider the mathematical processes (problem solving, reasoning and proving, reflecting, selecting tools and computational strategies, connecting, representing, and communicating) when planning. Finally, it is important that teachers incorporate a variety of resources when delivering their program.

Meeting Individual Needs is the second dimension in the framework. Essentially, this dimension encourages teachers to differentiate their instruction, provide a variety of choice in mode of delivery, and balance lesson styles. The use of open-ended tasks and problems is also encouraged. The main goal of this dimension is to honour different learning styles and offer a variety of options that will meet each learner’s needs.

The next dimension is Learning Environment. This area not only deals with the physical layout of the classroom and varying the organization of the room, but also on how the students are grouped in order to promote collaboration, co-operation, and interaction. Learning is a social process, and teachers need to set up their environment in such a way that communication is encouraged. In addition, teachers need to create a learning environment in which students feel comfortable to give their input and also allow students some choice in their learning.
One of the main teaching methods promoted in the reform movement is the use of rich tasks and problem solving. Thus, Student Tasks is the next dimension. It is important that mathematics teachers offer a balance between skill and practice, application of procedures and rich problem solving tasks. In addition, teachers should focus on as many real world applications as they can. Finally, all activities in the classroom, whether they are skill, procedures, or tasks, should be interesting and engaging for the students.

At the heart of the reform-movement is the belief that children learn by constructing their own knowledge. Thus, teachers should be encouraged to use a variety of approaches, but always use constructivism as a foundation. Thus, the fifth dimension is called Constructing Knowledge. One way to help students to construct knowledge is to use questioning. Teachers can use questioning techniques to elicit mathematical thinking and deepen understanding. Much research has been done that looks at the benefits of questioning techniques and how to use them to create a math talk learning community (Ball, 1993; Chapin, O’Connor, & Anderson, 2009; Hufferd-Ackles, Fuson, & Sherin, 2004; Lampert 1990). Such a community is the kind of ideal classroom that is described in the ten dimensions framework.

For students to achieve their potential, teachers, students, and parents must work together. The Communicating with Parents dimension honours this important relationship and encourages teachers to communicate regularly about student performance, the mathematics program, and mathematics education in general. Upfront and frequent communication with parents may also help with one of the barriers to reform implementation described on page 26 in the section entitled “Challenges to Reform”, which is the pressure from parents to teach in a more traditional manner. If parents are
regularly contacted about their child’s progress and the purpose of certain tasks or activities, their concerns may be alleviated. In addition, teachers need to show that they are open to the input of parents. Working together is the best way to help students achieve success.

Manipulatives and Technology is the next dimension. Students need to be given opportunities to use manipulatives as they are exploring mathematical concepts and procedures. Manipulatives can also help students communicate their understanding. As will be shown in the next section, technology can also be used to improve student learning. Once again, varying instruction and giving students choice is a key aspect of this dimension.

One of the most important aspects of a reform-oriented classroom is the presence of the student voice. Thus, Students’ Mathematical Communication is the eighth dimension. Students should be encouraged to use oral, written, and physical forms of communication to express their mathematical understanding. In addition, students should be encouraged to explore their own ideas and defend and justify their thinking to their peers.

Assessment is the ninth dimension in this framework. As classrooms become more student-centred and teaching practices change, assessment practices also need to change. Teachers should use a variety of assessment tools for a variety of purposes. Teachers need to realize that different tools can be used for different students. Assessment can also be done for a variety of reasons, and it is not always done to assign a grade. In addition, teachers should strive to provide students with frequent and immediate constructive feedback. Finally, students should be taught to self-assess and peer-assess.
The last dimension is Teacher’s Attitude and Comfort With Mathematics. Student learning is affected by the teacher’s attitude toward mathematics and their comfort level with mathematics. Showing a love for mathematics will trickle down to students and have a positive effect. In addition, being comfortable with the subject will enable teachers to open their classrooms up to the ideas of their students and will give them the confidence to use rich problem solving tasks where there is not always one clear answer.

I have chosen to use the Ten Dimensions of Mathematics Education as a framework to explore the influence of laptops on the mathematics classroom. I feel that using this framework will better enable me to see which aspects of the mathematics classroom are enhanced with the presence of technology and which are not. In addition, it will give me a clearer picture of what kind of a bearing laptop technology has on the teaching and learning of mathematics. Although these dimensions are separate areas of focus, many of them do intertwine and have an effect on one another. Since this framework has been used in the past to help teachers and administrators move closer to meeting the standards set out by the NCTM (2000), it will be interesting to see what bearing laptops have on each dimension.

**Technology in the Classroom**

Over the last decade, advances in technology have made computers in the classroom much more common place. As technology continues to improve, and the cost of devices such as tablets and laptops decrease, more and more classrooms will become environments in which each student has access to a computer. This type of access certainly has the potential to significantly change the classroom environment in elementary schools; yet, educators need to be careful. Simply placing computers in every
classroom will not necessarily change classroom learning. As Cuban (1986, 2001) found, teachers infrequently used computers in their classrooms. He also noted that classroom teachers tended to use computers for word processing and drill and practice.

Clearly, technology alone is not a magical solution to deepening student understanding. Teachers must be ready to change their teaching practices as they embrace technology in the classroom. NCTM (2000) states “the existence, versatility, and power of technology make it possible and necessary to re-examine what mathematics students should learn as well as how they can best learn it” (p. 25). Technology can assist teachers in deepening student understanding if they are willing to revise their beliefs about mathematics teaching and learning. Technology must be viewed as a tool to help inspire teachers to transform their teaching practices; otherwise, it will fail to have any meaningful effect on the learning of students. As NCTM (2000) states:

The effective use of technology in the mathematics classroom depends on the teacher. Technology is not a panacea. As with any teaching tool, it can be used well or poorly. Teachers should use technology to enhance their students’ learning opportunities by selecting or creating mathematical tasks that take advantage of what technology can do efficiently and well – graphing, visualizing, and computing. (p. 26)

**Effects of Technology**

Technology has been shown to have many positive effects on teaching and learning. Research by Gulek and Demirtas (2005) provides evidence that laptop programs have a significant effect on student achievement. Peck and Dorricott (1994) found that technology can help teachers individualize instruction and it can enable students to solve complex problems. On a similar note, advances in technology enabled students to work on problems that were richer and more real (Johnson, Schwab, & Foa, 1999; Sturdivant,
Dunham, & Jardine, 2009). Technology can also assist teachers in moving away from their traditional role. Technology “can help a teacher transition from being a ‘sage on the stage’ to being a real facilitator of student learning” (Mortensen, 2011, p. 20). Johnson, Schwab, and Foa (1999) made a similar conclusion:

Technology levels the playing field and creates true learning communities where everyone (including the teacher) is an active learner, and everyone becomes a teacher. Technological complexity therefore tends to change the traditional roles of teachers and students and how teachers organize their curriculum, students, and classrooms. (p. 29)

A great deal of research has also been done on the effects of laptops on the teaching and learning environment. Laptops can have a positive effect on the attitude of students. Laptops have been shown to raise student interest and engagement (Grimes & Warschauer, 2008; Holcomb, 2009; Maninger & Holden, 2009). Holcomb (2009) also found that one-to-one environments decreased absenteeism, decreased discipline issues, and improved the quality of student work. Student interaction and collaboration can also improve in laptop classrooms (Dunleavy, Dexter, & Heinecke, 2007; Grimes & Warschauer, 2008; Holcomb, 2009; Fonkert, 2010; Mortensen, 2011). “The use of laptops seemed to act as a magnet to draw students together. During my observations, students seemed to collaborate more frequently when they were using computers than when they were not” (Fonkert, 2010, p. 305). Finally, laptops can help teachers meet the needs of today’s learners. “Laptops facilitate the kinds of learning, thinking, and analysis that today’s world demands” (Warschauer, 2005/2006, p. 35).

Despite many of the positive effects of technology on teaching and learning, researchers have found that technology does not always enhance learning. Donovan, Green, and Hartley (2010) found that laptops did not improve student engagement. In
fact, the researchers found that laptops led to off task behaviour. The researchers noted that although students were using computers, this increased use of technology did not equate to increased use for academic purposes. Similar findings were reported by Hu (2007). In addition, Hu (2007) reports that many districts are dropping laptop programs because they are not improving academic achievement. Laptop initiatives have also been criticized as being high cost with little gain (Hu, 2007). Goodwin (2011) echoes these concerns and notes that research has shown mixed or no results for one-to-one programs.

**Technology and Reform**

Many believe that technology holds great promise for transforming education and making it more student-centred. As Fonkert (2010) writes, “an increasing potential exists for computers to help teachers make further changes in their instructional practice and to achieve the vision set forth by NCTM” (p. 307). On a similar note, Johnson, Schwab, and Foa (1999) write, “perhaps the real benefit of educational technology will be an institutional transformation to a more student-centred and learning-focused educational process” (p. 30). Finally, Fisher, Dwyer, and Yocam (1996) found:

> Technology itself is a catalyst for change, encouraging fundamentally different forms of interactions among students and between students and teachers, engaging students in high-order cognitive tasks, and prompting teachers to question old assumptions about instruction and learning. (p. 8)

Research specifically done in laptop classrooms is generally positive about the influence of technology on reform (Dunleavy, Dexter, & Heinecke, 2007; Fonkert, 2010; Lowther, Ross, & Morrison, 2003; Maninger & Holden, 2009). However, it may not be the laptops themselves that are creating this change. Rather, it may be what the laptops allow teachers to do that makes change possible.
It is really not about the laptops. It is about what the 1:1 laptops enable in terms of new ways of teaching and learning. Our results indicate that the 1:1 student to networked laptop ratio contributes generally and significantly to the effectiveness of being more learner-, assessment-, community-, and knowledge-centred. (Dunleavy, Dexter, & Heinecke, 2007, p. 451)

Research done in mathematics classrooms also shows support that technology can enable teachers to be more constructivist (Guerrero, Walker & Dugdale, 2004; Waxman & Huang, 1996). “There is evidence that teachers who use technology as an integral part of their mathematics instruction tend to foster a more constructivist learning environment” (Guerrero, Walker, & Dugdale, 2004, p. 18). That being said, Li and Ma (2010) found that the effects of computer technology on mathematics achievement were enhanced in environments where a constructivist teaching approach was utilized. Thus, what is still unclear is whether technology leads to reform methods or whether technology is more successful for those that already teach in a reform-oriented way.

What is clear is that there are still many questions about the ability of technology to act as a catalyst for reform. Despite the research that suggests that there are positive aspects of technology, there are still many mixed results. Ross, Hogaboam-Gray, McDougall, and Bruce (2002) found that “technology did not have a huge impact on the implementation of mathematics education reform” (p. 98). That being said, they did find positive effects on some dimensions of reform. Other researchers found that improving access to technology has not led to increased use or movement towards more student-centred methods (Cuban, 2001; Cuban, Kirkpatrick, & Peck, 2001; Wallace, 2004). Many teachers are still using technology for fairly traditional uses, such as note taking. In his review of many studies, Penuel (2006) concluded:
The most common uses appear to reflect the fact that the observed students’ teachers are in an ‘adaptation’ stage of technology adoption. In other words, they are adapting traditional teaching strategies to incorporate more adult productivity tools and having students work independently and in small groups, but they have not yet begun to implement widely more student-centred strategies for instruction. (p. 336)

Thus, it appears that more research needs to be done which looks at the connection between reform and technology and how effective computers are as a catalyst for transforming education. “We still lack evidence about how widespread and effective computers are for helping teachers become more effective implementers of constructivist approaches to teaching” (Becker & Ravitz, 1999, p. 380).

**Challenges of Integrating Technology in the Classroom**

Despite many of the positive effects of integrating technology in the classroom, it has been shown that many teachers are not using technology to its potential. It is possible that this lack of integration can be attributed to the challenges that technology brings to the classroom environment.

Teachers have many concerns about using technology in the classroom. The most common concern is the amount of time that it will take teachers to learn to use a new tool. (Bauer & Kenton, 2005; Bennison & Goos, 2010; Rice, Wilson, & Bagley, 2001). Another concern is the lack of access to technology (Bauer & Kenton, 2005; Becker, 1998; Bennison & Goos, 2010; Rice, Wilson, & Bagley, 2001). Finally, technical problems can be a barrier to frequent use of computers (Grimes & Warschauer, 2008). Many teachers do not have the training or knowledge to deal with problems as they arise. As a result, their fear of something going wrong may prevent them from using technology in the classroom. To summarize, Kay (2011) states:
Many teachers experience a number of challenges when trying to use computers in their classrooms including the amount of time required to learn new software, fear and anxiety associated with using technology, limited technological skills, and insufficient access to software and hardware. (p. 142)

In addition, teachers have not been shown how to use technology properly. Many teachers think that they can simply do what they have always done, but with computers. As Hawkins (1996) found:

In the early stages of development, technology failed to transform education. Instead it seemed that technology was more appropriate for the ways things were traditionally done. This is a dilemma as technology alone will not lead to an educational revolution. (p. 37)

On a similar note, DeCorte (2001) explains that one of the causes of the failure of educational computing is that it has been introduced as an add-on to an otherwise unchanged instructional setting (p. 15528). Instead, computer technology must be embedded in powerful educational environments.

Embedding means here that the computer is not just an add-on, but is judiciously integrated in the environment capitalizing on its specific strengths and potential to present, represent, and transform information and to induce effective forms of communication, interaction, and cooperation. (p. 15529)

Becker and Anderson (1998) found that mathematics teachers were less likely than other teachers to use computing technology in instruction. The teachers surveyed reported that computers were not worth the time commitment, were extraneous to “real” mathematics and were difficult to use. Sturdivant, Dunham, and Jardine (2009) found that teacher beliefs can be a barrier if a teacher believes that mathematics is all about learning rules and procedures. These teachers have the opinion that “technology is a ‘black box’ or a crutch that prevents students from learning ‘real’ mathematics” (p. 164). As a result, these teachers are less likely to integrate technology into their classrooms.
Another concern is that technology is supposed to support and enhance the learning of mathematical concepts. The point is not for students to focus on mastering the technology, but rather on understanding the underlying mathematical concept. In her reflection on using graphing calculators in the mathematics classroom, Hatten (2009) found that classroom talk was focused on how to use the technology rather than on what mathematical ideas the technology was assisting the students in discovering. As she states, “I now make sure that students are engaging in conversations that focus on their conceptual understanding of the mathematics rather than on the use of the technology” (p. 89).

Finally, teaching is about making personal connections. Ellis-Monaghan (2010) found that “web delivery of course content often shifts the onus of learning onto the student, which is valuable, but risks reducing personal teacher-student interactions. Educational technology must enhance, and not replace, valuable human contact time” (p. 335). As NCTM (2000) states, “technology does not replace the mathematics teacher….the teacher plays several important roles in a technology-rich classroom, making decisions that affect students’ learning in important ways” (p. 26).

As technology becomes more prevalent in classrooms, all of these challenges are important to consider and it will be important to find solutions to help teachers overcome these concerns. That is why this research seeks to find out how teachers are implementing laptop technology in their classrooms and what some of the barriers are to the implementation of laptop technology.
**Overcoming the Challenges of Integrating Technology in the Classroom**

The use of technology in the classroom requires teachers to make some significant changes in their teaching practices. If teachers do not embrace technology and use it to assist them in transforming their teaching practices, then there will not be any significant effect on the classroom community or on student understanding. As Cuban (2001) found, “most teachers had adapted an innovation to fit their customary practices, not to revolutionize them” (p. 97). Such a change is not easy one, however, and teachers will need a great deal of support. In addition, these changes take a great deal of time, and it can be years before a true transformation occurs (Sandholtz, Ringstaff, & Dwyer, 1997).

In order to overcome these challenges, educators must focus on four conditions that are necessary for using computers as a pedagogical aid (Becker, 2000). Teachers must have convenient and reliable access to technology, they must possess sufficient skills and knowledge, the technology cannot constrict their curricular freedom, and the technology must support constructivist beliefs. One of the purposes of this research is to focus on how educators are able to implement technology. Looking at these four conditions will play a key role in seeking answers to that research question.

The research is overwhelmingly clear that in order for technology to create significant changes in the teaching and learning that takes place in schools and achieve some of the positive effects related to Becker’s findings, teachers must be given a great deal of professional development and support (Becker, 1998; Holcomb, 2009; Penuel, 2006; Mortensen, 2011; Sturdivant, Dunham, & Jardine, 2009; Waxman & Huang, 1996). As Silvernail and Buffington (2009) found in their research:
Providing teachers and students abundant access to laptop technology is only the first step toward using the technology as an effective instructional and learning tool. It is a necessary step, but not sufficient to lead to improved student learning. Professional development is also needed. (p. 13)

In addition, Holland (2001) states:

Though technology in and of itself creates new and stimulating learning environments for teachers and students, without the necessary supporting infrastructure to support teachers’ knowledge and instructional use of that technology, it will be difficult if not impossible for technology to realize its potential as a catalyst for school reform. (p. 260)

Professional development must not simply focus on how to use technology, but rather, on how to integrate technology into the classroom. With regard to professional learning, Bennison and Goos (2010) found that “very few of these teachers wanted to learn more about how to use these forms of technology….Instead, their main desire was to learn how to effectively integrate technology into their classroom practice” (p. 39). Teachers want to be shown how to use technology so that it will lead to changes in their teaching. Finally, professional development must be on-going as one time sessions have been shown to have minimal effects. “Integrating technology requires more than just a one-off training session. It’s essential that the district’s instructional technology department support teachers before, during, and after introducing the technology” (Mortensen, 2011, p. 18).

Many researchers also recommend that schools assign someone a non-teaching role, like a technology coordinator, to assist teachers with integrating technology into the classroom (Bauer & Kenton, 2005; Becker, 1998; Cole, Simkins, & Penuel, 2002). Teachers are busy people and having someone on staff that can help them has been found to be beneficial. That being said, schools need to be cautious with this role. This role is
meant to assist the teacher, not replace them. As Holland (2001) found “teachers were observed who completely turned the instruction of their students over to the technology specialists” (p. 249).

A final piece to the success of integrating technology in the classroom is to ensure that schools have readily available technical support (Becker, 1998; Penuel, 2006). This is especially important in laptop schools because there are many more computers that can break and have potential problems. Schools that have excellent technical support enable teachers to focus on integrating technology into lessons rather than troubleshooting issues with the hardware and software.

The role of the teacher in the implementation of a laptop program or any other technology cannot be underestimated. Teachers must buy in before significant changes can occur. Schools that do not put in place a plan for training and supporting teachers will not be successful. As Holcomb (2009) writes, “schools must realize that successful 1:1 initiatives go beyond the technology itself; they must also address and include professional development, training, and support” (p. 54).

**A Model for Technology Integration**

To assist teachers and administrators with the process of integrating technology in the classroom, some researchers have created models (Hooper & Rieber, 1995; Madinach & Cline, 1992; Sandholtz, Ringstaff, & Dwyer, 1997). It is very important to understand that it can take quite a few years for an innovation such as laptops in the classroom to be properly implemented and for the positive effects on the teaching and learning environment to take place. These models can help teachers and administrators understand
that effectively integrating technology takes place in stages. One cannot expect to go from a non-user to an expert integrator right away.

I have chosen to describe the model presented by Hooper and Rieber (1995) as I feel it has the most application to the process of teacher transformation from traditional to student-centred. This model consists of 5 stages. These are familiarization, utilization, integration, reorientation and evolution. I will describe each stage in more detail below.

The model used by Sandholtz, Ringstaff and Dwyer (1997) is also very popular in the research I reviewed. It uses different language (entry, adoption, adaptation, appropriation, and invention), but is very similar in overall structure. This model is summarized in Table 1.

Table 1 Hooper and Rieber’s (1995) Model for Technology Integration

<table>
<thead>
<tr>
<th>Stages</th>
<th>Stage</th>
<th>Description</th>
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| Familiarization | Stage 1 | Initial exposure to technology  
-Teachers become acquainted with technology, but take no further action |
| Utilization       | Stage 2 | Teachers try out technology in their classrooms  
-Technology does not play a significant role  
-Teachers in this stage are quick to give up |
| Integration       | Stage 3 | Break through phase  
-Teachers consciously design tasks that use technology  
-Classroom would be negatively impacted if technology is removed  
-Technology uses are still somewhat traditional |
| Reorientation     | Stage 4 | Teachers reconsider and reconceptualize the purpose and function of the classroom  
-Instruction shifts from teacher-centred to student-centred  
-Technology use goes beyond traditional  
-Classroom environment is significantly affected by presence of technology |
| Evolution         | Stage 5 | Teachers are able to see that education is constantly going through changes  
-Teachers are open to change and continue to evolve and adapt as changes take place |
The first stage in Hooper and Rieber’s (1995) model is Familiarization. In this stage, a teacher is initially exposed to technology. For example, an inservice workshop on how to use a particular technology would be considered familiarization. Essentially, a teacher becomes acquainted with a technology in this stage, but no further action takes place. Unfortunately, because of the numerous one-off workshops that occur in education, many teachers never get past this stage.

Utilization is the second stage in this model. Teachers in this phase try out the technology in their classroom. The technology does not play a significant role in the classroom environment, but the teacher feels like they have tried it out and “given it a chance”. If the technology were taken away, it would not change the learning environment in any way. Teachers who are in this phase are very quick to give up on the technology at the first sign of difficulty. Hooper and Rieber (1995) report that this is the highest phase of adoption reached by most teachers (p. 158).

The third stage in the model is Integration. Hooper and Rieber (1995) consider this phase to be the break through phase. In this phase, the teacher consciously designates certain tasks or activities to the technology. In this phase, if the technology were to be removed from the classroom, instruction would be negatively affected. This is the most critical attribute of this phase. Often, however, the uses of technology in this phase are still somewhat traditional, such as worksheets, drills, note taking, and word processing. This phase marks the point where the model transitions from a traditional role of technology to a contemporary view which holds promise for true transformation. Unfortunately, many teachers stop here. As Hooper and Reiber (1995) state:
Although integration is the end of the adoption model for many, it really only represents the beginning of understanding educational technology. For some teachers, the integration phase marks the beginning of a professional “metamorphosis”, but only if they progress even further in their adoption pattern. (p. 158)

Reorientation is the fourth stage in the model. Teachers in this phase must reconsider and reconceptualize the purpose and function of the classroom. It is in this phase that instruction shifts away from teacher-centred and towards student-centred. The teacher’s role becomes one as facilitator and students are given an opportunity to construct their own knowledge. Teachers in this phase are open to technology that better enables this process. They do not worry about being replaced by the technology, nor do they feel the need to be expert users of the technology. In fact, more often than not, in this environment the students are more competent with technology than the teachers. In addition, it is not uncommon to find students helping each other and working together.

The final stage in Hooper and Rieber’s (1995) model is Evolution. This phase is simply “a reminder that the education system must continue to evolve and adapt to remain effective” (p. 159). There is no final answer, rather, reaching this phase means that a teacher has gained the knowledge to see that education is constantly going through changes. The learning environment should be a place that is open to transformation and new ideas.

Teachers need to be given the time and support to work their way through the stages in Hooper and Rieber’s (1995) model in order for technology to become a catalyst for change in education. Administrators and support staff need to understand the stages of integration so that they can help teachers progress through the stages, and ultimately, create the classrooms envisioned by education reforms.
Laptop Classrooms

The research on the effects of laptop classrooms is mixed. Some experts view it as a tool that could be used to transform education (Dunleavy, Dexter, & Heinecke, 2007; Fonkert, 2010; Sandholtz, Ringstaff, & Dwyer, 1997). On the other hand, there are experts who view laptop technology as a fad and as a distraction (Cuban, 2001; Oppenheimer, 2003). In addition, some schools who adopted laptop programs are now changing their minds and going back to classrooms that are not laptop based (Hu, 2007).

In the proceeding section, I will summarize research on the effect of laptop technology in the classroom. For the most part, the findings in these studies are positive; however, due to mixed results, the need for further research is still warranted.

In 1996, Microsoft Corporation and Toshiba America Information Systems began a laptop pilot program in schools across the United States. Rockman et al. (1998) conducted a study that looked at how laptops were being used in the participating classrooms during the second year of the laptop program. To collect data, Rockman et al. (1998) employed teacher and student surveys, problem solving tasks and student descriptions of their favourite activities. 144 teachers from 20 schools (middle schools and high schools) were studied. The results of this study indicate that computers were used more frequently in a laptop classroom than in a non-laptop classroom. The primary uses for the laptops in the classroom were writing, note taking, and research. It was found that laptop students were more enthusiastic and proficient with technical skills. There is also support that laptops serve as a catalyst for producing educational change as laptop classrooms were more active and collaborative. In addition, there was less lecturing in these classrooms. These results hold promise for my research that is looking at the effect
of laptops on the creation of a more reform mathematics classroom. Unfortunately, this study indicated that math teachers were less frequent users of laptop technology. This is something that I will have to address in my research.

Lowther, Ross, and Morrison (2003) sought to find out if student behaviour was different in laptop classrooms compared to control classrooms. In addition, they wanted to determine the effects of laptop technology on student achievement. To collect data, the researchers used surveys, teacher interviews, student focus groups, a writing and problem solving test, and observations. Students indicated that the laptop classrooms were more focused on project work, research, critical thinking, and cooperative learning. In addition, evidence was found that laptop students achieved better results on the writing and problem solving test. Lowther et al. (2003) found that control classes were more traditional and teacher-centred. Although I am employing different research methods in my study, this study is important as it lends more evidence that laptop classrooms can be more student-centred and collaborative.

In 2002, Maine created the Maine Learning Technology Initiative which provided all grade 7 and 8 students and their teachers with laptop computers, and provided schools and teachers technical assistance and professional development for integrating laptop technology into their curriculum and instruction. The state of Maine was one of the first states to adopt such a widespread initiative. Silvernail and Lane (2004) compiled a report on the effect of laptops during phase one of this initiative. The purpose of their research was to show the influence of technology on teaching behaviours and instructional practice. In addition, researchers wanted to investigate how laptops were being used and what the obstacles were for implementation. My research asks many of the same
questions. This was a mixed-method study that employed surveys, site visits, and observation. Students reported that they were more engaged, better organized, and got their work done more quickly and effectively when laptops were present. The primary uses of laptops were finding and organizing information and taking notes. It was once again found that math teachers were weak at utilizing laptop technology in the classroom. In addition, obstacles to integration included lack of technical support, lack of professional development, and lack of time. Given that this research took place during the initial phase of laptop implementation, it will be important for me to investigate what schools, who are more experienced with using laptop technology, have done to address these concerns. Finally, it was noted that using laptops for assessing student work was found to be a weak area in this study. This is significant since assessment is one of the ten dimensions that I will be looking at in my study.

Silvernail et al. (2011) conducted a follow up study on the Maine Learning Technology Initiative eight years after it was begun. In this follow up, Silvernail et al. noted that 80-90% of the teachers reported using their laptops a few times a week or more frequently (p. 5). It was found, however, that only half of the teachers reported using laptops to differentiate instruction and to conduct formative assessments (p. 5). This is a key finding, as the current research intends to look at whether the presence of laptops allows for improvements in meeting individual needs and assessment (two of the ten dimensions). Silvernail et al. (2011) recommend that further research be done in these areas. The researchers found that there has been a consistent increase over the years of using the laptops to develop curriculum and provide instruction (Silvernail et al., 2011, p.
6). Once again, however, it was found that mathematics teachers were still some of the least frequent users of laptop technology.

Silvernail et al. (2011) examined some of the reasons why the frequency of implementation of the laptops varied from teacher to teacher. They found that factors such as age, gender, and experience had no bearing on how the laptops were used. They did find that teachers who felt more competent in their ability to integrate laptops in their instruction were more likely to use the laptops (p. 14). In addition, teachers that classified themselves as having a more constructivist philosophy (as opposed to a more traditionalist philosophy) were found to use the laptops more frequently in instruction (p. 15). This finding is in line with what Li and Ma (2010) found in their research. One very encouraging finding, as it relates to the current study, is that the use of laptops appeared to have helped teachers shift their teaching philosophy. Silvernail et al. (2011) found that “almost 75% of the teachers who completed the MLTI [Maine Learning Technology Initiative] evaluation survey in 2010 reported that the availability of the laptops have helped them to be more student-centred” (p. 15).

After giving 25,000 teachers and students in grades 6 to 12 laptops, Henrico County Public Schools in Virginia became one of the largest school districts in the United States to implement one-to-one computing. Zucker and McGhee (2005) conducted a study to look at how laptops were being used in math classrooms. They also investigated what factors facilitated use and what barriers impeded use. This research study is similar to mine for a few reasons. First, I am investigating similar research questions. In addition, this is one of the few studies that looks specifically at mathematics teachers. Finally, the methodology is similar. Zucker and McGhee (2005) conducted a multiple case study at
four sites and used classroom observations and interviews to collect data. Laptops were found to have many benefits for teaching and learning. These include: increased motivation and engagement, improved organization, more interaction, and more flexibility in instruction. Zucker and McGhee (2005) note that laptops did not have any effect on test scores, but this was not a goal of the laptop program. It was once again found that math teachers made less frequent use of laptops than other teachers. Teachers indicated that they were more challenged to manage discipline issues in laptop classrooms. In addition, they noted an increased need for planning time. The researchers noted a few key factors that facilitated or presented barriers to laptop use. These were: administrative support, professional development for teachers, school based technology trainers to support teachers, and hardware and technical support. The findings of this study are important factors in my research. It seems that the barriers to laptop use had an effect on the teachers. It will be important to see if the teachers involved in my study experience the same barriers or if they have advice for overcoming these obstacles.

Dunleavy, Dexter, and Heinecke (2007) created a multiple case study design to further investigate how middle school teachers used laptops in the context of curriculum and instruction. Dunleavy et al. (2007) acknowledged that the presence of a technology-rich environment was not enough to enhance teaching and learning and wanted to learn more about how teachers used laptops in their classrooms. The researchers found that teachers used the laptops predominantly for online research and productivity. The second most frequent use was drill and practice exercises. Although this is a traditional use of computers, it was positive for a few reasons. First, teachers were able to tailor a program to the needs of each individual student, and second, peer to peer collaboration increased.
The third most frequent use of technology was for eCommunications. Teachers were able to make use of videos and websites to facilitate communication outside of the classroom. Some of the methods used in the study by Dunleavy et al. (2007) such as using a case study design and using data collection methods such as observations and interviews will be used in my study. The difference will be an emphasis on the use of technology to promote the dimensions of reform rather than simply looking at what teachers do in a laptop classroom. In addition, the proposed study will look specifically at mathematics while the one by Dunleavy et al. (2007) researched mathematics, science, and English teachers.

Freiman et al. (2007) conducted a study which looked at the effect of New Brunswick’s Notebook Computer Project on mathematics teaching and learning. This research was a two year study of grade 7 and 8 francophone school children at six public schools. This research is one of the few one to one studies which specifically looked at the effect of individual laptops on mathematics teaching and learning. The researchers conducted this study to address the concern that there was a lack of research tracking the teaching and learning that occurs with laptops. This study differs from mine in that the use of laptops was evaluated through the lens of problem based learning and interdisciplinary scenarios. Freiman et al. (2007) found that the use of computers in mathematics class opens the door to new mathematical content and can create opportunities for teachers to make changes in their teaching practices. Students had a more positive attitude, more autonomy, and their results improved. In addition, improved quality of mathematical work was also found. The research uncovered some concerns with a lack of critical thinking being shown by students, limited capacities to analyse
problem context, lack of details in mathematical representations, and limited meta-cognitive links between different parts of the problem solving process. Although this research and my own research are looking at mathematics teaching and learning through two different lenses, it is encouraging to see that mathematics teachers can use laptop technology to make changes in their practice. It will be interesting to see if I find similar results.

Follow up papers to the above research study were also written (Freiman et al., 2010; Freiman et al., 2011). In these papers it was found that laptops may not lead to improved results on standardized tests, but their presence may create opportunities for more open-ended, constructive, and collaborative learning tasks (Freiman et al., 2010; Freiman et al., 2011). In addition, the presence of laptops improved students’ mathematical communication (Freiman et al., 2010). In both reports, students stated that laptops changed the way they learned (Frieman et al., 2010; Freiman et al., 2011). It was also found that “direct access to laptops offers more choices and variety in terms of tools and resource management” (Freiman et al., 2010, p. 5692). Finally, Freiman et al. (2011) stated that “in mathematics, easy and equitable access to powerful technological tools and endless Internet-based resources may broaden traditional pedagogical spaces and create opportunities for all students to participate in new types of authentic mathematical learning experiences” (p. 138). These findings hold great promise for mathematics education and for this research study in particular.

Grimes and Warschauer (2008) conducted a longitudinal multi-site case study to look at how laptops change teaching and learning. Their main purpose was to address some of the gaps and weaknesses in previous research. Data collection was done through
interviews, surveys, and observations. It is also important to note that Grimes and Warschauer (2008) looked at schools that were in the early phase (first two years) of laptop adoption. Laptops were not found to significantly change student test scores. However, the researchers found that laptops raised student interest, increased the frequency of students helping one another, and allowed students and teachers to explore topics in more depth. As was the case with similar studies, Grimes and Warschauer (2008) also noted that math teachers’ use of laptop technology was less frequent than other teachers. Finally, the teachers in this study expressed a great deal of frustration with the technical problems that they faced. Since this study took place in the early implementation phase, it will be interesting if technical issues are still a concern in more established laptop programs. It will also be important to investigate whether math teachers who are more experienced with laptops will use the technology more frequently.

Maninger and Holden (2009) conducted a research study of 17 classes at a grade 5-8 laptop school. This school was in its first year of one-to-one implementation. The researchers wanted to find out how students and teachers were using technology, what its effect was on teaching and learning and how much integration took place. It is also worth noting that the laptops used in this school were tablet laptops in which students cannot only type, but also write. Maninger and Holden (2009) used observation, teacher surveys, and teacher interviews to collect data. I will be using similar data collection methods. The findings of this study support the notion that laptop classrooms are more constructivist in nature. Teachers were overwhelmingly positive about the effects of laptops on instruction. In addition, classrooms became much more collaborative after the introduction of laptops. Students showed improved engagement and interest, and
improved in problem solving and self-efficacy. It is interesting to note that this is one of the few studies in laptop schools that did not make a note of less frequent use in math classes. The reasons for this are unclear, but it may have to do with the use of a tablet style laptop in this particular study.

Bebell and Kay (2010) examined the educational effects of the Berkshire Wireless Learning Initiative, a program that provided 1:1 technology access to all students and teachers across five public and private middle schools in Massachusetts. The researchers studied these schools for five years and sought to determine the efficacy of a 1:1 laptop initiative in transforming teaching and learning. To collect data, the researchers conducted interviews with teachers and principals, surveyed students and teachers, conducted classroom observations, and assessed the students writing assessments and state assessments.

The researchers found that student engagement increased significantly. Student research skills and collaboration were also enhanced. As well, student achievement was improved. In addition, many teachers reported that the delivery of curriculum had changed as a result of the laptop program. The researchers found, however, that this change was dependent on the teachers and the results varied from class to class. As a result, the researchers stressed the importance of professional development and support. Like a few of the other studies mentioned in this section, Bebell and Kay (2010) also found that math and science teachers were less frequent users of the laptop technology. In addition, the researchers found that the use of computers was fairly traditional, such as taking notes and research. Clearly, this research shows that the use of laptops can lead to positive changes, but the lack of use of technology in math classes is distressing. My
research will seek out answers to whether math teachers are using laptops consistently, and if so, how they are being used.

Although research shows that laptops can be a catalyst for reform, the findings are mixed. It is clear that more research needs to be completed which looks at how laptops influence the classroom environment. As Dunleavy, Dexter, and Heinecke (2007) state, “further research is needed to provide detailed descriptions of teaching practices within classrooms with a 1:1 student to networked laptop ratio” (p. 441). In addition, many studies found that math teachers were less frequent users of technology in their teaching. None of the research studies provided reasons for such findings. Since I am interested in the influence of laptops on teaching and learning in math classes, this warrants further investigation. Many of the studies also reported barriers to use, such as technical difficulties and time. Since most of the previous research was done in schools new to laptop technology, further research needs to take place in more established laptop schools to see if the barriers remain the same or are diminished.

Research Studies on Technology and the Ten Dimensions of Mathematics Education

As was shown in the previous section, mathematics teachers appear to be less frequent users of technology in the classroom. Hitt (2011) states “the use of technology in the mathematics classroom, for one reason or another, has failed to permeate the mathematics classroom” (p. 723). In addition, as was previously presented, mathematics teachers are still hesitant to adopt many of the teaching practices in the reform-model of teaching. Some of the previous research showed that laptop technology can lead to positive changes in the creation of a more student-centred teaching environment. Although the results were mixed, the potential is there. As a result, I was interested in
seeing how laptop technology would influence the mathematics classroom. Specifically, I wanted to look at its effects on mathematics teaching and learning using the Ten Dimensions of Mathematics Education (McDougall, 2004) as a framework. The research on the effects of technology on the ten dimensions is very limited. One research study has been conducted which looks at this (Ross, Hogaboam-Gray, McDougall, & Bruce, 2002). Although this research did not take place in a one-to-one setting, it is similar to my research in many other ways.

Ross, Hogaboam-Gray, McDougall, and Bruce (2002) conducted a case study of three teachers (grades one to three) in which their purpose was to determine whether access to technology facilitated or impeded implementation of mathematics reform. These researchers were motivated to find out how to get teachers to change their teaching practices to a more reform-oriented method. As has already been discussed, there are many barriers to reform. Ross et al. (2002) reported that “there is ample correlational evidence that teachers who are more frequent users of computers in the classroom are more likely to adopt even the most difficult dimensions of reform such as constructivist teaching” (p. 90). These researchers wanted to find out, however, how computers aid in changing mathematics instruction to a more reform model.

Overall, Ross et al. (2002) did not find technology to have a large effect on the implementation of mathematics education reform. There was nothing that led them to believe that the computer could be a driving factor in getting teachers to change. “The computer was an amplifier providing additional means for teachers to accomplish their instructional goals. It was not a reorganizer that challenged existing ways of teaching” (Ross et al., 2002, p. 98). The researchers also found that the computer did not allow
students to work together in the construction of their ideas. In fact, opportunities for interaction were reduced on-line (p. 98). Technology did influence some of the dimensions of reform, but these effects depended on each individual teacher. The dimension that appeared to be affected the most was the program scope (p. 93). The computer also helped to promote more positive attitudes towards mathematics (p. 94).

There are similar methodological aspects between my study and the one conducted by Ross et al. (2002). I will be conducting interviews with my participants at the start and end of my research. Ross et al. (2002) conducted interviews before the start of the research, before and after site visits, and at the end of the research. In addition, I will be observing my participants in their classrooms which is something that Ross et al. (2002) also did. Finally, I will also be using a case study approach.

Although the results found were mixed, Ross et al. (2002) indicated that the teachers in their study had issues with hardware. I have purposely chosen to examine some teachers who are experienced with integrating technology in order to avoid this type of problem. In addition, the teachers studied by Ross et al. (2002) taught younger grade levels. The researchers suggested that perhaps teachers of higher grades might be more influenced by technology. This is part of the reason why I have chosen to research teachers who teach grades 7-9. Finally, Ross et al. (2002) reported that teachers in their study assigned students to individual computer tasks. This may have been a contributing factor to a lack of collaboration and communication. It is possible this occurred because this study was not done in a one-to-one environment. I will be observing how teachers use technology in one-to-one classrooms. It is hoped that experienced teachers who do not have problems with access to technology will have many strategies to integrate
technology in the classroom rather than simply use it as an individual learning tool. In addition, in this study, teachers were limited to using one type of mathematics software on the computers. This imposed limit may have influenced how technology affected the ten dimensions.

Although Ross et al. (2002) did not find that technology led to large changes in how teachers implemented mathematics reform, they still believed that computers in the classroom held a great deal of value for learners. As has been previously stated, there is some research that does indicate that technology can assist in promoting reform-oriented classrooms. In addition, Ross et al. (2002) found promising effects of technology on some of the dimensions of mathematics education. I have used the suggestions outlined by Ross et al. (2002) to design a study in which many of their problems can hopefully be avoided. Choosing teachers who are experienced with one-to-one environments will allow me to see what has allowed them to be successful, how they are able to implement technology in the classroom, and challenges they have faced. Researching teachers of students in grades 7-9 will help me to observe classrooms that might naturally use technology on a more regular basis. Finally, by choosing to follow more teachers at more schools, I will be able to collect more data and observe the strategies and techniques used by a variety of teachers.

**Summary**

For years, mathematics researchers have provided evidence that teaching mathematics for understanding has a very positive effect on students. At the heart of reform mathematics is the notion of emphasizing problem solving, critical thinking, and communication. The Ten Dimensions of Mathematics Education provide a framework for
successful mathematics programs. Included in this framework is a classroom that promotes individual needs, is centred on co-operation and collaboration, utilizes different instructional approaches, gives students the opportunity to learn with manipulatives, promotes communication, and allows for a variety of assessment methods. Many mathematics classrooms do meet this vision, but many more are still on the path to change. We owe it to our students to reach beyond traditional teaching methods and make our classrooms more student-centred and more in line with the reform vision.

Some of the previous research suggests that computers in the classroom hold great potential for changing the learning environment in classrooms, making them more student-centred and engaging. That being said, evidence has also been presented that computers have not been used to enact change in education. There are many reasons for this lack of change. Teacher beliefs and attitudes play a large role in any proposed change in education. In addition, proper support and professional development are key. Evidence shows that simply giving teachers computers will not make a difference; however, showing teachers how these computers can be integrated into their classroom can. As Waxman and Huang (1996) found:

The mere presence of computers or any other type of instructional technology in the classroom does not mean that it will be effectively used….Technology needs to be combined with properly trained teachers before it can be really beneficial for students. (p. 165)

In addition, access to computers is a concern. There is evidence that shows that putting computers in isolated computer labs will not be effective (Becker, 1998). Instead, computers need to be in the hands of each student, and each student needs to be able to bring these computers home. A one-to-one laptop or tablet environment holds much more
promise for success. It has been noted that these types of environments are growing rapidly in schools across North America (Grimes & Warschauer, 2008; Holcomb, 2009). As costs decrease, they will become more commonplace.

Before we jump in too fast, and as Becker (1998) puts it, we are “running to catch a moving train”, we must examine schools that have already gone one-to-one. As Penuel (2006) states, “the increasing popularity of laptop initiatives…makes the need for sound research-based evidence especially critical at this time” (p. 342). Without examining what is currently happening in one-to-one environments and learning from the successes and failures of these schools, money will be wasted. Change will not occur without the proper resources in place. We must look at what teachers are doing in their classrooms and how the laptops have had an influence on the teaching and learning that takes place. This is especially important in mathematics education where many research studies show that technology has failed to permeate the mathematics classroom in significant ways. As Li and Ma (2010) indicate, “how technology can be used successfully and effectively to affect the teaching and learning of mathematics in K-12 classrooms is the key research question that many primary studies have attempted to address. Unsurprisingly, findings have not been consistent” (p. 217).

The gaps in the research are clear. We must examine what aspects of mathematics reform laptops have influenced and what aspects they have not influenced. It is important that we listen to the challenges that experienced teachers have faced and some of their suggestions on how to more frequently implement laptop technology in the classroom. We need to look at the challenges that schools have faced when going one-to-one, and we must explore what these schools have put in place to ensure that their teachers are
effectively integrating laptop technology. Addressing these research gaps is exactly what this study intends to do.
CHAPTER THREE: METHOD

Research Context

At the heart of my study is the description of how teachers can use technology to promote the creation of a reform-oriented mathematics classroom. Since my intent is on understanding the ways in which technology can assist teachers in promoting reform ideals and which dimensions laptops have an effect on, I feel that the interpretive paradigm is the best fit for my research. Bhattacharya (2008) asserts, “[i]n interpretive research, meaning is disclosed, discovered, experienced. The emphasis is on sensemaking, description, and detail….Therefore, meaning-making is underscored as the primary goal of interpretive research in the understanding of social phenomena” (¶ 7). As well, my research will take place in the classrooms of the teachers being studied, in their natural environment, which is a key attribute of the interpretive paradigm. In addition, I want to see how the process of using technology to promote reform mathematics affects different classrooms. As Donmoyer (2008) states, “people live and work in different places and consequently construct reality in very different ways, the world consists of multiple realities rather than a single, unitary reality” (¶ 7).

Thus my task will be to “describe, as accurately as possible, how different people in different contexts have constructed reality and what these people take to be true” (Donmoyer, 2008, ¶ 8). My intent is not to prove if using reform methods or laptop technology in the classroom is better than a different approach to mathematics teaching; it is to provide a thick description of how the classroom environment changes when technology is used to support and promote reform methods, and to describe which dimensions of reform mathematics are enhanced when laptops are present in the
classroom. Thus, the interpretive paradigm makes the most sense. As Tullis Owen (2008) states, “claims about cause and effect as they relate to the human experience are not an aim of naturalistic inquiry. Thickly describing observed phenomena and illustrating the multiple realities of a scene take precedence” (¶ 10). In addition, I want to draw on the experience of the teachers in order to fully describe how teachers can embrace technology to help them change their teaching practice, as well as describe some of their challenges and get their advice on overcoming these challenges. As Tullis Owen (2008) states, “the researcher, the people under investigation, and the setting influence each other; thus, no explicit distinction exists between the researcher and the researched” (¶ 2).

**Research Design**

This research study is a qualitative inquiry that presents a thick description of how technology influences the teaching and learning of mathematics in the intermediate classroom using the Ten Dimensions of Mathematics Education as a framework. It also describes how teachers are integrating laptop technology in their classrooms. Ary, Jacobs, and Razavieh (2002) state that “qualitative inquiry seeks to understand human and social behaviour from the ‘insider’s’ perspective – that is, as it is lived by the participants in a particular social setting” (p. 422).

This is a case study of six mathematics classrooms in four schools. This method was used by many other researchers interested in the use of technology in the classroom (Dunleavy et al., 2007; Grimes & Warschauer, 2008; Rice, Wilson, & Bagley, 2001; Ross et al., 2002). Each teacher and their classroom will be a case on which I will focus. I will look for similarities within and differences between each case so that I can provide better a better portrayal of how technology can influence mathematics teaching and
learning and the ten dimensions. Since my main purpose is to describe the teaching and learning that takes place in a laptop environment, I feel that a case study approach would be suitable. Ary et al. (2002) explain that “case studies attempt to describe the subject’s entire range of behavior and the relationship of these behaviors to the subject’s history and environment” (p. 440). In addition, I feel that using a case study approach will help me to address many of my research questions. Ary et al. (2002) explain:

In a case study the investigator attempts to examine an individual or unit in depth. The investigator tries to discover all the variables that are important in the history or development of the subject. The emphasis is on understanding why the individual does what he or she does and how behavior changes as the individual responds to the environment….The investigator gathers data about the subject’s present state, past experiences, environment, and how these factors relate to one another. (p. 440)

**Research Participants**

For this study, I wanted to find schools that were one-to-one laptop teaching environments, and preferably schools not new to laptops. In addition, because of my background as a middle school mathematics teacher, I wanted to investigate teachers at the intermediate level (grades 7-9). Because this type of environment is still relatively rare in Ontario classrooms, it was hard to find schools that matched my criteria. The school at which I work has begun the process of implementing a one-to-one environment in our high school. Through the research that my school did to investigate going one-to-one, I knew that there were many independent schools in Southern Ontario that were one-to-one environments. Thus, I sought to use independent schools for my research. I did not intentionally intend to exclude public schools from my research, but there are very few one-to-one environments in place at this time in public middle schools. In addition, many independent schools have been using laptops for quite a while and have a large
infrastructure in place to support teachers and students. I felt that the teachers in an independent school would be well versed in using technology in their schools since they have more access to resources. In addition, their access to professional development is quite extensive. Since I wanted to investigate the effects of laptop technology on the teaching and learning of mathematics and how to effectively implement this technology in the classroom, I felt that teachers at independent schools would be the perfect participants to seek out. As the cost of laptops decrease, more schools in Ontario will have access to the resources that these independent schools have. I think that public schools interested in creating one-to-one laptop environments can learn a great deal from schools that have been using this type of resource for some time. In Ontario, these schools happen to be independent schools.

To find participants, I contacted one of the representatives on the Independent Schools of Ontario Mathematics Association (ISOMA) executive. This individual was aware of which independent schools were one-to-one laptop environments and passed this information along to me. I then contacted the mathematics department heads and school heads at these independent schools to see if any schools were interested in taking part in my research. This initial contact was done via email. Four of the schools contacted expressed interest in taking part in my research study. All of these schools are located in the Greater Toronto Area. Two schools had two teachers agree to participate and two schools had one teacher agree to participate, for a total of six participants. In addition, the Directors of Information Technology at three of the schools were interviewed, as well as the Assistant to the Director of Information Technology at the fourth school.
It is important to acknowledge that all the participants in this study are male. The exclusion of female educators was not intentional on my part; no female teachers volunteered to take part in this research. Although I feel that research in the area of technology and females is extremely important and relevant, the purpose of my research is to focus solely on the integration of technology and the effects of laptop technology on mathematics teaching and learning.

Data Collection

Data collection for this research was collected using the following instruments:

- Field Notes
- Interviews
- Surveys

The data was collected over a 5 month period from January 2012 to June 2012. Arrangements to observe and interview the teachers were scheduled based on their availability. Each teacher was observed twice and interviewed twice. Interviews were also conducted with the Directors of Information Technology at each school (in the case of one school, with the Assistant to the Director of Information Technology).

Field Notes

Observations of the classes were recorded as field notes. I recorded what I saw, heard, and experienced during my observations. In addition, I spent some time reflecting on my observations. As Ary et al. state (2002):

Field notes have two components: (1) the descriptive part, which includes a complete description of the setting, the people and their reactions and interpersonal relationships, and accounts of events (who, when, what was done); and (2) the reflective part, which includes the observer’s personal feelings or
impressions about the events, comments on the research method, decisions and problems, records of ethical issues, and speculations about data analysis. (p. 431)

I kept separate field notes for each of the classrooms I visited. The purpose of the classroom observations and field notes were simply to provide verification for the classroom environments that the teachers described in the interviews. It also allowed me a chance to see the type of classroom community that was created and how the students used the laptop computers in class. Finally, I was able to see the types of activities that occurred during class time and how the teacher integrated laptop technology into these activities.

*Interviews*

Formal interviews of the teachers at each school took place on two occasions, once prior to when I started classroom observations, and once after I had completed classroom observations. All interviews were audio taped. Both formal interviews were semi-structured in nature. This allowed me to ask a standard set of questions to each teacher, but also allowed me the freedom to ask questions as they came up during the interview process. In general, the initial interviews were used to gather background information about each teacher. I wanted to find out how long they had been teaching, how long they had been teaching with laptop computers, their comfort level with technology, their beliefs about mathematics teaching and learning, and also their beliefs about the use of technology in the classroom. In general, the final interviews were used to gather information on the participants’ beliefs and feelings about how technology was influencing the classroom and the learning environment. I also asked their opinions on the bearing that laptop technology had on each of the Ten Dimensions of Mathematics.
Education. These interviews provided information that was not always apparent during the observations. They also served to verify what I observed. The interview questions are included in Appendix A. In some cases, informal interviews took place before or after observed lessons so that I could get some more information about what I was going to see or had already seen. The informal interviews were all unstructured and occurred as the need arose.

In addition, the Directors of Information Technology (IT) from each school were interviewed at the end of this project. In one case, I was not able to meet with the Director of IT, but I was able to meet with their assistant. The purpose of these interviews was to provide multiple sources of data and to provide another perspective on how technology has influenced mathematics teaching and learning at each of the schools. I was also able to gather information about what each school did to prepare teachers for a one-to-one learning environment. Once again, all interviews were audio taped. These interviews were also semi-structured in nature, which once again allowed me to ask a standard set of questions to each person, while also giving me the opportunity to ask questions as they came up during the interview process. The interview questions are included in Appendix B.

*Surveys*

Two surveys were given to the participants in this study. The first survey was used to determine how well aligned the teacher participants attitudes and practices were with reform methods, and more specifically, how they felt about each of the ten dimensions. The second survey was used to gather more information about the teacher participants’ beliefs about how laptops influenced the classroom environment.
The first survey used in this study was the Attitudes and Practices for Teaching Math (McDougall, 2004) that was created to determine current attitudes and practices about mathematics education (Appendix C). This survey consists of 20 questions regarding alignment to reform-based teaching qualities categorized by dimension. Each statement on the survey requires teachers to agree or disagree on a 6 point scale (where 1 was strongly disagree and 6 was strongly agree). The answers to each statement were taken and scored in order to give each teacher a score for each dimension, as well as an overall score. The higher the score, the more consistent the teacher’s attitude and teaching practices are with reform thinking. Indicators for each level in each dimension were developed through research projects in which teachers were observed on multiple occasions in their classrooms (McDougall et al., 2000; Ross, McDougall, & Hogaboam-Gray, 2002; Ross, McDougall, & LeSage, 2001; Ross, McDougall, Hogaboam-Gray, & LeSage, 2003).

The second survey used in this study was an open-ended response survey (Appendix D). The survey was created by the researcher to obtain more information about the influence of laptops on mathematics teaching and learning. This survey consisted of seven true or false questions. Participants had to choose true or false for each statement and then were given the opportunity to offer a written explanation for their choice.

**Data Analysis**

As has been previously discussed in this chapter, multiple data collection techniques were utilized in this qualitative research study. These included field notes, interviews, and observations. Data was triangulated through the use of multiple types of
data (observations, interviews, surveys), multiple sources (teachers and directors of IT),
and multiple schools. Data was analyzed for common themes and was coded using the
themes that emerged.

A method of data analysis similar to that described by Bogdan and Biklen (1998)
was used. “Analysis involves working with data, organizing them, breaking them into
manageable units, synthesizing them, searching for patterns, discovering what is
important and what is to be learned, and deciding what you will tell others” (Bogdan &
analysis provides sufficient insight to shape the gathering of further data” (van den
Hoonaard & van den Hoonaard, 2008, ¶ 4). As data were collected they were reviewed
and organized into emerging themes, and a system of coding was developed to organize
the information into manageable units. Then, as the research unfolded these coding
categories were modified, adapted, and deleted. “Coding categories are reconceptualized,
renamed, reorganized, merged, or separated as the analysis progresses; categories are
seldom static and never inviolate, as they are subject throughout the analysis to the search
for alternative interpretations or disconfirming evidence” (Ayres, 2008, ¶ 3). The process
of data analysis concluded once I was no longer able to find new themes or codes. At this
point, saturation was reached.

The process of data analysis and coding was done by hand by the researcher. I
developed code categories from items in the data such as words or phrases that appeared
frequently. As I read through the interview transcripts, key ideas were highlighted. These
key ideas were labelled and colour coded to make the data more manageable. Five
categories were found: student-centred classrooms, exploratory classrooms,
implementation of laptop technology, overcoming barriers, and role of the teacher. Within the role of the teacher category, two subcategories were coded. These were professional development and information technology integrators.

**Ethical Considerations**

This research study involved human participants and thus was approved by the Ethics Committee at the University of Toronto and by each school. All teacher participants were given a letter of informed consent which they all signed. The teachers were given the opportunity to withdraw from the study at any time. They were also told that they could refuse to answer any questions that I asked them. In addition, the director of information technology from each school (or in one case, the assistant to the director of information technology) also signed a letter of informed consent before they were interviewed. Finally, all parties were given the option to request an executive summary of the research if they so desired.

Each teacher involved in the study was given a pseudonym and this was the only name used in any field notes, interviews, or other data collection methods. This was done to ensure that all study-related work would remain confidential. The same procedure was used to preserve the names of the directors of information technology as well as the names of each school. Once the research is completed, all materials will be shredded and disposed of by the researcher.
CHAPTER FOUR: FINDINGS

Introduction

In this thesis, I investigate six laptop classrooms and the influence of the laptops on the teaching and learning that occurs in these intermediate mathematics classrooms using the framework of the Ten Dimensions of Mathematics Education (McDougall, 2004). Before I introduce the themes that emerged from the data analysis, I will provide a brief description of the participating schools and teachers. Next, I will summarize the findings of the Attitudes and Practices to Teaching Math Survey (McDougall, 2004). Then, I will summarize each individual case. After presenting these findings, I will then detail the themes that emerged from this research.

Description of the Participating Schools and Teachers

King’s College

King’s College is an independent boys’ school in the Greater Toronto Area, and was founded in the early 1900s. The school’s population is just over 700 and encompasses students from grades 3 to 12. The administration of King’s College is led by a headmaster, and then a head of school for each of its three levels, Lower School (grades 3-5), Middle School (grades 7-8), and Upper School (grades 9-12). The teachers that took part in this research study came from the Middle School. There are approximately 20 boys in each class at the Middle School level. When the research study took place, King’s College was in its second year of going one-to-one. The school chose a Bring Your Own Device (BYOD) model in which the boys were allowed to bring in whatever laptop device best met their needs, provided that it met certain minimum standards. There is a Director of Information Technology at King’s College who oversees all things related to
IT. In addition, there is one teacher who is released from most of her teaching duties in order to serve as an IT Integrator. Her role is to work with teachers to help them integrate technology into their classes.

Aaron is one of the teachers from King’s College who volunteered to take part in this research study. Aaron has a Bachelor of Science degree and a Master of Science degree. He then went to teacher’s college. There he completed qualifications in the Intermediate/Senior division in biology. When he began teaching, he was offered a job in mathematics so he took Intermediate mathematics as an additional qualification. Aaron has been teaching for six years, all at King’s College. He currently teaches grade 7 math and science. He has been teaching in a one-to-one environment for 2 years. Prior to that, he was able to book a class set of laptops or a computer lab when he needed to use computers. The class that I visited as part of this research study was Aaron’s grade seven mathematics class.

Frank is the second teacher from King’s College who took part in this research study. Frank has a Bachelor of Science degree. He has a science teachable in the Junior/Intermediate division. Frank then took an additional qualification course to be trained in the Primary division also. He has been teaching for 15 years, 13 of which have been at King’s College. He has been teaching math for 7 years. He has taken many additional qualification courses, but no courses in mathematics teaching and learning. He has been teaching in a one-to-one environment for 2 years. Prior to that, he was able to book a class set of laptops or a computer lab when he needed to use computers. The class that I visited as part of this research study was Frank’s grade seven mathematics class.
**Radcliffe Academy**

Radcliffe Academy is a co-educational independent school in the Greater Toronto Area. Radcliffe Academy was founded in the 1960s as a Montessori School. Since then it has grown into a university preparatory school serving Junior Kindergarten to grade 12. Radcliffe Academy introduced the International Baccalaureate diploma in the late 1990s. The school’s population is approximately 600 students. Class sizes are an average of 18-20 students. The school is broken down into two levels, a Lower School (JK- grade 5) and an Upper School (grade 6-grade 12). At the time of the study they were about to introduce a Middle School which was to be grades 6-8. Radcliffe Academy is overseen by a headmaster and each level has its own school head. Radcliffe Academy has been a laptop school for 7 years. For the last 2 years the students have been using tablet laptops. The school chose to use a model in which the students’ families lease a prescribed device from the school. The devices are replaced every three years. There is a Director of Information of Technology at Radcliffe Academy who oversees all IT related issues. In addition, there are two Technology Teaching and Learning Coordinators who work full time with teachers to help them integrate technology in the classroom.

Bill is one of the teachers from Radcliffe Academy who volunteered to be a participant in this study. Bill has a Bachelor of Kinesiology degree. While at teacher’s college, he trained to be a physical education teacher in the Junior/Intermediate division. He has also taken two additional qualification courses in Primary/Junior mathematics. In addition, he is currently working on his Master of Education degree. Bill has been teaching for 12 years, all at Radcliffe Academy. He initially began teaching home form in grades 5 and 6. For the last few years he has been teaching math at the grades 6-9 level.
He has been teaching with laptops for 7 years. For this research study I visited Bill’s grade seven mathematics class and his grade nine mathematics class.

Earl is the second participant from Radcliffe Academy. Earl has a Bachelor of Commerce degree. His teachables are math and economics at the Intermediate/Senior division. Earl also has a Master of Education degree, where he focused on mathematics education. Earl has been teaching for 8 years, 2 of which have been at Radcliffe Academy. He has been teaching grades 9-12 math throughout his career. This year was his first year teaching at the grade 7 and 8 level. He had no prior experience teaching in a laptop environment before he was hired at Radcliffe Academy. Thus, he has been teaching with laptops for 2 years. For this research study I visited Earl’s grade seven mathematics class and his grade nine mathematics class.

**Westminster Academy**

Westminster Academy is an independent all boys’ school in the Greater Toronto Area. This school was established in the late 1800s and has approximately 600 boys from grades 5-12. About one third of its students are boarding students and the rest are day students. The average class size at Westminster Academy is 18-22 boys. The administration of Westminster Academy is led by a headmaster, and then a head of school for each of its two levels, Middle School (grades 5-8) and Upper School (grades 9-12). The teacher that took part in this research study came from the Upper School. Westminster Academy has been a laptop school for 9 years. For the last 3 years the students have been using tablet laptops. The school chose to use a model in which the students’ families lease a prescribed device from the school. The devices are replaced every three years. There is a Director of Information of Technology at Westminster
Academy who oversees all IT related issues. In addition, there is one teacher who works part time with teachers to help them integrate technology in the classroom.

Chris is a teacher from Westminster Academy who volunteered to take part in this study. Chris has a Bachelor of Arts degree. His two teachables are mathematics and English at the Intermediate/Senior level. He has taken his Honours Specialist in mathematics. In addition, he is currently completing his Master of Education degree. Chris has been teaching for 13 years, 5 of which have been at Westminster Academy. He has been teaching grades 9-12 math throughout his career. He had no prior experience teaching in a laptop environment before he was hired at Westminster Academy. Thus, he has been teaching with laptops for 5 years. The class that I visited as part of this research study was Chris’ grade nine mathematics class.

**Queen’s College**

Queen’s College is an independent girls’ school in the Greater Toronto Area. It was established in the early 1900s and has approximately 900 girls from Junior Kindergarten to grade 12. About 70 of its students are boarding students and the rest are day students. The average class size at Queen’s College is 16-18 students. Queen’s College is a fully authorized International Baccalaureate school. The administration of Westminster Academy is led by a principal, and then a head of school for each of its three levels, Junior School (JK- grade 6), Middle School (grades 7-8) and Senior School (grades 9-12). The teacher that took part in this research study came from the Upper School. Queen’s College became a one-to-one school two years ago. All of their students use tablet laptops. The school chose to use a model in which the students’ families purchase a device that the school has chosen. There is a Director of Information of
Technology at Westminster Academy who oversees all IT related issues. In addition, there are three Information Technology Integrators who work part time with the teachers to help them integrate technology in the classroom.

Bob is a teacher from Queen’s College who chose to participate in this study. Bob has a Bachelor of Science degree. He is qualified to teach mathematics and science at the Intermediate/Senior division. He also has a Master of Education degree. Bob has been teaching for 10 years, but only 3 of those have been full time. He has been teaching math at the grades 9-12 level throughout his career. This is Bob’s first year at Queen’s College. His previous school was a laptop school, however, so Bob has been teaching in a laptop environment for 3 years. The class that I visited as part of this research study was Bob’s grade eight mathematics class.

**Results of Attitudes and Practices to Teaching Math Survey**

Table 2 Results of Attitudes and Practices to Teaching Math Survey

<table>
<thead>
<tr>
<th>Program Scope and Planning</th>
<th>Aaron</th>
<th>Frank</th>
<th>Bill</th>
<th>Earl</th>
<th>Chris</th>
<th>Bob</th>
</tr>
</thead>
<tbody>
<tr>
<td>Meeting Individual Needs</td>
<td>5.4</td>
<td>5</td>
<td>5</td>
<td>4.6</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>Learning Environment</td>
<td>6</td>
<td>5.33</td>
<td>5.67</td>
<td>5</td>
<td>5</td>
<td>4.33</td>
</tr>
<tr>
<td>Student Tasks</td>
<td>5.4</td>
<td>4.6</td>
<td>5.2</td>
<td>4.6</td>
<td>5</td>
<td>4.6</td>
</tr>
<tr>
<td>Constructing Knowledge</td>
<td>5.6</td>
<td>5.2</td>
<td>5.4</td>
<td>4.8</td>
<td>5</td>
<td>4</td>
</tr>
<tr>
<td>Communicating with Parents</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>4</td>
<td>4.5</td>
<td>5</td>
</tr>
<tr>
<td>Manipulatives and Technology</td>
<td>6</td>
<td>5</td>
<td>6</td>
<td>5</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>Students’ Mathematical Communication</td>
<td>5.75</td>
<td>4.25</td>
<td>5.75</td>
<td>4.75</td>
<td>5.5</td>
<td>4.75</td>
</tr>
<tr>
<td>Assessment</td>
<td>5.5</td>
<td>4.75</td>
<td>5.75</td>
<td>4.75</td>
<td>5.5</td>
<td>5</td>
</tr>
<tr>
<td>Teacher’s Attitude and Comfort with Mathematics</td>
<td>5.6</td>
<td>5.2</td>
<td>4.8</td>
<td>5</td>
<td>5.2</td>
<td>4.6</td>
</tr>
<tr>
<td>Overall Score</td>
<td>5.53</td>
<td>4.89</td>
<td>5.29</td>
<td>4.79</td>
<td>5.05</td>
<td>4.61</td>
</tr>
</tbody>
</table>
As can be seen from the results of the Attitudes and Practices to Teaching Math Survey in Table 2, all of the teachers taking part in this study have beliefs that are very much in line with those in the reform movement. These teachers are also quite open to further changes in their practice. All of these teachers see the importance of teaching for understanding and realize the importance of communication in the math classroom. These teachers believe that manipulatives and technology are key tools in helping students construct and explore their own knowledge of mathematics. These teachers are very comfortable with mathematics and they consider many facets of the subject when planning their programs. For these teachers, mathematics is more than just a set of rules and facts to memorize. Mathematics can be taught through open tasks and problem solving activities.

In addition, the teachers in this study believe that every student learns math differently, and they endeavour to meet the needs of all their students. The teacher participants know that assessment is more than just a result on one paper pencil test. They are open to exploring alternate assessments and are working towards building more self and peer assessment in their programs. These teachers also see the importance of assessment for learning in addition to assessment of learning. Finally, these teachers work hard to create a comfortable and open classroom environment in which students are encouraged to work together to deepen their understanding.

**Summary of Teacher Participants’ Interviews and Classroom Observations**

In the following section, I will briefly describe each teacher involved in this research study. I will provide a summary of their approach to teaching math, the challenges they have faced, how they use the laptops in their classroom, and the influence
of these laptops on their teaching. I will also comment on where each teacher falls in Hooper and Rieber’s (1995) model of technology integration. Once each teacher has been examined separately, general themes will be discussed.

**Case Study: Aaron**

I consider Aaron to be the most flexible and the most willing to take risks. His overall score on the Attitudes and Practices to Teaching Math Survey was 5.53 out of 6. This result was the highest of the participants, and suggests that Aaron is the most open to the ideas of reform math thinking and is very receptive to future changes in his practice.

Three years ago, Aaron took an Additional Qualification (AQ) course in Intermediate mathematics. For him, this course was a turning point:

> A couple of years after I went to teacher’s college, I did my additional qualification in math. The course I took was completely eye-opening for me. I knew how I thought I wanted to teach math. This course gave me ways that I could get there. It reinforced my whys and gave me the how. (Aaron, January, 2012)

He was motivated to take this course because he felt that he was teaching in a traditional manner and he wanted to make changes in order to better reach his students. This course gave Aaron the push he needed to change his teaching practice. He brought the ideas that he learned in the course to his teaching partners at King’s College and together they began to make changes. One of his teaching partners was Frank, another teacher taking part in this study. The main ideas in the AQ course were to teach math for understanding and to highlight the importance of critical thinking, problem solving, and communication. The teaching team began to create activities and tasks that were problem-based and more
open-ended. They decided to stop using a textbook, and instead, created their own resources for the students to use.

At first, the teachers offering this revised program struggled to find their way. They felt enormous pressure from parents, students, and the administration to change back to a more traditional method, but they felt strongly that what they were doing was the right thing for the students and they had the courage to continue on their path to change.

At first it was a challenge. Parents were not happy and students were not used to doing what we were asking them to do. Because the parents were not happy, the administration was not happy. But, we believed in what we were doing and we stuck with it. It was hard. We are now getting there with the program. I think it is a long process, but I think it is getting better and we are starting to see a lot of positive things coming out of it. (Aaron, January, 2012)

Now, in the third year of offering a more reform program, Aaron feels they are on the right track. Aaron and his teaching partner Frank have now created a document for parents that explains why they are teaching in a more reform method, and the parents seem to be more supportive. “We had to get better at communicating to parents why we are teaching in this way” (Aaron, January, 2012). In addition, Aaron now realizes that it can take a bit of time to get the students used to a new way of teaching, but once they do, they find the class quite enjoyable and engaging. The administration is also on board with what is going on in the classroom, but Aaron admits that this might be due to the fact that parent complaints have subsided.

In addition to challenges from parents, students, and the administration, Aaron has faced some further challenges. He struggles with finding the right balance between getting through the curriculum and teaching in a more reform manner. “It is a balance.
We feel that they understand better but we might not get through as much” (Aaron, January, 2012). In addition, he constantly questions whether what he is doing is best for the students. “I think the biggest challenge is making sure you are doing the right thing. Doing what is best for the boys. That is our number one concern. Is this what is best for the students?” (Aaron, January, 2012).

As well, no one else in the department has tried to open up their programs and teach in a more reform manner. Most of the teachers in the department teach in a more traditional manner. Aaron and Frank’s program was not highlighted by the department as a model for what teachers can do to break away from the traditional. Unfortunately, they are not being treated as examples. They are tolerated but not celebrated. This has been another challenge for Aaron.

We are faced with the challenge where this is only a one year thing that the boys are doing. They are learning one way from grades 3-6 and then in grade 7, we do something completely different. In grade 8, they go back to a more traditional model. You are always questioning - is this the best for them? (Aaron, January, 2012)

Aaron tries to create a comfortable learning environment for his students. When I observed his class, the boys were very relaxed and seemed happy to be in class. They were extremely comfortable sharing their ideas with one another, and it was very clear to me that Aaron has spent a great deal of time creating this learning atmosphere. “The classroom seems to have a very relaxed atmosphere. The boys are happy to share their ideas with one another or with the whole class” (Field Note, February 23, 2012). The desks are arranged in groups of four. Pairs and groups are used quite a bit in lessons. In my observations, it was evident that the boys are used to seeking help from their peers when they are working on a problem. At the start and end of each lesson, time is spent in
a whole class discussion. The students and teacher either discuss the premise of a task, or they summarize the big idea that a task was meant to uncover. Aaron always gives students a chance to share their ideas and explain their solutions. Students rarely work individually.

Aaron tries very hard to make math class a fun place to be. He always tries to get the boys to make personal connections to the math that they are learning and see why mathematics is important in their lives. On one occasion when I was observing a class, the boys were very engaged in creating a new flag for the school. They could choose colours that matched their house and school colours and could be creative with the symbols and pictures that they used to represent their school. This activity was related to fractions and ratios, and as they were working they had to meet certain criteria demanded by the teacher. At the conclusion of the task, the headmaster of the school visited their math class and each boy was given a chance to present their flag to the headmaster and justify their choices. All of the boys were extremely engaged in this task and saw a personal connection between the math they were learning (fractions and ratios) and something meaningful in their lives (a new flag for the school).

*Use of Laptops*

This lesson was also a great example of how the laptop computers were typically used in Aaron’s class. The boys could use the laptops to research flags of the world, they could use draw programs to create their flags, and they could use spreadsheets to keep track of the math required for the assignment. That being said, the boys did not have to use the laptops. Although many chose the laptops, some chose to draw their flags by hand. Aaron’s philosophy is to give the boys the freedom to choose the tool that works
best for them. “I am very open to letting the boys choose when they feel that the laptop works best for them” (Aaron, January, 2012). Aaron is also very open to the ideas of the boys as they approach each task:

As a teacher, you must be flexible. Sometimes I will throw things at the kids and see what they come up with. Often, I do not know where it will go, but I like to do it. I’m very comfortable just trying ideas and seeing what the boys do with it. (Aaron, January, 2012)

Aaron is very comfortable with using technology. Prior to going a one-to-one laptop school, Aaron was able to book the laptop cart of computer lab. Having each student have access to laptops at all times, without having to book a lab or a cart, has made a big difference in the teaching and learning that takes place in his classroom. He is no longer limited to the amount of time spent on any given activity nor is he constrained by whether he can or cannot book the computers. He is now free to use them as needed to enhance learning. “I like having the laptops because they are there everyday and they work. The laptop carts did not always work or I could not book them. It is really frustrating to use the laptop carts” (Aaron, January, 2012).

Aaron views technology as a tool. “I look at it as a tool. I do not think it is the be-all, end-all” (Aaron, January, 2012). He finds that the laptops allow students to explore more. There are many games and applets available that make learning more engaging and enjoyable for the boys. “The laptops give kids a chance to practice and explore, and they are fun to use” (Aaron, January, 2012). He finds it a challenge, however, to get the boys to see that the laptop is an educational tool and not a toy. “The kids see their laptops as a gaming tool. It is hard for them to get past that and see it as an educational tool” (Aaron, May, 2012).
Although he finds that the laptops can be a distraction, this had not deterred him from using them. He simply seeks to create more engaging tasks or he modifies his classroom management. It has also been a challenge to find useful tools to use in the classroom. There are so many web-based programs and activities that it is hard to find the time to sift through them all. Aaron finds that working with a teaching partner is an advantage because they can share resources. Unfortunately, Aaron’s math department does not spend time in meetings discussing technology and how to best integrate it into the classroom. Aaron feels that doing this would be a great assistance in encouraging more teachers to use the laptops in the math classroom.

Aaron sees the positive benefit of laptops in the classroom because they open up more choice for the boys and they allow for more differentiation. “The laptops allow you to meet the needs of the variety of learners in your room. You can meet your auditory learners, your visual learners, and so on” (Aaron, May, 2012). In addition, he sees the potential for laptops to improve student communication and reflection, but he admits that he is not there yet. He would like to experiment with using blogs or other online communication tools in the math classroom, but has not yet had an opportunity to do so. “I would love to see the reflections that we get the boys to do take some sort of online presence, like almost an online journal. I would like to see that, but we are not quite there yet” (Aaron, January, 2012). Laptops have also made teaching with open problems and teaching through problem solving much easier. As well, it is much easier to show students the real life connections of mathematics when using laptops. “The laptops make learning more relevant for the boys” (Aaron, January, 2012). Aaron finds that he can more frequently make use of manipulatives with the laptops because the world of digital
applets and virtual manipulatives is now at his fingertips. “The laptops are a useful tool. It is great in terms of programs that are out there that allow you to explore” (Aaron, January, 2012). He no longer has to wait to get access to concrete materials, which are often shared among many teachers. Finally, having laptops in the classroom have led to significant changes in assessment. Aaron can now give students more choice in what their final product might be and the laptops allow for more variety.

The laptops allow me to do more assignments instead of just always a test. Also, I can give students more options. Sometimes I will say ‘this is the concept I want you to show me you understand’ and then I will allow them lots of different options in how they can show me that. The students can choose how they want to show me they have mastered something. (Aaron, May, 2012)

Although he always saw the value in assessing things other than pencil and paper tests, the laptops have made the ability to offer these alternate assessments much easier. Thus, Aaron feels that laptops have influenced teaching and learning in a positive way. Because the laptops are still relatively new at the school, he acknowledges that they are not quite there yet with full integration. That being said, he feels that the possibilities are endless.

Although Aaron is still relatively new to having laptops in the classroom, I would consider him to be moving out of the Integration phase and towards the Reorientation stage of Hooper and Rieber’s (1995) model for technology integration. Aaron is beginning to design more activities specifically for the laptops in the classroom. Without the laptop computers, these activities would either be impossible to do or would be far less effective. In addition, Aaron does not usually use the laptops for traditional uses such as note taking or drills; instead, he uses the laptops to enable him to create a more student-centred learning environment. He is very open to letting his students help each other and he does not feel that he will be replaced by the laptops. In fact, he is quite
excited to see activities occur where the students are not reliant on him as a teacher. “The laptops are really exciting tools. It’s neat to see what the kids can come up with. It’s also nice to see that the kids can do a lot of exploring on their own or with their peers” (Aaron, May, 2012).

**Case Study: Frank**

Out of all the teacher participants in this study, Frank has the least amount of background in mathematics and he admitted to me that he does not feel his first few years as a math teacher were very good. “I taught in a very traditional approach from the textbook. I would argue that my math training and expertise were quite weak at the time. Looking back, I am not sure I did that great of a job” (Frank, January, 2012). Frank’s overall score of 4.89 out of 6 on the Attitudes and Practices to Teaching Math Survey was one of the lowest of the participants. However, his score shows that he is open to the idea of teaching in a reform manner. In addition, I believe that Frank’s beliefs about teaching and learning have changed the most over his career and I would also consider Frank to be one of the most courageous teachers taking part in this research. A few years ago, his teaching partner Aaron, came to him with the idea to radically change their grade seven math program. Although Frank was a very traditional teacher before this point, he was courageous enough to make changes in his practice. Many teachers that do not have a math background are very reluctant to open their classroom up to the ideas of their students. Frank was willing to change. He attributes this change in attitude and approach to his teaching partner:

I am very lucky to have Aaron as a teaching partner. He has really helped me to develop my understanding of teaching math and really helped me get away from
the traditional model of teaching. I am not sure that I would have gone down this path without Aaron. (Frank, January, 2012)

Frank admitted to me that the first year of their new program was very challenging. He was challenged by parents, students, and the administration. He was close to giving up many times, but did not. “My first year was really hard, I wanted to quit and revert back, but I believed in what we were doing so I kept on trying” (Frank, January, 2012). There were a few things that kept him going. First, he knew that change took time. He needed to be patient and give the program a chance. Second, he saw the potential in what they were trying to do and he knew that it was the right thing for the boys’ mathematical understanding. Slowly, teaching in a more reform manner became easier and he was able to persevere. Frank is a reflective practitioner and he is not afraid to try new things:

I am reflective. I always look back on what is working and what is not working. When things are not working well, I will sit down and try to do background reading or figure out what is going wrong. I’m not afraid to experiment and try new things. (Frank, January, 2012)

I think it was these qualities that helped him make changes and get through the challenges he faced.

Three years later, he still faces challenges. It can be hard to help parents understand why teachers are no longer teaching in a traditional manner. Aaron and Frank created a document for parents to help them better understand. “Parents were complaining so the administration came to us and asked for our rationale so that is when we created the ‘why’ document” (Frank, January, 2012). It is also a challenge to get the students to dig deeper and go beyond memorizing.
Frank is also frustrated that no one else in the department is willing to try to teach in a similar manner. At times, he feels that he is not supported by his department and he questions whether only giving students one year of exposure to such a program is a good thing. He believes in what he is doing, however, and hopes that as new teachers enter the department the program that he and Aaron have created will soon become the rule, and not the exception.

Sometimes I question whether I am doing these kids a service if they are just going back to a traditional way of teaching in grade 8, but a lot of me thinks that I have to stay the course. Over time, we are going to get new teachers that have new ideas. The department is really frustrating. They are not always supporting us in what we are doing. They want to pretend that what we are doing is not happening. No one understands what we are doing. None of the other math teachers come into our classrooms to look at what we are doing. We are unique. There is a lot of reluctance to change. Maintaining the status quo seems to be easier rather than looking at what is best practice. (Frank, January, 2012)

When I observed some of his lessons, it was obvious to me that the students liked coming to class. Frank has created an environment where everyone is held accountable and where everyone participates. It is a very collaborative environment and students are most often working in groups of four. At the start of the year, Frank takes the time to develop a group or community mentality. “I use Kagan’s collaborative learning structures all the time. My first three or four lessons are on developing group dynamics and how to work and be a learner in a group. That is more important than the math itself initially” (Frank, January, 2012). Students in Frank’s class are always explaining their thinking to one another and they feel very comfortable asking each other questions. “I am amazed at how open the lines of communication are in this class. Boys can sometimes be hesitant communicators, but not here. They seem to be encouraged to discuss their ideas with one another” (Field Note, February 23, 2012). Again, this is where I see Frank’s courage. He
is very happy to open his classroom up to the ideas of his students. “My students are free to voice their opinions about what they are learning or explain what they are thinking. I trust that the students will probably be able to explain it better than I can” (Frank, January, 2012).

Many of Frank’s lessons are problem based and meaningful to the students. For example, on one classroom visit, the boys were assigned a task in which they had to create a game that showcased their understanding of probability. They had to create a game of chance that was fair and then they had to show the difference between expected probability and theoretical probability. When the games were finished, the boys would then get a chance to go around and play everyone else’s games. They were very excited and highly motivated. On the day that I visited, they were in the initial stages of designing their games so a lot of experimenting and researching was taking place. “There is a buzz of excitement in the classroom. The students are going around talking to each other about possible ideas, trying things out, experimenting to see what they think will work” (Field Note, April 5, 2012). Most of the boys had their laptops out in some way. All were using the laptops for research, but they had the choice to make a computer based game or make a game by hand. Some were choosing to use the computers and some were not. Again, like Aaron, Frank believes that the boys should be given the opportunity to choose the tool that works best for them. “The laptops are often an option for kids. If they want to use it they can, but they don’t have to” (Frank, January, 2012).

Use of Laptops

Although Frank is very comfortable with using technology, he admits that, at this point, he uses the laptops minimally. “Right now the laptops are being used minimally. I
use them as a tool for creating and doing research or if I am having the class do an exploration or activity. I use them when I see they will serve a useful purpose” (Frank, January, 2012). He is not convinced that the students use technology as a learning tool and he is also concerned about the health implications of too much screen time. “My concern is for student health. The kids are choosing to be on a computer rather than go outside and run around and play. There is too much time being spent in front of a screen” (Frank, May, 2012).

At this point, the laptops are a big distraction in class and classroom management has been a challenge. Unlike Aaron, who sees this as a minor problem that can be worked around, Frank is still grappling with this issue. He knows, however, that he will get past this issue as laptops are a very powerful learning tool. “The pull towards the leisure uses of the computer or trivial uses of the computer at this moment in time are still quite strong, but I know that laptops have huge advantages to learning and I will continue to work through that challenge” (Frank, May, 2012). Laptops can inspire creativity and they can help with communication of ideas. In addition, projects and open tasks would be much more difficult to do without laptops, especially those in which a real world connection is being made.

The laptops have changed my thinking in terms of being more flexible and diverging from traditional ways of teaching becomes much easier. For example, one day we were looking at perimeter and area and we looked at Google Earth and used the perimeter and area tool to calculate the distances around the King’s College sports field. I see laptops as a way to introduce a new way of thinking and I see them as a new opportunity to grow. (Frank, May, 2012)

At the moment, Frank is most concerned with purposeful use of technology. “Teachers need to think carefully and plan how they are going to use the laptops…Make
sure that when the laptops are used they are being used well and efficiently and for a purpose” (Frank, May, 2012). Because he is also very willing to consider the ideas of his students, he is more than happy to consider his students using a particular program or piece of software for their work, as long as they can justify its use. “I’m open to having students come to me and ask if they can use a certain program. I ask them to justify that program and if they give me a good reason then I’m more than happy to let them use it” (Frank, May, 2012). Although he is somewhat of a reluctant technology user, Frank can see the positive benefits for use in the classroom. He does feel that student engagement and level of choice has been improved. He can also meet the individual needs of his students more effectively as a result of the laptops.

The computer is a really useful tool to help students express their mathematical thinking. I think it also allows me to offer more options in a lesson that might meet all the different learning styles. Sometimes I can choose to use a video, or an audio clip, or I can choose to use a dynamic type of exploration like Geometer’s Sketchpad where the kids can see things happening right on their screen. Those options help all the different types of learners I think. (Frank, May 2012)

In addition, Frank feels that he is more creative with the use of a variety of resources. “Within the tasks we give the students, there are a lot more options available and we can bring in a lot more of those digital resources” (Frank, May 2012). Frank prefers to use concrete manipulatives in his teaching, but acknowledges that he has not really spent time investigating the potential of virtual manipulatives. “I think the potential is there with virtual manipulatives. I have not explored them that much and I need to. They are a cheap and easy way to get manipulatives if you do not have the money to buy the physical ones” (Frank, May 2012).
I would consider Frank to be at the Utilization phase in Hooper and Rieber’s (1995) model of technology integration. He is willing to try out technology in the classroom, but technology does not yet have a significant place. With the help of his teaching partner Aaron, I do believe that Frank will work past this phase into the Integration phase. I also think that Frank would benefit tremendously from ongoing professional development focused on how to effectively integrate laptops in the classroom.

King’s College is in the stages for planning such professional development, but at the moment there is nothing formal in place. In addition, Frank’s department does very little in terms of looking at effectively integrating technology in the classroom. All they have done is looked at a very traditional use of technology such as a worksheet generator. Frank finds this discouraging as he wants to be shown how technology can enhance or change learning, not just do the same old things in a different way.

All [the members in] my department has looked at is an online worksheet creator, which is a very traditional use of the computer. This was a little frustrating to me, that that’s where the department decided to look, as opposed to some of the more dynamic programs that are out there. (Frank, May, 2012)

Frank does have access to a technology integrator at his school, however, and I think this person can help move him along the path to full integration.

I think that, as Frank gains more professional development in the area of effective integration of technology, Frank will continue to move along the stages in technology integration. Because Frank is a flexible and courageous teacher, I think that with time and support, he will soon see that laptop technology has lead to positive changes in his teaching.
Case Study: Bill

Bill is one of the most experienced mathematics teachers taking part in this research. He also has the most experience teaching in a laptop environment. Bill is very open to change and, as can be seen from his overall score of 5.29 out of 6 on the Attitudes and Practices to Teaching Math Survey, his beliefs are in line with those in the reform movement. Bill has spent some time as a research chair of mathematics at his school. As a result, he is very up to date with current trends in mathematics education and he is quite willing to try new things in his classroom.

It took Bill some time to feel confident as a mathematics learner when he was in school. The traditional model of teaching did not work very well for him as a student so when he began teaching he was very eager to investigate alternate ways of teaching mathematics. Because math was not always easy for him, he feels he is a better teacher.

I think one of my best qualities is that it has taken me a while to master math. When I was in school, math was not always easy. I try to convey that to my students. I try to convey to them that math is a skill that takes a lot of practice and perseverance. I also try to relate math to the lives of my students. My teachers did not do this for me and I think that is part of the reason why I struggled. (Bill, February, 2012)

Bill is also very open to the ideas of his students and encourages class discussions. He tries to get his students to see that, in math, it is alright to be wrong and that wrong answers can actually enrich learning.

I always try to tell a student that in order to be good at math you have to be ready to be wrong and you have to ask questions. It is not so much about the steps of what to do. It is more about the hows and whys. I try to convey that in my math class. We spend a lot of time looking at how you get an answer and why we get an answer….I try to be a teacher where it does not matter what the answer is. It is more important to show me how you got there. I am also a teacher that’s more than willing to put wrong answers on the board and then I ask the class for their opinion about the answers…. When they are on their own, they need to be able to
assess whether they are on the right or wrong path. They need to be able to see wrong answers. Only seeing correct answers will kind of steal some of the learning from students. (Bill, February, 2012)

Bill has faced a few challenges in his teaching. At first, Bill finds that the students can be quite resistant to discussing mathematical ideas. It takes time for the students to understand that it is alright to be wrong. “At first, it is a huge challenge to get kids to admit they are wrong” (Bill, February, 2012). Bill works hard to break down the perception that mathematics is all about the right answer. Instead, he gets his students to focus on the process. He also finds that it can be a challenge to convince parents that math is being taught differently now than it once was. At Bill’s school, the parents want a fairly traditional program, and it takes time to get them to see that how their children are being taught math is an effective method. “Our parents want a more traditional program. They want homework, they want tests and exams. Getting them to see that math is taught in a different way now is hard” (Bill, February, 2012). Bill’s final challenge is to find the balance between getting through the content and teaching through problems and activities, all in a very limited amount of time. “One of my biggest challenges is time. It takes time to do an investigation and have a discussion and sometimes we do not have that. Our schedule does not allow for much time for content. Finding the right balance is hard” (Bill, February, 2012).

When I observed his classroom, it was clear to me that the students were comfortable communicating their mathematical ideas with one another. It was also apparent that Bill makes an effort to create engaging and meaningful lessons. On one visit, the class was taking part in a Battleship game with another grade seven class down the hall. Using Skype and instant messaging, the students were able play against the other
class even though they were not in the same room. Bill had pushed the desks aside in the classroom and set up the floor like a Cartesian Plane. The students then had to physically mark all of the hits and misses on the floor, as well as keep track of where their ships were. Each student had a role, and these roles switched every five minutes. The students were very engaged and excited about this lesson, and it was a very creative way to review the Cartesian Plane and how to plot points.

The classroom has been transformed into a Battleship playing field. The students are having a lot of fun trying to outwit their peers in another room. Communication with the other class is taking place using Skype. There is a lot of excitement – there are loud cheers when they hit their opponents and groans when their opponents hit them. This is a really great way to get the kids to practice coordinate graphing. (Field Note, February 2, 2012)

This lesson demonstrates some of Bill’s positive qualities as a teacher. He is not afraid to explore and experiment. He is also willing to give up control in his classroom and put things in the hands of the students. Once Bill laid the ground work for the Battleship game, he let the kids do what they wanted. During the game, the classroom was quite chaotic, but the students were always on task. He was there to help them if they had any questions, but he was mostly observing the students to see who understood the concept of plotting points and who did not. At times, he would privately talk to a few students who needed assistance. He would also wander around and make sure that students were on task and that they were switching roles every few minutes.

Bill has not said much in the lesson. He introduced the activity, but then he stayed on the sidelines. I have observed him talking privately with a few students to help them out, but for the most part he is observing the students and watching what they do. (Field Note, February 2, 2012)
Use of Laptops

Although Bill has been teaching in a one-to-one laptop environment for seven years, he has only begun to fully implement the laptops in the math classroom for the past two years. The major driving factor to this increased frequency of use is that the school switched from using laptops to using tablet laptops. “I would say before the tablets I barely used the laptops. Now that we have the tablets and use Microsoft One Note, I use them all the time” (Bill, May, 2012). As a math teacher, Bill feels that the ability to write down work is very important and the tablet laptop allows for this to happen.

In addition, the integration of technology has become a bigger focus in department meetings and in school professional development (PD) sessions. The teachers are required to attend technology PD sessions as part of their regular timetable. These sessions are led by one of the technology teaching and learning co-ordinators. The sessions have helped the teachers find tools that they can use in the classroom. “She [the technology teaching and learning co-ordinator] will show you how a program works or she will give you lesson ideas or things to try in your classroom. Not only will she help you find things, she will also help build it into your lessons” (Bill, May, 2012).

Teaching in a one-to-one environment has been very positive for Bill. He finds that the tablet laptops have been a tool that gets the kids to collaborate more. He can also bring in more real world applications to mathematics through videos and other tools.

It has been easier to bring in real-life applications. You can have videos, you can look at websites, you can use manipulatives. There are so many resources available. The tablets open up so many more things you can do in the classroom and so many more ways to bring math to life. (Bill, May, 2012)
In addition, technology has made a big difference with the explorations and investigations that can take place in the classroom. Bill now makes more use of Geometer’s Sketchpad, applets, and virtual manipulatives than he did before having laptops in the classroom. He finds that these tools help students to see the mathematics they are learning and they make teaching in a constructivist manner so much easier.

I am more creative with the laptops and it is easier to design activities in which the students need to construct their own understanding. There are videos, apps, websites, and software programs that help students discover math. A lot of these things you could not do without technology. (Bill, May, 2012)

The tablet laptops have also enabled Bill to be more creative with his lesson planning. For example, the Battleship lesson I described would not have been possible without technology. Although the class would still have been able to play some form of Battleship, it was playing another class and communicating electronically with them that made the lesson so engaging for the students.

The Microsoft One Note Program that is used with the tablet laptops has also been a critical component of Bill’s increased use of technology. With this program, Bill can create a digital binder for his students. He can also differentiate lessons very easily because he can send different things to different students. “I can put together a package for different kids and send it to them via One Note. Technically speaking, with the touch of a button, each student in my classroom could have a customized notebook” (Bill, May, 2012). He also finds this program to be an excellent tool for formative assessment because he is able to synchronize his computer with his students’ computers so he can see their notes any time they are in the building. He uses this to check his students’ level of understanding and he can write comments to his students on their digital binders. “The
ability to sync in One Note has given me better accessibility to my students work. It has allowed me to better see who is getting it and who is not” (Bill, May, 2012). Bill can also easily embed YouTube videos, podcasts, and other tools to make his lessons more engaging and dynamic. “I have been playing a lot with embedding websites and videos into my lessons. The kids love these” (Bill, May, 2012).

Despite the positive changes that tablet laptops have made in the classroom, Bill makes it clear that these are just tools. “Technology is just a tool. The teachers are the important part. How the teachers are choosing to use the technology is what makes the difference” (Bill, February, 2012). If used properly, the learning environment can become less teacher-directed and more collaborative and student-centred. If not used properly, the learning environment will not be transformed. “I have seen technology being used well and I have seen it being used not so well, like to show a PowerPoint. There is a big range” (Bill, February, 2012).

Bill has faced a few challenges with the introduction of laptop technology to his classroom environment. The first challenge is that computers in the classroom can be a distraction for the students. Bill stresses, however, that this is just a different form of distraction than others, it is not worse than those previous distractions. The key is to learn classroom management strategies for dealing with misuse of the computers. If this is done, then distraction should not be a barrier for using them in the classroom.

Distractibility is a factor, but the one neutralizer is that in tablet mode the kids cannot surf the net. So, I will often demand that the kids have their computers in tablet mode. It is just a matter of changing your classroom management. (Bill, May, 2012)
In addition, Bill finds that power management is a challenge. Students come to class with low batteries on their laptops and this can then be a frustration for the teacher. Again, it is simply a matter of teaching students how and when to properly charge their batteries. “Kids are constantly running out of power. We need to teach them how to reduce the computer’s need for power and teach them when to charge” (Bill, May, 2012). Bill does not feel that this should be an excuse to avoid using laptops in the classroom.

Using Hooper and Rieber’s (1995) model, I would say that Bill is in the process of shifting away from the Integration phase towards the Reorientation phase. He still uses the laptops for traditional applications such as worksheets, drills, and note taking, but he is beginning to see that laptops allow him to better reach the goals of reform math teaching. He is now able to design lessons that directly use technology to enable students to explore mathematics and make it come alive. In addition, he is better able to play the role of facilitator and it is now much easier to differentiate his lessons. I think over the last year, Bill has been much more open to what the tablet laptops enable him to do in the classroom. In a few more years, I think that Bill will continue along this journey and head towards to Evolution phase.

**Case Study: Earl**

In my opinion, Earl is a risk taker. He is not afraid to try new things, and is not satisfied with doing things in a traditional manner. His overall score on the Attitudes and Practices to Teaching Math Survey was 4.79 out of 6. Although this was one of the lowest scores of the teachers in this study, it is still quite high. Clearly, Earl is open to change and his beliefs are in line with those in the reform movement.
Earl finds it challenging to convince his students that they can do math. Many students come to his class with the attitude of either “I am good at math” or “I am bad at math”.

For me, one of the biggest challenges is to break down this preconceived notion of you are good in math or bad in math. It is hard to convince students who think they are bad math students to see that they can actually be good at math. (Earl, February, 2012)

He finds this frustrating because, as a student, he had many of the same challenges. In one of our interviews, Earl admitted to me that he was not a great student. “I was not a great student. I was never engaged. I failed my grade 11 math course because it was just not interesting. It was not applicable to me at all” (Earl, February, 2012).

Because of his lack of interest when he was in school, as a teacher, he is determined to focus on ways to get his students engaged in their own learning process. This is another challenge for him, as he feels that many of his students are apathetic. He is constantly trying to find ways to reach each and every student. One way he does this is to show his students that there are many paths to reaching a solution in mathematics.

I do not always see the natural path through things, and so for me, I am really interested in showing students that there is more than one way to approach a problem. We’re not all the same and we don’t approach things the same. Kids need to see that and often teachers only show one way. I think that is why a lot of people find math difficult. (Earl, February, 2012)

In addition, he always strives to show his students the usefulness of mathematics.

Earl tries to create a light and fun environment for his students. “I try to make my class a place where kids do not mind to come in. I try to keep it a light and fun environment” (Earl, February, 2012). In addition, he wants his students to feel comfortable working together and sharing their ideas with one another. On my visits, it
was very clear to me that the students were having fun and they were happy to share their ideas with one another. For example, on one classroom visit, Earl gave the class a warm up problem that involved a mystery algebra problem. In this problem, the students had to pick a number and then Earl told them to do several things to that number. In the end, Earl was able to predict their final answer using “magic”. In actual fact, he predicted the result using algebra and showed the students how he was able to do this. He then gave the students the task of creating their own mystery problem and proving how it worked. The students then had to go around and try their problems on one another. At the end of the class, Earl gave them another mystery problem and asked the students to prove how it worked for the next class.

The class began with a mystery problem. The students were amazed that Earl could guess their result and were intrigued to figure out how that happened. Once they had a chance to make up their own problems, they were very excited. Many worked to create complex problems to try to stump their peers. They had a lot of fun presenting their problems to one another and showing each other the algebra behind their problems. (Field Note, February 2, 2012)

*Use of Laptops*

Lately, Earl has been experimenting with the use of a flipped classroom, in which the homework that he assigns is for students to watch a video at home in order to get the background on a topic (or a more traditional lecture). Then, they come to class ready to discuss what they learned and apply it in some sort of activity. The fact that Earl is experimenting with using a flipped classroom shows his strong comfort level with technology and his willingness to embrace it in his classroom. Earl feels that technology should be used to change the teaching and learning environment, not just do traditional things with a computer.
One of the reasons I wanted to try the flipped classroom was to use the technology for something innovative, something I would not have done before having the technology. I think that is the power of effective use of technology, using it to do something new. I don’t want to still do the same old things I have always done. (Earl, May, 2012).

As a result, he is really trying to integrate the tablet laptops so that they transform the way that math is taught. He is still relatively new to using tablet laptops, but he has embraced them completely. Earl has also taken advantage of the support offered at his school in order to learn how to better integrate the tablet laptops into his teaching. Without this support, Earl feels that he would not be using the tablet laptops very much.

The support that Radcliffe has given me has been instrumental in me using the tablets effectively in the classroom. Without it, I would not be as innovative with my use of technology….When I wanted to try a flipped classroom, I was able to book an entire day with one of the technology teaching and learning co-ordinators and he showed me how to use Camtasia Studio to record and edit videos. With his help, I learned to make professional videos and was able to try flipping my classroom. (Earl, May, 2012)

Earl has found many positive effects of the tablet laptops in the classroom. It is much easier for him to give problems or activities to his students and let them work in pairs or groups. In addition, he finds that the computers have improved communication and collaboration between students. With the laptops, Earl can offer more variety in his class and can give students more choice. As a result, he feels that his lessons are more differentiated and student-centred. “The tablets have allowed me to better meet the needs of my students. I have always known that different kids learn in different ways, but the technology has made it easier for me to meet those different needs” (Earl, May, 2012).

He also likes that with a laptop the math course is no longer focused on the textbook. Earl feels that he has more freedom to use various websites and dynamic tools to help guide his lessons.
The ability to have everything digital allows you to bring in so many more resources. Before, the courses were often really focused around the textbook. Now they are not because now we can provide them with a variety of different resources in a digital format and you are not as reliant on the textbook. (Earl, May, 2012).

Finally, because access is no longer a factor, he is able to use programs like Geometer’s Sketchpad and tools such as virtual manipulatives whenever he needs in order to help students explore a mathematical concept. “With the tablets, it is easier for me to design more exploratory type lessons” (Earl, May, 2012).

For the last two years, Earl’s math department has been focused on integrating the tablet laptops in the classroom. “My department head has been an excellent role model and given us a ton of support and ideas for integrating technology into our lessons” (Earl, May, 2012). They are very focused on using Microsoft One Note in all lessons and use this program to create a digital binder. The Microsoft One Note program allows the students in Earl’s class to be more organized because all of their notes and work is saved right on the computer. It also improves his ability to assess the students because he can synchronize his computer to theirs and see their digital binder anytime they are at school.

I find that I am much better at formative assessment with the tablets. I can sync my computer up with my students’ computers and then see what’s on their screens. I can check their work. I can leave them comments. I find that I have a better understanding of what my students understand and what they don’t understand. (Earl, May 2012)

Although the tablet laptops have had a positive effect on the learning environment, Earl has had some challenges. Initially, parents were not happy about the idea of him trying a flipped classroom. Once they were provided with an explanation and justification, they were more amenable.
With my flipped classroom, there was a bit of pushback from parents. At first they thought I was not doing any work and I was not teaching their kids. When you try something that is new or different, there can be pushback and then you need to explain why we are teaching in a certain way. With a little bit of explanation, the parents were on board. (Earl, May, 2012)

In addition, technical issues such as low battery power and students losing their stylus have been issues. There are many solutions to these minor problems, however, so Earl has not found them to be a barrier to use.

It can be frustrating when a student comes to class and their tablet doesn’t work, even though we have an IT help desk. Also, sometimes when they lose something like the stylus for their tablet and they have not done anything about it, but I would not say they are major barriers. With a little bit of patience and understanding, you can more or less get over those issues. (Earl, May, 2012)

Earl also finds that the tablet laptops can be a distraction in class. At times, students are focused on their screens when they should be doing work. “The tablets can be distracting. It is hard to know what the students are doing on the computers, but you learn to adjust” (Earl, May, 2012). Again, however, this just means that teachers need to learn how to manage a classroom now that their students have access to a computer at all times.

Earl believes that, without the tablet laptops, it would be much harder to meet the individual needs of his students. He also feels that classrooms would become more traditional and teacher-centred because there would be fewer options available to teachers. “Without a tablet, I think that I would go back to teaching in a more traditional way. It would be harder to differentiate the classroom. I would go back to having everyone doing the same thing” (Earl, May, 2012). Earl is confident that laptops can move teachers away from the traditional model of teaching but only if they want to change.
For sure, I think laptops can help transform teaching, but I think it allows it for the teachers that want to change. Just giving a laptop to teachers will not necessarily create a change. For teachers who want to change the classroom, I think that the technology opens up a lot of possibilities. (Earl, May, 2012)

In his case, he was never satisfied with the traditional teaching method, and he has found that laptops have enabled him to reach his goals of a reform math classroom much easier.

Because Earl is not afraid to experiment with using technology in his classroom, I would consider him to be in the Reorientation phase in Hooper and Rieber’s (1995) model. Through experimenting with the flipped classroom, Earl has spent a great deal of time reconsidering the purpose of the classroom and the purpose of the teacher. His classroom has become very student-centred. None of this would have been possible without access to tablet laptops.

**Case Study: Chris**

Chris is one of the most experienced math teachers taking part in this research. Although he has not been using the laptops the longest, he has been using them for a significant amount of time. In addition, his school was one of the first independent schools in Ontario to go to a one-to-one laptop environment so there is a large support structure in place. As a result, out of all of the teacher participants, Chris is probably the furthest along with integrating laptops into the math classroom. Chris’ overall score of 5.05 out of 6 on the Attitudes and Practices to Teaching Math Survey shows that his beliefs are in line with those in the reform movement. He is also very open to further changes in his practice.

Chris was taught math in a very traditional way when he was in school. It was not until he got to teacher’s college that he was exposed to any other method of teaching.
math. The professors he had in teacher’s college were very progressive and helped shape his vision of mathematics teaching to one that was more constructivist in nature.

I enjoyed math. I found it fun. I found it a challenge. But, I had very traditional teachers. Every day was pretty much the same. The teacher would take up homework, do some examples. I do not think I did an activity in math class until I was in teacher’s college. My experiences in teacher’s college were great. I had fantastic profs and they really made it clear that math was not all about chalk and talk. You need to reach all students and not just those that naturally pick it up. They demonstrated so many different activities that I think by the end of the year I realized what a big variety was out there. (Chris, April, 2012)

Because Chris is a very enthusiastic teacher who has a willingness to try things out, he is not afraid to open his classroom up to the ideas of his students and teach in a more student-centred way. “I purposefully create an environment in which kids are encouraged to talk to one another about the math they are learning and share their ideas with the class” (Chris, April, 2012). Chris is a life long learner and he is currently in the process of completing his Master of Education degree.

Chris sets up his classroom so that students are working in pairs. He will often have two pairs working together to form a group of four. Rarely does Chris demand that students work independently. His goal is to create a respectful and comfortable learning environment where his students problem solve, work together, and share their ideas.

I try to create a comfortable and respectful classroom environment. I want every child to be able to feel comfortable to ask if they don’t understand something. I also want it to be an environment where students are problem solvers. Where if I present a problem or if they, you know, come across a problem that they know that their first instinct in class is “okay, let’s see if I can solve this”. That’s what I aim for. (Chris, April, 2012)

When I visited his classroom, it was clear to me that he has achieved this goal. On one occasion I observed a lesson on optimization. Chris began by asking the class to brainstorm what they knew about optimization with a partner. Chris then gathered the
whole class together and they collectively discussed their understanding of optimization. Chris would write down what the students were saying on the SMARTBoard, but would not offer his opinion. He allowed the students to construct their understanding of the topic and he only spoke to probe for deeper or fuller explanations. “The students’ ideas really seem to be at the forefront of the lesson. Chris is really just recording what is being said and guiding the students to go deeper” (Field Note, May 15, 2012). Chris then directed the students to download the current lesson into their Microsoft One Note math notebook. Within seconds, all of the students had the day’s lesson up on their tablet laptops and with a few instructions from Chris, were working in groups of 4 on the task that was assigned.

When they were in groups, Chris set up the computers so that each group could share a Microsoft One Note file. This enabled everyone in the group to see what was being written and helped them to work together to solve the tasks they were assigned. “The shared One Note files are amazing. One student can write on their screen and everyone else in their group can see what was written. This is an amazing tool for collaboration” (Field Note, May 15, 2012). In addition, the students were encouraged to use the Internet to help them solve their assigned tasks. Because the tablet laptops enabled the boys to find the information they needed, Chris was able to play the role of facilitator. As the students worked, Chris wandered around the room, listened in to the conversations, and asked probing questions if necessary. Chris then asked the class to reconvene for a group discussion. In this discussion, the students were asked about their conclusions to the problems assigned. As students talked about their solutions and what
they thought, Chris was able to access their Microsoft One Note files and with the push of a button he could project their work on the SMARTBoard at the front of the class.

With the click of a mouse, Chris can put student work up on the board for the whole class to see. No time is wasted having the student come to the front and write it all down. Wow! Powerful learning can come out of this because it is so easy to show student work and talk about it. (Field Note, May 15, 2012)

*Use of Laptops*

As can be seen from my description of Chris’ classroom, it is a place in which students communicate and collaborate frequently. The tablet laptops are used every single class and are an integral part of the learning process. At times, the tablet laptops are used to just take notes, but most often they are used to research, to communicate with group members, to show solutions to the class, and to dynamically investigate mathematical topics using programs like Geometer’s Sketchpad or virtual manipulatives.

We use the tablets every class. How we use them varies by class and by topic. Sometimes we use Geometer’s Sketchpad, sometimes it’s to see a video, sometimes to collaborate in a group, sometimes to present ideas to others, sometimes to take notes, it just depends. They are always being used for something. (Chris, April, 2012)

There are many positive effects of the tablet laptops in Chris’ classroom. He finds that students are more organized. “The biggest advantage, I would say, is that students do not lose things. They are more organized” (Chris, April, 2012). They are also more enthusiastic about learning. “The students are a lot more motivated and they are a lot more engaged” (Chris, May, 2012). Chris finds it much easier to do investigations and explorations in the classroom.

If you look at the curriculum, there are a lot of specific expectations that essentially require a constructivist approach to teaching. It will say, ‘Students will investigate’ or ‘Students will discover’. I find that this is much easier to do with having tablets. (Chris, May, 2012)
Meeting the individual needs of the students is also much easier. “I think I’m better able to meet their needs. It’s easier for me to provide extension activities and similarly it is easier for me to provide remedial work” (Chris, May, 2012). In addition, it is easier for Chris to show his students the real world connections of mathematics. Finally, there are many tasks and projects that Chris would not be able to do without the laptops.

I have done various things like have the kids create videos that demonstrate certain mathematical functions. The boys did all the research online and created the videos and edited them right on their tablets. I probably could do that without a tablet, but it would be hard. I would probably see it as too much work and I do not think I would do it. (Chris, May, 2012)

Chris does admit, however, that many positive effects are because his school uses tablet laptops and the Microsoft One Note program. He has been at his school for 5 years and for his first 2 years, the students had laptops. The math teachers, including Chris, did not use the laptops very much.

Do you mean laptops or tablets? If the question was about laptops I would have a very different answer than if I am talking about tablets. In the first few years I was at Westminster Academy, we had laptops. In math, we rarely used them. Now, my learning has definitely improved on how we can use them, but at that point, we might have used some graphing software occasionally or use it to search for things, but the reality was it did not serve much purpose. I wanted my students to be able to do math and use the tool to help them communicate mathematically. If you cannot write on it, then what is the purpose? Now that we went tablet, that made a big difference. Now we use them all the time. (Chris, April, 2012)

Since they switched to tablet laptops three years ago, there has been a tremendous shift, not only in frequency of use, but also in how the computers are being used. For example, with the Microsoft One Note program, the students can share a note when working in groups and their work can also be shared with the class. Chris finds that this improves communication and collaboration and makes group work much better. He would not be
able to do this without the tablet laptops. In addition, his ability to formatively assess students has improved because he can synchronize his computer to his students’ computers and he can check what they are doing, what they are not understanding, and he can send them additional work or leave them notes.

Although Chris has found that the tablet laptops have positively influenced the classroom environment, he does acknowledge a few challenges. At first, it takes time for the students to adjust to using a laptop and to using new programs. As a teacher, he has to be patient and be willing to give up some time to show students how a program works. In addition, teachers have to be flexible with technical problems, which can also be a frustration. “Technology can sometimes be an issue if there is an Internet issue or something is just not functioning properly on your computer. You have to be flexible with some of the tech issues” (Chris, May, 2012).

Classroom management is also a challenge. Chris believes that the laptops are a huge draw for the students’ attention. Teachers need to learn new management strategies to keep kids on task. Distractibility has always been a factor; the computers are simply a different kind of distraction.

Some of the boys do really struggle with control so it is a distraction, but those are probably the same kids that would be doodling in their book anyways. It is more of a draw when it is a computer game where they are really focused. Doodling you might still be half listening, but with a game, you are not listening at all. I will often tell the boys to turn it to tablet mode and that is one way to manage the class and keep them on task. (Chris, May, 2012)

Finally, finding the time to design lessons which effectively integrate technology is a struggle. Having a supportive department and teaching partners can help because when someone finds a good program it can be shared with the rest of the team. “We work
together as a department so when we find something good, people tend to pass it along to
the whole department” (Chris, May, 2012). In addition, it is important that the school
gives teachers time to learn effective ways to integrate technology. “Our professional
development sessions are the key to our success. They are often focused on the more
practical side of how to use the tablets in the classroom” (Chris, April, 2012).

Chris also believes that it is important for teachers to realize that technology is
simply one tool at their disposal. Technology is not a solution. Teachers should be wise
about when it is best to use it and not feel that they have to use it all the time.

My advice to teachers would be to work at being wise. Ask yourself, when is it
best to use technology? It is a tool, not a solution. You need to know when it can
be a useful tool and when it is not. You do not have to use it if it does not fit.
(Chris, April, 2012)

In my opinion, Chris falls into the Reorientation phase of Hooper and Rieber’s
(1995) model of technology integration. He is very willing to try out new things in his
classroom. The laptops have enabled Chris to step out of the traditional role of the teacher
as the sole source of knowledge and have made it much easier for Chris to act as a
facilitator. Chris’ classroom is very student-centred, and I believe that this would be
much harder for him to do if it were not for the laptops. If the tablet laptops were taken
away from the learning environment, I believe there would be a significant negative
effect on the classroom environment since Chris now designs every lesson around the
fact that his students have access to a tablet laptop at all times.

**Case Study: Bob**

Bob’s overall score of 4.61 out of 6 on the Attitudes and Practices to Teaching
Math Survey is the lowest of all of the teacher participants. I think that this is, in part,
because Bob is the most inexperienced teacher in this study. Although he earned his Bachelor of Education degree 10 years ago, he has only been teaching full time for a few years, and he has only been at Queen’s College for one year. Although his score is the lowest, his results on the Attitudes and Practices to Teaching Math Survey are still quite high and suggest that he is open to change and I believe that once he has more experience teaching his own class he will continue to grow.

Bob is a very patient and empathetic teacher. It is very clear to me that he cares about his students and their learning. He wants his students to understand math and feel good about their ability. As a result, he does tend to explain things in great detail and lead discussions rather that let the students do too much inquiring on their own. He wants to be a facilitator, but is nervous to release full control over to his students.

I am not very good at putting a problem out there for students and having them do the inquiry. It is something I do, but I just get so nervous about trying to do more because it takes longer and some of the students get lost. At least with the teacher-centred lesson, which I know is horrible, but at least I can keep everyone on the same page and I feel like everyone understands. That is where I really struggle. As soon as I open it up more to the students I feel like I am going to lose some of them. I feel like it is my job to explain the concepts to them so that they understand. I’m really struggling with that in trying to work on the idea of inquiry. (Bob, April, 2012)

His department has a goal to become more student-centred in their teaching, however. I believe that, with a focus on this area, Bob will continue to grow into the teacher he wants to be.

Bob frequently uses pairs and small groups in his classroom. Because he teaches at an all girls’ school, he feels that it is very important to let his students talk to one another and share ideas. He strives to make his classroom a comfortable and social learning environment for the girls. On my visits, it was very clear to me that the students
are happy to be there and that they are comfortable asking each other questions to aid their understanding. “The students ask each other a lot of questions and help each other quite a bit. Bob has obviously created an environment where asking questions is the norm” (Field Note, April 24, 2012).

Bob always tries to give his students a real world connection when he is presenting mathematical ideas. For example, on one of my visits, the students were investigating measurement. They were investigating a few new shapes, one of them being a pyramid. To make the lesson more engaging, he began by allowing the students to brainstorm familiar objects that were shaped like pyramids. This eventually led them to talk about Egyptian pyramids and he steered the conversation towards the Luxor Hotel in Las Vegas. Then he split the girls into groups and challenged the students to think about how they might calculate the surface area of the hotel. He wanted them to focus on the net of a pyramid and what that might look like. Bob then encouraged the groups to determine a formula for the surface area of a pyramid. Once each group had their formula, he took some time to lead a class discussion about each group’s formula. Eventually the class came up with a conclusion for the surface area of a pyramid. Each group then had to work to determine the real life surface area of the Luxor Hotel. The students used Google Maps to find the measurements of the hotel. At the end of the class, each group shared their results with the class.

What an engaging way to introduce SA of pyramids! The students had a chance to brainstorm their ideas and then the lesson focused on pyramids and the Luxor Hotel. A few of the students have been to Las Vegas and were quite excited to be looking at something that they had seen. They were challenged at first to come up with a formula. They knew it was four triangles and a base, but they were a bit challenged to realize that the height of the triangle and the height of the pyramid were not the same. Once they agreed on a formula they used it to determine the
SA of the hotel. The girls were amazed at how big the hotel actually was and how big the SA was. (Field Note, May 17, 2012)

*Use of Laptops*

This lesson showcases Bob’s approach to using laptops. He feels they should be embedded naturally in a lesson to make the lesson more engaging or to enhance the teaching of a mathematical concept. “Technology should not be seen as an add-on or as something forced. Technology should be embedded naturally in lessons. It should be seen as an enhancer” (Bob, April, 2012). Bob’s school uses tablet laptops and his students also regularly use the Microsoft One Note program. In the surface area lesson I just described, the students were asked to download the skeleton of the lesson into their Microsoft One Note math folder and then they were able to make all their notes right on the screen. Bob finds this aspect of the tablet laptops to be invaluable because the students are more organized and never lose their notes. “I think one of the most positive aspects of the tablet is the organizational aspect for students. Students can have everything they need in one place” (Bob, April, 2012)

Bob feels that the tablet laptops have led to many positive changes in the classroom. First, student organization has improved. In addition, it is much easier for Bob to incorporate real world applications into his lessons.

The way that I can present the content is much more fluid and dynamic with a tablet. I can present it in a real-life way that the girls will interpret and understand more easily. Bringing in real-life applications is easier and more effective. (Bob, April, 2012)

He could have simply given his students the measurements of the Luxor Hotel, but allowing them to go on Google Maps was much more engaging and exciting for the students. “I always think about how I can make a personal connection to a sort of dry and
boring concept in the kids minds and how to get them to remember what they are doing” (Bob, April, 2012). Bob also feels that his lessons have more variety now that he can have his students use a computer whenever they need it. For example, he can use videos or websites to demonstrate concepts. He can also use programs like Geometer’s Sketchpad or virtual manipulatives as they are needed rather than waiting to book a lab. “I use virtual manipulatives a lot now. I would say that there is something like that embedded into most of my lessons. It is so much easier to access those kinds of things and use them when appropriate” (Bob, April, 2012). In addition, Bob can more easily meet the individual needs of his students now that he has access to tablet laptops. “The classroom has become more student-centred and more differentiated. It’s much easier to do those activities that are student-centred and meet varied needs” (Bob, May, 2012).

Bob is a fairly laid back teacher, so although he has faced some frustrations, he is hesitant to call them challenges. His colleagues have talked about distractibility being a problem, but Bob does not find it one.

Other people will say that there is a distraction problem, but I do not find that. You need to give students a choice and they need to learn from their mistakes. Students will learn very quickly that if they go on Facebook in the middle of class and they miss something, then they will get behind. They need to learn from that mistake. My attitude is, let the kids learn and make mistakes and then they are more likely to see the benefit of staying on task and paying attention. (Bob, April, 2012)

Bob does acknowledge that there are many resources available out there and it can take a great deal of time to wade through them all. Rather than let this deter him, Bob chooses to focus on one thing at a time and he starts small. “You need to take your time and try not to be overwhelmed by the sheer volume of things that are out there. Do one thing at a
time” (Bob, April, 2012). He also relies on members of his department and the information technology integrator to help him find good resources.

Next year, Bob would like to experiment with using the tablet laptops to improve communication. For example, he would like to try using blogs or Google Docs in the math class. He would also like to begin investigating synchronizing his computer with those of his students. The school has not yet enabled this feature, but he has seen it at other schools and he feels that it could lead to large changes in assessment and on communication and collaboration.

I have not been able to explore the synching aspects of the tablets yet, but I see a lot of potential. That is something I would like to look into more next year. I think that would help me to have a better understanding of what the kids get and don’t get because I would be able to look in their notebook at any time. I have also seen other schools used shared One Note files in group work so I think it might help with that also. (Bob, May, 2012)

I believe that Bob is at the Integration phase in Hooper and Rieber’s (1995) model of technology integration. Bob’s classroom would be a different place without the tablet laptops, and he has experimented with using laptops beyond the traditional use of note taking and word processing. That being said, Bob has not yet fully reconceptualized the purpose and function of the classroom. In addition, although he is on the path towards student-centred learning, I do not believe he is fully there. Bob is still not completely comfortable with opening his classroom up to his students and giving up control. As he gains more experience as a teacher, I feel that he will make progress in this regard and soon enter the Reorientation phase.
Cross-Case Analysis

After I summarized each case, I examined common themes that emerged. Many of the teachers spoke about a laptop environment making it easier to differentiate their lessons, offer more choice, and use of variety of resources. As a result, they all felt that laptop classrooms are more student-centred. The teachers in this study were better able to use manipulatives and design investigative lessons. Thus, these laptop classrooms are more exploratory. The participants in this study spoke about challenges they have faced. They found, however, that patience and collaboration with others helped them overcome these difficulties. Finally, many of the teachers in this study viewed technology as a tool. Although it is a powerful tool, it is the teachers themselves that are the key to the success of using technology in the classroom. Technology alone will not transform education; it is the teachers that use technology to its fullest potential that will. In the next section, each of these themes will be described.

Student-Centred Classrooms

The first common theme that was evident in all of the interviews I conducted and all of the classroom observations I made was that these laptop classrooms are more student-centred. As was outlined in Chapter Two, the previous research in this area was mixed. Some studies showed that laptop classrooms were more student-centred (Dunleavy, Dexter, & Heinecke, 2007; Lowther, Ross, & Morrison, 2003; Maninger & Holden, 2009) while others were less positive (Cuban, 2001; Ross, Hogaboam-Gray, McDougall, & Bruce, 2002). Based on the feedback from the teachers in this study, and based on my many observations, it is clear that laptops in these classrooms do create learning environments that are more student-centred and constructivist in nature.
With laptops, these teachers are able to use a variety of resources that can better meet the individual needs of each student.

The laptops allow for more access to varied resources that are out there. Will one program work for every kid? Probably not. The laptop allows you to show them three or four that all meet different learning styles or different ability levels. Why not present these to the kids and give them the option of choosing what works best for them? (Aaron, May, 2012)

Lessons can be easily differentiated for many levels and interests. Prior to having laptops, these teachers had to photocopy various resources for students and had to pre-plan how they were going to differentiate. Now, these teachers can have resources available digitally and can simply send different documents to different students with the touch of a button.

I have always had all of these great resources in my office, but wondered how I could get them into my classroom. Now I have turned them all into PDF files and then I can create extension activities or remediation activities and send them to students that need them. If someone finishes their work or needs extra help, I no longer have to search for something and then run to the photocopier, which takes a lot of time. Now, with the touch of a button, I can put it right into their One Note folder and the kids have it instantly. (Bill, April, 2012)

Students can also be sent to various websites that are levelled to meet various needs.

In addition, because of the wide variety of resources that are available digitally, these teachers are more likely to design lessons that reach various learning styles. For example, the teachers in this study have experimented with using videos, podcasts, interactive websites, digital applets and other programs. Although teachers in a non laptop environment can also meet the various learning styles of their students, this task is much easier when digital resources can be employed. “I think the tablets improve my ability to meet the varied learning styles in my class. I can bring in videos or websites to
appeal to some of the more kinaesthetic or visual learners. Before, I never did that”

(Chris, May, 2012).

All of the teachers in the study also commented that they were able to give students more choice because of the access to laptop technology.

Given the amount of different websites, digital manipulatives, videos, etc. that are out there, it allows the students to choose the path that is best for them. The students can become the centre of their own learning. Students can learn more at their own pace and start to create their own understanding of the material, rather than be given it in a more teacher-centred model. (Aaron, Open-Ended Response Survey)

This choice ranged from how the students could learn a topic all the way to how students would be assessed. When students are given choice, they are more likely to engage in a task, and they are more likely to make meaningful connections to what they are learning. For example, Frank describes a project he assigned in which one of his students wanted to use the game Mine Craft to demonstrate his understanding.

A student asked me when we were doing a project on probability if he could use Mine Craft to do his project. He had to demonstrate that this game would meet all of the requirements of the probability project and explain his purpose behind wanting to use that game. Once he did that I was okay with his choice and let him use the game. He still had to do all of the mathematical work, but I would argue he got so much more out of the project than many of the other students because it was very engaging for him. He was able to take a game that he loved to play and demonstrate how math came into it. (Frank, May, 2012)

This comment from Frank shows that students can make very powerful connections to the mathematics they are learning when they are given the freedom to choose something that has meaning to them.

Finally, the technology available in these classrooms makes it easier for assessment to be more student-centred. Now, instead of giving one assessment for all, these teachers can assess each student in a way that matches their strengths. For example,
Chris has experimented with having students that are better at explaining orally make a video explaining their understanding of a concept, while another student can choose to write a response in a digital journal. As Frank explains, laptops make this much easier to do.

With laptops, there are more assessment options. You can choose different things that meet the kids’ strengths. For example, some kids prefer to type up their thinking so you can do that….Some kids are not very good at writing so being able to record themselves explaining a mathematical concept is great. They can also do a video if they prefer. You can try doing digital portfolios and see a student’s growth over time. Those are all things I would not be able to do without IT. (Frank, May, 2012)

In addition, assessment can now be focused more on assisting students to see what their strengths and weaknesses are. Many of these teachers can synchronize their computer with their students’ computers and can check work and leave comments for them about what they need to work on or what they have done well. “I can monitor what my students are doing because I can see their work in their One Note file. Then, I can help them identify areas where they need some help by leaving them comments” (Earl, May, 2012). Technology makes assessment for learning, such as what was just described by Earl, much faster and easier.

The wide variety of digital resources available in a laptop classroom allow these teachers to more easily meet the needs of their students and allow them to design more creative lessons around those needs. As a result, their students are able to see that they do not have to follow one set path, but rather can choose the path that works best for them. Non-laptop classrooms can also be student-centred places, but creating such an environment is much harder. Laptops allow more variety because they give teachers and students constant access to the digital world and all of its resources and tools. For all of
the reasons I just described, the teacher participants felt that the laptops helped to make their classrooms more student-centred.

**Exploratory Classrooms**

A key aspect of the reform movement is to get students to construct their own understanding of mathematical concepts. Battista (1999) found that “mathematical ideas must be personally constructed by students as they try to make sense of situations” (p. 4). One way to do this is to design tasks in which students work together to investigate and explore mathematics. Laptop classrooms make it much easier for teachers to design these exploratory activities. As a result, teachers in this study reported that teaching in a laptop environment allowed them to plan and utilize more investigative tasks and make their classrooms more exploratory. “Computers allow students to explore and experiment. I find that computers allow students to take risks and play with mathematical concepts” (Frank, Open-Ended Response Survey).

The teacher participants gave many reasons for why they felt that laptop classrooms are more exploratory. First, students with computers have access to more tools for investigating concepts. In addition, these digital tools are more dynamic and more engaging for students.

I have looked at little applets that with sliders allow the students to make changes to things like linear or quadratic equations. Kids can see right in front of them what changing one value in an equation does to the function and they can start to make connections. Those things are super nice. They help students to make predictions and then test their predictions and realize they were right or wrong and then readjust their predictions based on that. (Chris, May, 2012)

In addition, teachers can use virtual manipulatives at any time and do not have to worry about whether or not they have the physical tool.
We use manipulatives a lot more now. We have three grade seven classes going on at the same time. We do not have three sets of manipulatives and so we would not be able to use them. Now, you can get digital resources so everyone can have access to them and everyone can be using them at the same time. (Earl, May, 2012)

There are also many applets available to teachers either through paid websites such as Explore Learning, or available for free on the internet. The teachers in this study were quite excited about all the tools that were available to them and have seen student engagement increase when they use these tools. “Technology has allowed me to better demonstrate to students the beauty and power of mathematics through visual explorations and other things. The kids are more interested in learning math because it becomes more dynamic” (Earl, May, 2012). The teachers also know that everyday more and more of these tools are becoming available.

Second, teachers can use digital tools whenever they want and can easily utilize them any time they are appropriate. In a laptop classroom, teachers do not have to pre-plan when they want to use exploratory tools and then try to book the lab. In addition, they do not have to rush students with their explorations because they are not limited to a set time on the computers. Booking and using computer labs was quite frustrating for teachers.

Prior to the laptops, I would have to book the lab or the carts. I would keep my fingers crossed that they were free during the period that I needed them. There was a lot of frustration with booking the lab or carts. This has been alleviated with the students having laptops. In the past, I would try to book the lab for multiple periods for an activity, but sometimes I could not. In that case, we would rush to get it done in one period or we would do it for one class, then go back to the classroom, then back to the lab later. You lose some of that continuity. (Aaron, May, 2012)
Teachers are busy. If it is hard for them to access or book computers, then they will probably choose to not use them. Then, their students will lose out on all the great exploratory tools that are available. When accessing exploratory tools is easy, then teachers will be more likely to use them to enhance student understanding.

Third, laptop classrooms appear to be more collaborative. Some of these teachers have experimented with shared files in which students can work on the same document and see what ideas their peers have.

The tablets improve their group work. You can link their One Notes. I can open up a shared One Note session and then everyone in the group can join that session. They can all work on the same document and it is synchronous. So, as one student is writing on it, it can show up on other people’s screens. It is really cool and it works well for collaboration. (Chris, May, 2012)

In addition, students working together to investigate a concept are excited to share what they have learned with those around them. I observed a moment in Frank’s class in which students were working with a program called Google Sketch Up to complete their task. One boy picked up the program very quickly and soon many of the students surrounded his desk and this boy did a mini tutorial for the class showing them what he had learned to do.

It was so neat! One boy suddenly became very excited about what he was creating and another boy came over. Suddenly, a small group was surrounding the computer and the boy then gave a short lesson to the group on how to use the sketch up program. (Field Note, February 23, 2012)

Earl describes a similar moment in his class:

If it was a math textbook, there is no way kids would be excited and run over and see what everyone is doing, but with the laptops the kids are really interested in seeing what other kids are doing. When one student finds something, everyone else runs over and tries to figure out what they are doing. (Earl, February, 2012)
Finally, many of the teacher participants commented that creating problems and tasks for students to complete was much easier now that they knew that students could use a laptop at any time. “The laptops give us more options. They give us more ways that boys can explore their learning so we can more easily create tasks. We always did tasks, but the range of what you can do is now wider” (Aaron, May, 2012). Once again, if things are easier for teachers then they will be more likely to use them in their teaching.

Because these laptop classrooms are more exploratory in nature, the teacher’s role has shifted. All of the teachers in the study commented that they were able to play the role of facilitator much more easily now that their classrooms were laptop environments.

With laptops, it is easier to play the role of facilitator. I can make my lessons more student-centred and I am not just at the front of the room lecturing. With the laptops, the students can work on their own or with each other and I can walk around and facilitate that learning. (Bob, May, 2012)

On many occasions, I observed that, when students got stuck, they searched the Internet for answers or consulted with their peers rather than just immediately go to the teacher for help. The teachers were then freed up to wander around the room asking each group questions or working individually with students that needed more assistance.

**Implementation of Laptop Technology**

Despite the previous research that indicated that math teachers were not frequent users of laptop technology in the classroom (Bebell & Kay, 2010; Becker & Anderson, 1998; Grimes & Warschauer, 2008; Hitt, 2011; Rockman et al., 1998; Silvernal & Lane, 2004; Zucker & McGhee, 2005), the math teachers in this study were effective implementers of laptops. This shows promise that laptops can lead to positive changes in mathematics teaching and learning. Many of the teachers in this study used the laptops
everyday as an integral part of their lessons. Some of the previous research indicates that when math teachers do use laptops in the classroom, the use is fairly traditional (Dunleavy, Dexter, & Heinecke, 2007; Silvernail & Lane, 2004). Once again, however, the teacher participants all demonstrate that having laptops in the classroom can lead to a variety of creative uses that all make the classroom more student-centred. For most of the teachers in this study, their classrooms would be very different places without the laptops. In fact, at both Westminster Academy and at Radcliffe Academy, the mathematics departments are seen as leaders at the school in technology integration. “The school is starting to see the math department as leaders in integrating technology” (Earl, May, 2012). The classrooms I observed were far from traditional.

One interesting finding that came up was some of the differences that were evident in the classrooms in which tablet laptops were used compared to classrooms in which traditional laptops were used. Teachers in tablet laptop schools were better able to use the laptops for collaboration because of their ability to create shared notes and these teachers were also better able to explore alternate avenues for assessment using the synchronization feature of Microsoft One Note. Frank and Aaron, whose students use traditional laptops, were not able to do as much with the laptops and their students still relied on using a binder for note taking and group work that required writing. Both Bill and Chris who have taught in both environments commented that prior to getting tablet laptops the mathematics teachers at their schools rarely used the laptops in their classrooms.

In mathematics, it is important that students have the ability to write down formulae and other notations. Both Chris and Bill felt that the change to tablet laptops
was the driving force to a more frequent and meaningful use of laptops in the mathematics classrooms at their schools.

For us, the switch to tablets has been a game changer. Before, we did not really use the laptops. Now, with the tablets, we use them all the time. The kids can write on them so that now all of their notes and their homework can be done on the computer and stored in one place. This has been huge. Now I can see what they are doing and I can have a better understanding of their work. (Bill, February, 2012)

Thus, perhaps one of the reasons that the mathematics teachers in this study were effective implementers of laptop technology was because the majority of them used tablet laptops. This is hard to say, however, because, although Frank and Aaron used the laptops less frequently than others, they still used them quite a bit. Perhaps the use of laptops did not lead to as many changes in assessment and amount of collaboration in their classrooms because they were newer users of laptop technology. With time, it is quite possible that they will be able to do as much with the traditional laptops as the other teachers were able to do with tablet laptops.

**Overcoming Barriers**

Every teacher in this study mentioned that distractibility was a problem in a laptop classroom. This finding was also mentioned by other researchers (Donovan, Green & Hartley, 2010; Hu, 2007; Zucker & McGhee, 2005). Students are used to using computers to play games so a laptop in the classroom can be a big draw for students’ attention. In addition, teacher participants acknowledged that time can also be a barrier to effective implementation of laptop technology. It takes time for teachers to find new programs that they can use in their classrooms and then it takes them time to learn how to
use these new programs. None of these teachers felt that these barriers were insurmountable.

   Instead of letting distractibility to become a problem, as was found by Hu (2007) the teachers in this study found that they needed to be patient and understanding with their students. Students are used to using computers as a toy, not as a learning device.

   It is hard to get the students to realize that the laptops are an educational tool. Part of it is we have to look back and see that these kids are 12 and 13 and for a decade this has been a toy. Now all of a sudden you are saying that this is an educational tool. (Aaron, January, 2012)

As a result, teachers need to be patient and need to teach students appropriate uses of the computer while at school. There have always been distractions in the classroom.

Technology is simply a new distraction for students. Teachers need to adapt and learn new classroom management strategies.

   Kids have always tuned out in class. Technology is a bit more of a draw because there is more of immediacy to it. For example, if a kid is wondering if they got an email they can check it right away and tune out. But, there have always been distractions. Teachers just need to figure out management strategies that work for them. (Chris, May, 2012)

   Administrators also need to be patient and allow teachers time to integrate laptops in the classroom. “Everyone needs to understand that integrating laptops effectively takes time” (Bill, February, 2012). The previous research also found that support for teachers from the one-to-one schools was a key factor in success (Becker, 1998; Silvernail et al., 2011). All of the teacher participants were very appreciative that their schools did not put any pressure on them to use the laptops in the classroom. Instead, the administration was patient and allowed the teachers to use technology as they saw fit.

   I really appreciate that the school has not dictated to us that we have to use the laptops a certain amount of time. It allows me the freedom to use the laptop as a
Along this same train of thought, teachers need to be patient with themselves. Teachers cannot suddenly change overnight and they must allow themselves time to integrate laptops into their teaching. “I think patience is a huge part of success. You cannot suddenly become a great integrator. You have to start with one thing and reflect and build on that” (Frank, May, 2012). The teacher participants all mentioned that, when they began using laptops, they started slow. They started with one lesson and went from there.

When I started, I picked one class and started slow. I focused on a few aspects of integrating technology into that class. As the resources get built up then you can move onto a new class. You need to take your time. You cannot expect to do everything at once and that is okay. It can take maybe three or four years to get where you want to go and then, even at that point, there is probably something new that has come out or something different. So, you have to be patient with yourself and just pick a few things and do your best with that. (Earl, May, 2012)

Patience on the part of both teachers and administrators can assist with making sure that laptops will be used in the classroom and that when they are used they will enhance learning.

Many of the previous studies noted that time was a barrier to the use of laptops (Bauer & Kenton, 2005; Bennison & Goos, 2010; Rice, Wilson & Bagley, 2001; Silvernail & Lane, 2004; Zucker & McGhee, 2005). The teachers in this study agreed that teaching in a laptop environment will initially take more time to plan lessons and that teachers will always require time to keep up with what is available digitally. As a result, collaboration with colleagues is extremely important to overcome the barrier of time. All of the teachers indicated that being a part of a teaching team was very helpful because they could share the work when planning lessons, activities, and assessments. “It is very
important to have a teaching partner or colleagues that you can share resources with or ask them how they are doing things or visit their classroom and see what they are doing” (Frank, January, 2012). In addition, working as a collaborative team helped lessen the time it took to keep up to date with new programs that were available. Most of the teachers indicated that, when someone in their departments found a useful tool, they took the time to show everyone how to use it.

As a department, we work together to find resources. When someone finds something useful it gets passed along to others. Or, we can say ‘I am looking for this type of thing’ and everyone looks out for that for you. We share and discuss with one another. (Bob, May, 2012)

This collaborative approach to sharing tools was very helpful in alleviating the barrier of time.

What was very evident in this research is that, when teachers try new initiatives, such as integrating laptops into the classroom, there will be challenges that they face. Teachers cannot let these challenges stand in their way and allow them to become barriers that prevent educational transformation. Instead, teachers must be open minded and seek solutions to these challenges before they become impediments to change. In this study, the participants found that the challenges they faced could be overcome with patience and collaboration with others.

Role of the Teacher

For a laptop classroom to be effective, the focus must be on the teachers, not on the technology. “Technology is only as good as the people that can deliver it and utilize it” (Bill, May, 2012). In their interviews, all of the Directors of Information Technology at the participants’ schools, as well as the teacher participants themselves, acknowledged
that one of the main keys to success was to focus on supporting teachers with ample professional development. The message was also very clear that the laptop technology is just one of many tools that teachers have at their disposal. As has been described, laptop technology is a tool that makes it easier for teachers to teach in a more student-centred way that emphasizes the different needs of learners, but it is still just a tool.

Technology is not the key to an educational transformation. It is just a tool that can be used to make a lot of things easier and better and a lot of things more engaging for the kids. It’s the teachers, they are the key. The teacher is the most valuable component of any classroom, the human being with the knowledge, the understanding, and the expertise. Technology use is only as good as the teachers. At King’s College, that is where we are now going to focus, on giving the teachers the support they need. (Director of Information Technology, King’s College, May, 2012)

Administrators cannot expect education to be transformed by simply placing laptops in the hands of every student. Similar cautions were made by Holcomb (2009), Holland (2001), and Waxman and Huang (1996). For true transformation to take place, teachers must be shown how to meaningfully integrate technology into their lessons.

Teachers need to be shown what to do with the laptops. If you just give them the laptops and leave them on their own, a lot will not figure it out. A lot will not use the technology. It is not always because they do not have the ability, but they do not have the time. Teachers are focused on the curriculum, on assessment, on giving help, on doing the paperwork that comes along with that. For the most part, teachers are willing and eager, but they want to be shown what to do. They want to see how the laptops will make a difference in their classrooms. (Assistant to the Director of Information Technology, Radcliffe Academy, May, 2012)

This study suggests two main ways to do this: through professional development and through hiring information technology integrators to work with teachers.

*Professional Development*

Professional development is an important component to any educational change (Boyle, While, & Boyle, 2004; Guskey, 2002; Wood, Cobb, & Yackel, 1991).
Professional development can take many forms, however. It can be one time sessions focused on a given topic, it can be a regular part of department or faculty meetings, or it can take place as part of a professional learning community.

This study revealed that, for laptop technology to lead to significant transformative changes in mathematics teaching and learning, professional development must be ongoing and, if possible, it should be embedded into a teacher’s normal schedule.

We meet as a group every eight days with one of the technology teaching and learning co-ordinators. This has been a vital part of my learning to effectively use the laptops in my class. If we just had one-time sessions, I would not learn as much and I do not think I would have come as far. I might forget things or we would not learn about new things as frequently. I also like that this is built into our prep times. It is not something else that has been added on. We are already so busy. I think some people might resent that and would not be as willing to try new things. (Earl, May, 2012)

If ongoing professional development does not happen, then laptops may not lead to significant changes.

At my school, we do not meet very frequently to talk about how IT can be used. There also is not any time within our schedules to help with PD in any way. These things do not help you be very successful. The teachers that believe in it will be, but in terms of overall change I do not think it can happen without frequent support. (Frank, May, 2012)

Professional development should also be focused on ways to integrate the technology rather than how to use the technology. Although it is important to initially teach teachers some of the basics of how certain programs work, what they really want are practical ideas of what to do with the laptop technology in their classrooms. “It is important for teachers to be given ideas of what to do. That is what we want, how the laptops can be used” (Bob, May, 2012). Previous research supports this finding (Bennison & Goos, 2010; Mortensen, 2011).
Another key point is that professional development should also focus on constructivist methods of teaching in conjunction with how technology can support this type of teaching.

Every PD session that is instruction based, we are always taking about collaboration and student-centred learning, we are talking about tapping into co-operative learning strategies. There is a big focus to give us professional development that is aligned with a more student-centred approach and then layer the technology into this approach…..I definitely do less Socratic teaching now than I used to and I think that is partly tied together with the technology, but also tied with my growth as a teacher about student-centred learning. (Chris, April, 2012)

Previous research shows that teachers who teach in a more constructivist manner are more effective integrators of technology (Li & Ma, 2010). If the goal is for laptop technology to bring about transformative changes in education, then professional development must focus in some way on helping classroom teachers shift their beliefs away from the traditional teacher-centred model and to a more constructivist learner-centred model. Otherwise there is some concern that the laptops will just allow teachers to do old things in a new way.

The thing that bothers me the most is a teacher that just takes all of their regular lessons and says they are using technology by putting the old lessons on PowerPoint or on their SMARTBoard. They are still just doing the same thing. (Bob, May, 2012)

Instead, teachers need to see how laptops can help them do new things. This is very hard to do without effective professional development.

In my opinion, Radcliffe Academy had the most effective model of professional development of the schools researched. New teachers to the school were asked to attend some professional development sessions before the beginning of the school year where they could learn some of the basics about the laptop program in place at the school, they
could familiarize themselves with the laptops, and they could learn more about specific programs, such as Microsoft One Note. Each year, teachers are placed into small groups, often by grade level taught or by subject taught, and as part of their schedule meet as a group with one of the technology teaching and learning co-ordinators where they learn about new programs, share tools they are using in the classroom, and share ideas for integrating technology into their lessons.

I think our model is very solid. It is great to have the PD built into preps. We see the teachers very frequently and can support them a lot better. Sometimes we’ll show the teachers an activity or resource, sometimes we answer their questions, sometimes we’ll introduce something new. The other day we showed the teachers TED-Ed. It really depends. These tech sessions have become part of the culture here. Teachers have no problem coming to them and some people actually get excited because it is pushing their curriculum in new ways. Teachers can also book us one-on-one outside of these sessions if they need more support. Plus we also build in time for technology PD at the start and end of every school year. I think the teachers here are well supported. (Assistant to the Director of Information Technology, May, 2012)

The fact that teachers at Radcliffe Academy feel supported was confirmed by Earl. When I asked him why he thought that Radcliffe Academy was so effective with laptop technology integration, his reply was, “the support structure we have in place for teachers. I think that is one of the things that makes technology so effective here” (Earl, May, 2012).

Many of the other schools had some professional development practices that were also successful. For example, at Queen’s College, at every staff meeting a teacher presented something they were doing with laptops in their classroom. Each staff member was required to present at some point. The intention of these sharing sessions was to build on the creativity and expertise within the staff. As some of the previous research has shown, teachers are very busy and are often quite isolated (Stigler & Hiebert, 1999).
This isolation can sometimes prevent teachers from changing their practice. At Queen’s College, they made collegial sharing part of the school culture in order to try to break teachers out of their isolation and enact school wide change.

As part of our professional development, every teacher is required to present in either a department meeting or a staff meeting something that we have done in our classroom that incorporates technology. It is great because it is not someone coming from the outside. You want your teachers standing in front of their colleagues showing them what they are doing in their classroom. That shared collaborative feeling is so important. (Bob, April, 2012)

In addition, Westminster Academy puts on a technology boot camp at the beginning of every school year where teachers learn about new programs that they can try in their classrooms. “We find that the intensive boot camp at the start of the year gets all the teachers in one place and we can then give them some instruction on how to use new programs” (Director of Information Technology, Westminster Academy, April, 2012). They also focus on new features of the laptops. For example, when they made the switch to tablet laptops, the focus was on how to use Microsoft One Note.

If teachers are not given ample professional development then they will be less likely to use the laptops in the classroom (Donovan, Hartley, & Strudler, 2007; Sandholtz, Ringstaff, & Dwyer, 1997). Silvernail and Buffington (2009) found that “teachers who participate in effective professional development programs use the laptops almost twice as often in designing and delivering instruction as their colleagues who do not participate in these professional development programs” (p. 2). Frank and Aaron both expressed some frustration about the lack of professional development that was provided to them when they made the switch to a laptop school.

Unfortunately, I think we did it wrong. We went the route of here are the laptops, now use them. We need to show teachers that this is how technology can assist
you with getting away from the traditional. Just giving the laptops and saying go does not make that much of an impact. It will for some, but not for all. (Frank, May, 2012)

Although the technology department and the administration were planning on offering professional development, this had not yet taken place. It seemed that, in the case of King’s College, the laptops were introduced first, and then the professional development plan was somewhat of an afterthought. Although Aaron and Frank were able to work past this frustration and they worked together to find ways to implement laptop technology in their programs, the previous research outlined in the Literature Review shows that not every teacher would react in this same way. For many, the absence of effective professional development would lead to decreased use of the laptops in the classroom.

*Information Technology Integrators*

Another critical component of success is for laptop schools to have educators working full time in a non-teaching role to help other educators with ideas for effective integration. Some of the previous research supports this finding (Bauer & Kenton, 2005; Becker, 1998; Cole, Simkins, & Penuel, 2002). At the schools participating in this study, the name most often used for this position was an information technology integrator. It is important the people in this role are educators. This is important because other educators need to relate to the information technology integrators, they need to share common language, and they need to feel comfortable going to the integrators for assistance. “I am not a teacher. I do not know the lingo. We wanted the integrator position to be a teacher, someone who can relate to teachers and who has some credibility with teachers” (Director of Information Technology, King’s College, May, 2012). In addition, the people in this role do not need to be the best users of technology. Instead, they need to
relate well to others and they need to have a willingness to learn and try new things. An affinity for technology is very important, but being the most expert user is not necessarily an advantage.

We do not necessarily look for teachers that are strong with technology. We look first at people who are really good at working with others and who are really strong with the classroom pedagogy and then lastly they are good with technology. (Director of Information Technology, Queen’s College, April, 2012)

Each participating school in this study had at least one information technology integrator. The models used varied. King’s College has one full-time information technology integrator for the school (grades 3-12), Queen’s College has three part-time integrators serving the school (JK-grade 12), Westminster Academy has one part-time person serving the school (grades 5-12), and Radcliffe Academy has two full-time integrators for the school (JK-grade 12). In all schools, teachers can book time with the information technology integrators whenever they would like to. The integrators will then assist teachers with finding resources, with ideas for how to integrate technology into lessons, and with how to use technology.

In some cases, these individuals can also be booked to come to classrooms and assist teachers with teaching a lesson where technology is being used. This is especially useful for new or hesitant teachers. Although Holland (2001) found that some teachers do not learn from this co-teaching, and instead, they leave their classrooms when the integrator arrives and use this as an opportunity for a break, this did not happen in the participating schools. Everyone I interviewed mentioned how important this role was in helping teachers integrate technology, especially with helping reluctant teachers feel more confident.
We have our tech integrator. If we have a pedagogical idea and we are not sure how to integrate technology with it we can book time with her, as much time as we need, and she will help. This is great for me because I am a bit unsure about integrating technology into my lessons. It is probably the best support mechanism that we have. (Frank, May, 2012)

Summary

All of the teachers in this study appeared to have constructivist beliefs. As a result, previous research suggests that the teachers in this study were more likely to effectively integrate technology into their teaching (Li & Ma, 2010). In this case, however, as in previous research, it is hard to say whether these teachers had constructivist beliefs prior to having laptops in the classroom or whether the laptops in some way changed their beliefs. That being said, this was not the intention of the current study. Based on the data gathered from the interviews, I believe that these teachers already had constructivist beliefs prior to the addition of laptops in the classroom. As was shown, however, laptops have made it easier for these teachers to teach in a constructivist manner. These teachers have moved further along the continuum, away from a teacher-centred classroom and towards a student-centred classroom. Laptops have also increased the number of resources that can be accessed in the classroom. As a result, these teachers were more likely to use manipulatives, and it was easier for them to create student tasks.

Many of the participants commented that technology must enable teachers to transform their practice. Teachers cannot use technology to do the same things they have always done. Cuban (2001) had similar concerns when he found that “most teachers had adapted an innovation to fit their customary practices, not revolutionize them” (p. 97). Technology needs to transform education and allow teachers to do things they have never been able to do before, or things that have been very difficult to do without it.
This study found that the key to this process was to focus on the teachers. Professional development is an integral part of the success of a laptop program. When used properly, laptops can shift education away from the traditional and make classrooms more student-centred. In addition, it was found that teachers can more easily design exploratory activities in a laptop environment. It was also found that mathematics teachers regularly use laptop technology in their classrooms. These uses also go well beyond traditional note taking, drills and worksheets. Instead, the teachers in this study used the laptops to create varied and engaging lessons, provide more choice to their students, differentiate their teaching, and assess their students in more comprehensive ways. Finally, using technology in the classroom is not without challenges. Some teachers can use these challenges as an excuse and they will then create a barrier for using technology. It was found, however, that by collaborating with others and by being patient, the teachers in this study were able to overcome any challenges they faced.
CHAPTER FIVE: DISCUSSION

Introduction

In this chapter, I revisit the research questions that were posed in Chapter One and explore how the six case studies presented answer those questions. I will also connect my findings to the previously reviewed literature. Then, I will discuss the major findings from this study. Recommendations for schools that are planning on going one-to-one will be presented. In addition, suggestions will be made for how math teachers, who do not teach in a laptop environment, can still utilize computers in their classroom to make changes in teaching and learning. Finally, areas for further research will be presented.

The Research Questions

This thesis focused on the research questions posed in Chapter One. To review, these questions were:

1. How does laptop technology influence mathematics teaching and learning in the intermediate classroom?
2. What bearing does the use of laptop technology have on the framework of the Ten Dimensions of Mathematics Education?
3. How do mathematics teachers implement laptop technology?
4. What are the barriers to the implementation of laptop technology?

I will examine each research questions in light of the findings of each case study.

Discussion of Each Research Question

1. How does laptop technology influence mathematics teaching and learning in the intermediate classroom?
The first research question seeks to determine what kind of influence laptop technology has on mathematics teaching and learning in the intermediate classroom. With more schools going to a one-to-one laptop environment, it is important to closely examine how this kind of environment changes the classroom and whether it is influenced in a positive or negative way. In addition, because much of the previous research indicated that math teachers were not frequent users of laptop technology in the classroom (Bebell & Kay, 2010; Becker & Anderson, 1998; Grimes & Warschauer, 2008; Hitt, 2011; Rockman et al., 1998; Silvernal & Lane, 2004; Zucker & McGhee, 2005) this is an extremely important question to address.

To begin, this research provides evidence that the mathematics teachers in this study were effective implementers of technology. Almost all of the participants in this study used the laptops every day as an integral part of their lessons. All six of the teacher participants in this study were overwhelmingly positive about the influence of laptops on the teaching and learning of mathematics in their classroom. Frank was the only teacher who was still somewhat hesitant to fully integrate the laptops into his teaching. Frank saw that there were many advantages to using laptops in the classroom, and as he gains more experience, he will probably move further along the path to full integration.

Every teacher participant acknowledged that laptop technology in the classroom made it much easier for them to play the role of facilitator and allowed them to be more student-centred in their delivery. Some of the previous research supports this finding (Johnson, Schwab, & Foa, 1999; Mortensen, 2011). Bill, Earl, Chris, and Bob, who all use tablet laptops, commented that they often directed their students to download the lesson instructions into their Microsoft One Note folders and then the students can get
right to work without waiting for the teacher to get started. “There are many times that the students will download the lesson, get the notes they need, read the instructions, and get started on the activity before I tell them to” (Chris, May, 2012). Bill shares a similar story. “With Microsoft One Note, the teacher is no longer the gatekeeper. The teacher is freed up to wander and facilitate. They no longer have to control the lesson” (Bill, February, 2012). Although Frank and Aaron do not have tablet laptops, they also commented on being able to break away from the traditional role of teacher as expert because the laptops enabled their students to explore and research on their own or in groups without needing the expertise of the teacher. “The laptops allow the students to explore in groups. I can then go around and check in with each group and facilitate the learning. I do not have to stand at the front and lecture” (Aaron, May, 2012).

Every teacher commented that the laptops enabled them to better meet the individual needs of their students. The laptops allowed the teachers to use a variety of programs for lesson delivery, and in many cases, the teachers could give the students a few options and allow the students to choose what worked best for them. When students can choose what works for them, they are more likely to be engaged with what they are learning and they are more likely to understand the material. When I visited the classrooms, it was very clear to me that the students were engaged with what they were doing. The teacher participants commented that the laptops have improved engagement and enthusiasm. “The students are more interested in doing things online or with the computer. Look at the world in which kids live in today. Everything is done digitally. That is what they want. That is what engages them” (Aaron, May, 2012). Research by Grimes and Warschauer (2008), Holcomb (2009), and Maninger and Holden (2009) also
found that laptop environments improved student engagement and enthusiasm, which then led to improved learning.

The laptops also allowed these teachers to be more creative with their lessons. This finding is extremely important because some of the previous research (Bebell & Kay, 2010; Rockman et. al, 1998) showed that laptops were not being used in a creative way, but were used for traditional means such as research and word processing. Many of the teachers in this study were able to experiment with different ways of delivering lesson material. For example, Earl was experimenting with the use of the flipped classroom. Bill used Internet-based communication tools to conduct an educational game against another class in a different location. Frank and Bob both experimented with the use of Google Maps to measure real world objects and connect mathematics to their students’ world. Every teacher commented that the laptops allowed them to bring more real life applications into their classroom. “The laptops take the kids out from the four walls of the classroom. Things are not just happening on a piece of paper. They are learning about what is going on in the world and how math can be applied to those things” (Bob, April, 2012). Dunham and Jardine (2009) and Johnson, Schwab, and Sturdivant (1999) also found that laptops allowed students to work on problems that were more real. In addition, all of the teachers were more easily able to use tools such as virtual manipulatives, web-based applets, and Geometer’s Sketchpad to create dynamic investigations for their students. It is clear that the teachers in this study were using the laptops as a means to change the way they used to teach mathematics lessons.

Almost all of the teacher participants mentioned that their students were more organized with the laptops. Similar benefits were found by Silvernail and Lane (2004)
and Zucker and McGhee (2005). The teachers mentioned that students rarely lost anything because it was saved on their computers. This is especially true for the teachers using the Microsoft One Note program because with that program, the computer is the math binder. “The benefits to student organization have been tremendous. Before, when you gave the kids a sheet, it may or may not have left the room with them. Now, it is in their digital One Note file” (Chris, May, 2012).

Despite the positive influence of laptops on the learning environment, every teacher mentioned that the laptops were a distraction. This distractibility factor did negatively affect the classroom at times. Most of the teachers acknowledged that there have always been distractions in the classroom; laptops are simply a new one. To adapt to this new distraction, teachers just need to learn new classroom management strategies. Donovan, Green, and Hartley (2010) and Zucker and McGhee (2005) also found that laptops were a distraction in the learning environment and that teachers had to learn new management strategies. “Having distractions was not a new problem for teachers to contend with, but managing instant messaging, e-mail, appropriate Web sites, and computer games was new. As a result, teachers and administrators had to learn appropriate management strategies” (Zucker and McGhee, 2005, p. 25). In addition, being patient and understanding with students as they adjust to using a laptop as an educational tool can help.

2. **What bearing does the use of laptop technology have on the framework of the Ten Dimensions of Mathematics Education?**

The Ten Dimensions of Mathematics Education (McDougall, 2004) were outlined and summarized in Chapter Two. One of the main purposes of this research study was to
find out which aspects of mathematics education were most influenced by the laptops and whether the laptops assisted teachers in making changes in their teaching to a more reform method. This is an extremely important question to address, as none of the previous research looked at using the framework of the Ten Dimensions of Mathematics to investigate the influence of individual laptops on mathematics education.

The first dimension, Program Scope and Planning, is somewhat affected when laptops are introduced into the classroom environment. The teachers indicated that their curriculum has not changed very much with the introduction of laptops. In other words, these teachers are still teaching the same material that they were teaching prior to having laptops in the classroom. In addition, the teachers in this study have always tried to emphasize the big ideas and to connect the strands of mathematics where it is appropriate. Thus, the laptops have not had changed this aspect of their programs. What has been influenced, however, is the variety of resources that can be utilized when delivering their programs.

I would not say that the laptops have changed my implementation of the curriculum in a positive or negative way. What it has done is it has certainly given me more avenues in terms of how I want to possibly go about certain aspects of the curriculum. (Bob, May, 2012)

To do this, all of the teachers indicated that it takes them longer to plan lessons and they have to think more carefully about the resources they would like to use when delivering content. “My lessons take longer to plan because I am trying to bring in a variety of resources” (Bill, May, 2012). In addition, the teachers indicated that it is much easier to incorporate the process strands into their lessons. For example, with laptops it is much
easier for teachers to promote problem solving and it is easier for students to represent their ideas.

In my class, the laptops have helped to improve and promote problem solving. Because I can create shared One Note files, I find that the boys are better able to work together on problems and learn strategies from one another. I can also project student work onto the screen for everyone to see so my kids can learn a lot from looking at the work of their peers. (Chris, May, 2012)

Students can also work on more complex problems. “Computers have allowed my students to engage in mathematical problems that are bigger and more complex than if they were to work with pen and paper and the textbook” (Frank, Open-Ended Response Survey).

All of the teachers interviewed felt that laptops in the classroom allowed them to better meet the individual needs of their students. Thus, the second dimension, Meeting Individual Needs, was one of the most significantly changed dimensions as a result of the laptops. The teachers all mentioned that they were easily able to differentiate lessons, that they were able to give students more choice in their learning, and they were able to meet various learning styles through the use of multiple programs.

I think through the use of laptops, teachers can use a variety of different strategies that can help all their students learn mathematical concepts. It can also be an easy way to show different variations/solutions on the same concept. Laptops allow you to bring visual/auditory/kinaesthetic examples right into the classroom and meet the students where they are and how they learn best. (Aaron, Open Response Survey)

Peck and Dorricott (1994) also found that laptops help teachers individualize instruction. It is very encouraging that this dimension has been influenced in such a meaningful way. As more is uncovered about how students learn best, meeting individual needs is of the utmost importance. For too long, math has been seen as a subject for the elite, however,
everyone can do math (Boaler, 2008). Having laptops in the classroom can better equip teachers with the resources they need to reach all learners and allow all students to be more successful.

All of the teachers in this study created very comfortable and welcoming learning environments for their students. They organized their desks into either pairs or groups of four because they all felt that it was important to encourage communication, collaboration, and sharing of ideas. None of these teachers felt that the laptops had any bearing on their decision of how organize their classrooms, nor did the laptops have any significant bearing on how they chose to group their students. “The way I choose to group my students or set up my classroom is not changed by the laptops. It would only change if you did not have enough access to laptops which does not happen in our environment” (Aaron, May, 2012). Thus, the third dimension, Learning Environment, did not appear to be significantly changed by the presence of laptops.

Student Tasks is another dimension that appeared to be somewhat affected by the introduction of laptops in the classroom. The teacher participants all indicated that they always tried to incorporate open-ended tasks, problem solving and inquiry problems, as well as real world connections in their classrooms. In addition, all of the teachers saw that mathematics was a balance between skill, application, and discovery. The addition of laptops to the learning environment has not changed their approach to teaching mathematics and their use of rich tasks. What it has done, however, is make it much easier to teach in this way. Because they find it easier to use problems and rich tasks in their teaching the teachers indicated that they use tasks more frequently.
We used rich mathematical tasks prior to going laptops, but the laptops have allowed us to open these up a bit more and now we are integrating technology into these tasks. I would also say we probably use tasks more now because the technology gives us more options and makes this kind of approach to teaching a bit easier. (Frank, May, 2012)

This finding is very relevant to mathematics education because in their review of research on reform, Ross, McDougall, and Hogaboam-Gray (2002) found that “classrooms that provide rich tasks, with rich discourse about mathematical ideas, and a focus on children’s thinking, contribute to deeper understanding” (p. 10).

Laptops in the classroom did not initially appear to have a significant influence on the fifth dimension, Constructing Knowledge. All of these teachers spoke about their attempts to teach mathematics with a constructivist foundation. In addition, these teachers all made an effort to ask their students questions in order to delve more deeply into a topic and help students construct their own knowledge. The laptops were seen as being neutral in their effect on questioning – they did not help, nor did they hurt.

I think it is very important to ask students questions about the math they are learning to help them construct their own understanding of a concept or to deepen their understanding. I don’t believe that having laptops has changed this belief in any way. (Bob, May, 2012)

Upon further reflection of the interviews and my observations, however, I feel that this dimension was influenced by the presence of laptops in the classroom. Teachers were more easily able to create explorations and investigations for their students using computer based programs such as Geometer’s Sketchpad and web-based programs such as applets. These investigations enabled students to construct their own knowledge in a much more real and dynamic way. This is very important because, according to NCTM (2000), “if students are to learn to make conjectures, experiment with various approaches
to solving problems, construct mathematical arguments and respond to others’ arguments, then creating an environment that fosters these kinds of activities is essential” (p. 18). The laptops make it easier for teachers to create an environment in which these activities are promoted. Essentially, the wide variety of programs that are available to teachers in a laptop environment make it easier for them to teach in a constructivist manner. “Technology provides you with a way to enhance what you do. It can allow me to do things more easily, to teach in a way that is more aligned or matched to my beliefs” (Aaron, May, 2012). In addition, some of the teachers were starting to experiment with using blogs and journals. These tools enabled the students to reflect on their learning, which assists with knowledge construction. “With online journals or blogs my students can reflect on what they are learning which helps them deepen their understanding” (Earl, May, 2012).

The teacher participants all realized the importance of frequent communication with parents. They also realized that this communication should not just be about student progress, but also about sharing what was happening in the mathematics classroom. For example, Frank and Aaron created a document for parents that explained their program and reasons for its design. The teachers felt that email helped them communicate with parents more frequently, thus, teacher access to a computer or laptop was very important. Student access to laptops did not appear to have any effect on the ability to communicate with parents, however.

Laptops significantly influenced the seventh dimension, Manipulatives and Technology. Every teacher studied explained that they use manipulatives more frequently in a laptop classroom. This is due to a few reasons. They were no longer limited by their
access to physical manipulatives because they could use virtual ones instead. In addition, having access to laptops at any time is less restrictive because they can use a tool whenever they would like rather than be limited to when a computer lab may or may not be available.

Booking labs was very unpredictable and sometimes was not worth the headache. Now that I know my students always have access to computers I am using digital tools such as virtual manipulatives and Geometer’s Sketchpad more often. The time I put into finding these tools is worth it. With the labs it was sometimes frustrating. (Chris, April, 2012)

Thus, because the teachers knew they had ubiquitous access, they spent more time finding new tools to use in the classroom. As a result, they were more creative and offered more choice to their students. This is very important as NCTM (2000) encourages teachers to use a wide range of tools for exploring, representing, and communicating mathematical ideas. In addition, mathematics needs to “shift from a cut-and-dried, right-answer orientation to one that supports and encourages multiple modes of representation, exploration, and expression” (Ball, 1992, p. 47). When used properly, manipulatives can help achieve this goal. All of the teacher participants felt that the laptops took away any excuse that a teacher might have for not using manipulatives and technology in the classroom. They also felt that because they were able to use these tools more frequently, their ability to achieve the curriculum expectations and offer their mathematics program was enhanced. “The changes in the Ontario mathematics curriculum include a lot more references to having students discover or investigate. Technology makes this easier to do” (Bill, May, 2012).

The teachers in this study were somewhat unsure of the influence of laptops on the eighth dimension, Students’ Mathematical Communication. The teachers surmised
that laptops would have a positive effect on this area, but were unsure because many of
them have not yet fully explored the potential of laptops to enhance this aspect of
mathematics. “I do not know about the impact of laptops on communication. I do not
know if I have spent enough time exploring that” (Bob, May, 2012). A few of the
teachers have started to experiment with using blogs, Google docs, and online journals
and indicated that these are excellent ways to increase student communication of
mathematical idea.

I am just starting to explore more with things like blogs and Google docs to see
how that can change communication. A lot of students do not normally like to
write, but when it is digital they do not seem to mind as much. So far it has been a
good way to get them to explain their thinking. (Bill, May, 2012)

As well, the teachers felt that collaboration seemed to be better in a classroom
with laptops. “Tablets can allow for greater collaboration between students” (Chris,
Open-Ended Response Survey). Previous research also found improved collaboration in a
laptop environment (Lowther, Ross, & Morrison, 2003; Maninger & Holden, 2009;
Rockman et al., 1998). In addition, many of the teachers mentioned that the laptops
seemed to be a tool that brought the students together.

The laptops open up a lot of windows and doors for more collaboration and
communication. I do not think that computers have isolated children. I think in a
math class, when used effectively, they have actually pulled them together in
terms of being able to collaborate and talk about what they are learning. (Frank,
May, 2012).

Fonkert (2010) also noted that computers were a great tool to bring students together.

Finally, the teachers who use Microsoft One Note, and Chris in particular, mentioned that
the tablets were great because students can share a One Note file and can collaborate and
communicate with one another right on their screens. “Shared One Note files are a really
great way to have students working together on a problem and sharing their ideas as they write them on the screen” (Chris, May, 2012). Clearly, the potential is there for this dimension to be changed positively when laptops are present in the classroom. The extent of this change has not yet been fully explored by the teachers taking part in this study.

Assessment was significantly changed when laptops were present in the classroom. This is a significant finding, as previous research (Silvernail & Lane, 2004) found that the influence of laptops on assessment was weak. The teachers who taught with the tablet laptops and who have fully explored the synchronization capability of the Microsoft One Note program were especially positive about the influence of student laptops on assessment. All of the teachers indicated that the laptops have allowed them to be more creative with offering alternate assessments. Far too often, mathematics is assessed by the use of traditional pencil and paper tests. Now that the teachers have access to laptops, however, they are experimenting with using projects and tasks to explore understanding. Some teachers have asked students to make videos or audio files in which they explain a concept. Teachers can then watch these videos or listen to the audio file and assess a much deeper view of student understanding than they could from a single question on a test.

I have now been able to assign assessment tasks that allow for a variety of potential products that provide evidence of student understanding. These assessment pieces provide greater insight into what students truly understand compared to paper and pencil tests. (Frank, Open-Ended Response Survey)

The fact that laptops can help teachers change their view of assessment is very important as this is a key part of mathematics reform. NCTM (2000) believes strongly that assessment is more than “merely a test at the end of instruction to see how students
perform under special conditions” (p. 22). Instead, teachers need to look at several pieces of work in order to see what students understand.

To make effective decisions, teachers should look for convergence of evidence from different sources. Formal assessments provide only one viewpoint on what students can do in a very particular situation – often working individually on paper-and-pencil tasks, with limited time to complete the tasks. Over reliance on such assessments may give an incomplete and perhaps distorted picture of students’ performance. Because different students show what they know and can do in different ways, assessments should allow for multiple approaches, thus giving a well-rounded picture and allowing each student to show his or her best strengths. (NCTM, 2000, p. 23)

In addition, many of the teacher participants indicated that the laptops have allowed them to do more formative assessment and have allowed them to give more constructive and immediate feedback to their students. For example, Chris, Bill, and Earl all spoke about the ability to look at a student’s Microsoft One Note math file to check for understanding and to write comments to the student about what they have mastered and what they still need to work on.

I have been able to better formatively assess my students by synchronizing my laptop with my students’ laptops. I find that I am able to better have an understanding of each student as the course progresses and not just at test times. I am then better able to give students feedback that can help them to be more successful. (Earl, Open-Ended Response Survey)

Because files can be shared so easily electronically, students are able to do more peer assessment. “Using shared One Note files I can have two students look at one another’s work and give each other feedback on how to improve” (Bill, May, 2012). Laptops have a great deal of potential to alter how teachers assess and when they assess. Laptops can change a student’s view of assessment away from a high stakes, one shot attempt to show understanding to a more holistic view of showing understanding over the course of a period of time. Students in a laptop environment can start to see assessment as a way to
improve their own learning and the learning of others around them rather than something to be scared of. As NCTM (2000) writes “assessment should not merely be done to students; rather, it should also be done for students, to guide and enhance their learning” (p. 22).

Teacher’s Attitude and Comfort Level with Mathematics did not appear to change with the presence of laptops. All of the teachers in this study seemed to have very positive attitudes towards mathematics. When I observed their classrooms, they were all enthusiastic and positive about math, and they showed a genuine love of the subject. In addition, they all seemed very comfortable with their ability to teach the subject. Most of the teachers were very willing to open their classrooms up to the ideas of their students. It did not appear that laptops in the classroom led to any changes in the teachers’ attitudes about math or on their comfort levels with math.

3. How do mathematics teachers implement laptop technology?

For the most part, the teachers in this study were all very effective at integrating laptop technology into their lessons. As has already been mentioned, this finding holds great promise for mathematics teaching and learning as much of the previous research showed that mathematics teachers were reluctant implementers of laptop technology (Bebell & Kay, 2010; Becker & Anderson, 1998; Grimes & Warschauer, 2008; Hitt, 2011; Rockman et al., 1998; Silvernail & Lane, 2004; Zucker & McGhee, 2005). The teachers in this study were all effective implementers because they were all flexible, open to new ideas, and confident. The key to effective implementation of laptops is the teachers themselves. This finding is consistent with previous research (Dunleavy, Dexter, & Heinecke, 2007). For the most part, these teachers were not afraid of the technology
and were not afraid of trying things that they were new to them. They did not feel the need to be expert users in everything, and were perfectly fine if their students were better users than them.

In Chapter Two, I described research by Becker (2000) that spoke about four conditions that are necessary for using computers as a pedagogical aid. He said that teachers must have convenient and reliable access to technology, they must possess sufficient skills and knowledge, technology cannot constrict their curricular freedom, and the technology must support constructivist beliefs. All of the participating schools had a large infrastructure. The technical support available at these schools was excellent. Bill and Earl spoke about minor technical issues, but none of the teacher participants spoke about technical problems hindering their use of the laptops in the classroom. This is contrast to some of the previous research where technical issues were a problem (Grimes & Warschauer, 2008; Ross, Hogaboam-Gray, McDougall, & Bruce, 2002; Silvernail & Lane, 2004).

In addition, all of the teachers interviewed were confident technology users, and they also had information technology integrators that could assist them if they needed it. All of the teachers mentioned that the laptop technology made it easier for them to teach in a constructivist manner. Rather than constricting their curricular freedom, the laptops actually gave them more choice and allowed them to be more creative. Thus, by using Becker’s (2000) research as a guide, I noticed that the teacher participants were all very effective in using laptop computers as a pedagogical aid because all of the necessary conditions were met.
With the exception of Aaron and Frank’s school, the teacher participants indicated that the support that their schools gave them was instrumental in their success. None of the teachers in this study (including Aaron and Frank) felt pressured by their administration to use the laptops. Everyone commented that this relaxed approach allowed them to use the laptops when they felt they enhanced learning instead of feeling forced to use them at all times. “Technology should be something that enhances student learning. You cannot use it just for the sake of using it. The use of technology cannot be forced or mandated” (Bob, April, 2012). They also felt that this approach actually helped them use the laptops more because they could start small and build lessons around the technology. If they felt forced, they would probably have resented the technology and not been as open to its use. “If technology use was mandated then I think teachers would feel pressure. I think this pressure would either lead to less creative uses or would result in teachers not using the tool at all” (Aaron, May, 2012).

Most of the participating schools provided their teachers with ample professional development in order to be effective users of laptop technology. The importance of professional development to the success of a laptop initiative was also found by Becker (1998), Holcomb (2009), Penuel (2006), and Mortensen (2011). This study also found that professional development must initially begin with some basic how to’s, but then must shift its focus to purposeful integration. It is very important that this professional development be ongoing and be embedded into the regular teaching schedule in some way. It is also essential that schools have at least one information technology integrator who assists teachers with ideas for integrating technology and who can come to classrooms to help teachers. This person can alleviate the initial stress that some teachers
feel about using unfamiliar technology in the classroom and can help teachers gain confidence in their ability to use technology. This finding supports the research of Bauer and Kenton (2005), Becker (1998), and Cole, Simkins, and Penuel (2002).

The advice these experienced teachers gave about implementation of laptop technology was very useful. They all felt that teachers need to start small and focus on one thing at a time. It is important that administration and teachers understand that effective implementation of technology takes a great deal of time. Very few people can become expert users overnight and setting small goals can allow teachers to feel more successful. If teachers feel success, then they will be more likely to continue to use technology in their classes. “I know I am somewhat reluctant, but as I do things with technology, and I see them working, I feel like it is worth it to try more things. I definitely see the potential” (Frank, May, 2012). As teachers continue to use technology, they will become more comfortable with it and then they will be more apt to allow the students to drive the use of laptops. It is impossible for a teacher to keep up with all the new tools that are available, so they must be willing to allow their students to suggest tools and become the expert users. “Kids are digital natives. They pick things up so quickly. It is impossible for a teacher to keep up. Teachers must be able to relinquish some control and be ready to admit that they will not know how to use everything” (Assistant to the Director of Information Technology, Radcliffe Academy, May, 2012).

4. What are the barriers to the implementation of laptop technology?

As far as the teachers in this study were concerned, there are very few barriers to implementing laptop technology. All of the teachers indicated that the most important factor in the implementation of laptop technology is the teacher. Technology is just a
tool, and unless a teacher is shown how to use it effectively, then it will not lead to changes in teaching and learning. As was outlined in Chapter Four and briefly in the previous section, effective implementation depends on giving teachers ample professional development. If teachers are not shown how to integrate the technology then they will not be as likely to use it in their classroom.

Another challenge to implementation of laptops is the distraction that they provide to students in the classroom. This finding supports the research of Donovan, Green, and Hartley (2010) and Zucker and McGhee (2005). The teachers interviewed for this study stress, however, that distractibility should not be seen as a barrier because it is easy to overcome. This finding differs from the previous research as many teachers in those studies found distraction to be a significant challenge (Donovan, Green, & Hartley, 2010; Zucker & McGhee, 2005). In fact some schools list this as one of the reasons for dropping laptop programs (Hu, 2007). The teachers in this study stated that patience is very important. In addition, teachers must be willing to adapt and learn new management strategies. They may even need to closely examine their lessons and make sure they have created engaging and meaningful activities for their students. “The laptops can be a distraction so it is incumbent upon teachers to design lessons and activities that will be engaging. If students are engaged in what they are learning they will be less likely to be distracted” (Aaron, May, 2012). Finally, teachers can also give their students break times in a long class where they are allowed to check email or surf the internet.

I am not sure what is so wrong with giving the kids a few minutes to play around on the computers if they have been working hard. For example, they spend 20 minutes working hard on something. They can get a couple minutes for a mental break and can use the computers if they want. (Bob, April, 2012)
For many teachers, time can also be a barrier to implementation. This supports the findings of Bauer and Kenton (2005), Bennison and Goos (2010), Rice, Wilson and Bagley (2001) and Zucker and McGhee (2005). Unlike some of the previous research, however, the teachers in this study did not find that a lack of time prevented them from integrating laptops into their teaching. Because there are so many digital resources that are available to use, it can be very overwhelming and time consuming to wade through them all. Almost all of the participants mentioned the additional time that they had to devote to planning lessons that effectively integrated technology. “I spend a lot of time designing lessons and finding ways to integrate technology into my lessons. There is a lot of initial work when you are trying to integrate laptops” (Bill, May, 2012). The teachers interviewed did not allow this to hinder their use of technology in the classroom, however. To find a solution to this challenge the participants worked with their teaching partners or their department to share the work of searching for valuable resources.

In addition, having information technology integrators is an asset. Part of the job of these individuals is to search for effective digital tools that can be used and show teachers how to integrate these into their lessons. “One of the roles of the integrator is to search for programs that teachers can use in their classroom and present these programs to the teachers. Teachers are busy and the integrators help them do some of the searching” (Assistant to the Director of Information Technology, Radcliffe Academy, May, 2012).

Some of the previous research found that technical problems with computers were a barrier to frequent use (Grimes & Warschauer, 2008; Ross, Hogaboam-Gray, McDougall, & Bruce, 2002; Silvernail & Lane, 2004). Bill and Earl did mention a few
technical problems in their interviews such as students coming to class with low batteries or missing stylus’ for their tablets, but they did not feel that these issues were barriers to using technology in the classroom. None of the other teachers mentioned any technical problems that hindered the use of laptops in the classroom. Clearly, for schools that choose to go one-to-one, having a great deal of technical support is very important.

We are so lucky here. We have a tech department that is so quick at fixing things and troubleshooting and problems that may occur. Often we do not even know if kids are having technical issues because there is a help desk they can go to. (Earl, May, 2012)

Parents can often be barriers to change in education, but for the most part, parents did not have any bearing on how the teachers in this study implemented the laptops. The only teacher who had some problems with parents was Earl when he experimented with using a flipped classroom. At first, the parents thought that he was not properly teaching their children, but once the rationale for this type of learning was explained, the parents were supportive. Many of the teacher participants mentioned parents as being barriers to trying to implement a more reform teaching method. For example, Aaron and Frank mentioned many struggles with parents when they first moved away from a traditional model of teaching. However, most of the teachers did not consider parents as being barriers to implementing laptop technology into the classroom.

**Major Findings**

This thesis examined six case studies of intermediate mathematics teachers who taught in laptop classrooms and how the laptops influenced the teaching and learning of mathematics using the framework of the Ten Dimensions of Mathematics Reform (McDougall, 2004). The study showed that the laptops in the classrooms researched did
lead to significant changes in the teaching and learning of mathematics. In addition, this study revealed many ways in which these six teachers were effective implementers of laptop technology.

There are many important findings in this thesis. First, this thesis provides evidence that mathematics teachers are effective users of laptop technology. Many of the previous research studies summarized in Chapter Two noted that mathematics teachers were reluctant or less frequent users of technology (Bebell & Kay, 2010; Becker & Anderson, 1998; Grimes & Warschauer, 2008; Hitt, 2011; Rockman et al., 1998; Silvernal & Lane, 2004; Zucker & McGhee, 2005). This study shows quite the opposite. In fact, at a few of the schools I visited, the mathematics department was seen as the leader of technology integration.

Second, this thesis is filled with many uplifting and positive descriptions of how a one to one laptop environment has allowed the teachers studied to make changes in their teaching that have resulted in significant changes to how their students learn mathematics. As I mentioned in Chapter Two, Dunleavy, Dexter, and Heinecke (2007) indicated that “further research is needed to provide detailed descriptions of teaching practices within classrooms with a 1:1 student to networked laptop ratio” (p. 441). This thesis provides very detailed descriptions of teaching practices in a laptop classroom. The participating teachers were able to better meet the individual needs of their students and were able to create more dynamic and engaging lessons which involved manipulatives and technology. The presence of individual laptops also resulted in significant changes to how students were assessed and how they were asked to demonstrate their mathematical understanding.
Finally, this thesis shows that teaching in a laptop environment can allow teachers to break away from the traditional. Some of the previous research showed that teachers were using laptops in traditional ways and were not using them as a means to challenge their existing ways (Dunleavy, Dexter, & Heinecke, 2007; Rockman et al., 1998; Ross, Hogaboam-Gray, McDougall, & Bruce, 2002). This thesis shows that teachers can use the presence of laptops as a catalyst to break away from the traditional and challenge how things are done. Teachers in this study were extremely creative. Some began to experiment with the idea of flipped learning, some used Skype to communicate with other classes, some used internet tools or programs to explore mathematical concepts in a more dynamic and engaging way. The laptops were not used for word processing or research, but instead were used to transform the teaching and learning of mathematics.

The major findings of this study can be summarized as follows:

1. There is potential for laptops classrooms to become more student-centred and constructivist in nature. For this to happen, schools must support teachers with ongoing professional development that is focused on both constructivist teaching and on effective technology integration.

2. There is potential for mathematics teachers to be effective implementers of technology. For this to happen, professional development should focus on showing teachers math specific software and programs such as Geometer’s Sketchpad, Graphmatica, Excel, and other applets and websites. Schools should also consider the use of a tablet laptop which enables kids to write on the screen.
3. Laptops can allow for more variety and student choice. As a result, laptops can help teachers differentiate their classrooms and better meet the individual needs of their students.

4. Laptops can enable educators to assess their students in new ways. Assessment methods can be designed around the student’s strengths. The synchronizing ability of some computers can also help teachers formatively assess and better gauge the level of understanding of their students.

5. Laptops encourage teachers to use manipulatives and other tools to help students explore their own learning and construct their own understanding of mathematical concepts. It is much easier to use these tools in the classroom because the laptops give teachers access a wide variety of resources such as graphing software, applets, websites, and virtual manipulatives.

6. Laptops make it easier for teachers to bring the world and real-life applications into their classrooms.

7. There are some challenges when teaching with laptops. For example, laptops can be a distraction to learning mathematics. Teachers need to realize that there will always be distractions in the classroom and they need to adapt their classroom management strategies. It can take longer for teachers to plan lessons that effectively integrate technology. Teachers need to collaborate and share resources. Finally, with technology, there are always technical glitches. Schools need to have a solid IT department and teachers need to be patient and flexible.
8. One-to-one laptop schools should hire at least one full-time information technology (IT) integrator who is a teacher, but whose job it is to support other teachers with IT integration.

Preparing to go to a One-to-One Laptop School: Recommendations for Schools

The increase in one-to-one computer teaching environments over the last few years has been rapid (Grimes & Warschauer, 2008; Holcomb, 2009). It is only a matter of time before more schools go in this direction. The findings of the current research study suggest a few helpful recommendations that schools planning to go one-to-one can use.

First, if the budget allows, schools should provide their teachers with laptops at least a year before going one-to-one for students. Doing this will allow teachers time to learn how to use the laptops, to play with what laptops can do, and to discover resources that they can use in their classrooms. “The teachers at Westminster Academy received laptops before the students did. We felt that it was important to give teachers a bit of a head start and allow them to start exploring” (Director of Information Technology, Westminster Academy, April, 2012). Teachers will feel more comfortable with students having laptops in their classrooms if they themselves have been given plenty of time to become familiar with the device.

Second, schools who are preparing to go to a one-to-one laptop environment should create a professional development plan as soon as possible. They should also begin professional development sessions well before the laptops are introduced. This will allow teachers a chance to become more familiar with how to integrate technology into their lessons, and it will give them a chance to explore the programs that are available to them. Again, teachers will be more likely to use technology in their classrooms if they
feel comfortable and confident with it and if they see a purpose to its use. It was clear to see the frustration that Aaron and Frank felt when they suddenly went to a “bring your own device” model, without really being exposed to any professional development surrounding using laptops in the classroom.

I wish that we had been given the laptops and then been given professional development. I wish they had thought about this is where we are going to be going and what do teachers need to use them effectively. I feel like the laptops have suddenly appeared and I feel prepared because I have done some work. I have worked with Aaron and I have gone to sessions outside of school on how to use technology, but I think that others at my school do not feel prepared to be using them as effectively as they could be. If we walked around to some classrooms we know that laptops are there but the teachers are choosing not to use them. (Frank, May, 2012)

Luckily Aaron and Frank are confident teachers who are risk-takers so they did not let this stop them from using the laptops. Not every teacher would fall into this category, however. Although Aaron and Frank used the laptops, they were the least frequent users in the group I studied. This may be because they were the newest to having laptops in the classroom, but this may also be because they were not given sufficient professional development. Laptops are an expensive learning tool and schools need to make sure they are being used effectively. Without a professional development plan in place, this is hard to do.

Third, when creating the professional development plan, schools need to create time within the daily schedule to give teachers support. This study revealed that the most effective professional development was on-going and embedded into a teacher’s day. The most effective model appeared to be the one created by Radcliffe Academy. Teachers will be more receptive to a new idea if they know that time has been set aside for them to be given professional development. The support that teachers receive cannot be seen as
an add-on to an already busy schedule. Otherwise, teachers may resent the initiative, no matter how great it may be. “Teachers are busy. We need to make the support we give them as easy as possible for them to access if we want technology integration to be a success” (Director of Information Technology, Westminster Academy, April, 2012).

In addition, professional development surrounding laptop integration must be ongoing and constant. Integrating technology can take time, and one time initiatives will not be enough to sustain interest and excitement. “We have found that embedding professional development into a teacher’s schedule every eight days has worked very well. Teachers are always focused on new ways to integrate technology because we are constantly meeting with them” (Assistant to the Direction of Information Technology, Radcliffe Academy, May, 2012).

Fourth, schools that are preparing to become laptop environments should hire an information technology integrator as soon as possible. This person may be part-time or full-time, depending on the budget, but hiring them before a school goes one-to-one will allow them to build a relationship with the teachers on staff. It will allow them to see the comfort level of the teachers and will allow them to see what the teachers need in terms of information technology support. The role of the integrator is one of the keys to the success of a one-to-one initiative, so the sooner they can start working with teachers and build a collaborative learning environment, the better. “If you do not build a relationship with the teachers then you have little buy-in. It takes time for the integrator to build rapport and trust with the staff, but it is critical that they do this” (Assistant to the Director of Information Technology, Radcliffe Academy, May, 2012).
Fifth, school administrators should not put pressure on their teachers to use the laptops in the classroom. This research has shown that effective implementation of technology can take time. School administrators should support their teachers and encourage them to use the laptop technology in their classrooms, but they should not dictate a certain amount of use. All of the teachers interviewed appreciated that their administration had a relaxed approach to technology use. They felt it was better for administrators to realize that technology is a tool that can be used to enhance teaching and learning, but should not be used just for the sake of using it.

At my school they trust us to use the tablets when we feel it is best. It’s not forced. That would be pointless because then I might just use them to say that I have. I think the way my school does it works….we are definitely strongly encouraged to use the tablets, but we are not forced to. (Earl, May, 2012)

Finally, schools that are preparing to go one-to-one should do a great deal of research. They should send teachers to other laptop schools and have them see first hand what it is like. They should bring in teachers that are experienced with teaching in a laptop environment into their school to talk to their staff and answer questions. Teachers will have many questions about what it is like to teach in a laptop classroom and many will be quite apprehensive. Allowing teachers the chance to talk to others who are more experienced with teaching in a laptop environment will allow them to feel more comfortable.

Prior to going one-to-one, we did a number of things. We sent a lot of teachers off to other schools with very solid, well-established one-to-one laptop programs. The teachers were sent there to ask questions and observe. We also brought in a few teachers from Westminster Academy to show our teachers some of the neat things they were doing with Microsoft One Note. We also sent about 15 teachers down to a PD conference on technology integration hosted by a school with a fantastic tablet PC program. All of these things helped our teachers see what other schools
and other teachers were doing. It also helped development enthusiasm for going one-to-one. (Director of Information Technology, Queen’s College, May, 2012)

Recreating the Findings in a Non-laptop Teaching Environment

Although there are many laptop classrooms in North America and this number is growing each school year, the majority of classrooms are not one-to-one. Thus, the question for many educators is how can the teachers in these classrooms recreate some of the findings in this study in a non-laptop environment?

First, some of the previous research indicates that computers should be moved out of stand alone labs and be redistributed into classrooms (Becker, 1998). The findings of this study support that idea. Many of the teachers in this study reported frustration with booking a computer lab or laptop cart (prior to when they went one-to-one). Often, booking a lab can be difficult for teachers. They must pre-plan exactly what they want the students to do and they are often rushed to get everything done in the time allotted to them. Teachers do not have the freedom for to use the computers when they fit best with a question that was just posed by a student. In addition, the time for exploration becomes very limited.

When we were working with the computer carts, that was such a headache. Sometimes you go to all the effort of booking the cart and you have your lesson planned and suddenly some of the computers don’t work. Or, you can only get them for one day and you need them for two. Then what do you do? Do you rush through it and not really allow the boys a chance to investigate? I found it such a frustration that often I would just choose not to use them at all. (Frank, May, 2012)

Instead of computer labs, schools should redistribute these computers and get as close to one-to-one as they can. There may also be some money in the budget to purchase a few more computers so that the ratio of computers to students is as low as possible. This way,
teachers can create a computer station within their classroom or split students into groups and have them work on an investigation in groups of four or five (or less, depending on the number of computers).

One of the main findings in this study reveals that laptops in these mathematics classrooms lead to the most changes in the use of manipulatives and other exploratory activities. There were a few reasons for this. First, with laptops, the teachers did not have to worry about whether or not they had the physical manipulative, instead they could just use digital ones. Schools that are not laptop environments can easily get around this by purchasing a variety of manipulatives for their mathematics departments and making sure that they have enough so that when teachers want to use them they are available. Second, with laptops, more exploratory activities take place because the variety of programs available is quite large. For example, teachers can use Geometer’s Sketchpad or some of the Explore Learning gizmos to get students to dynamically investigate a concept. Without laptops, this is harder to do, but there are some creative solutions. If your school has redistributed the computers from the lab to the classrooms, you can either make the exploratory activity one of your stations (and then each student can do it individually) or you can split the students into groups and each group can do the exploration on one computer. If your school has not redistributed the computers from the lab and you do not have many computers in the classroom, then you can do the demonstration on your computer and use it as a teaching tool. Although this option is not ideal because the students are not exploring themselves, they are still able to see a dynamic representation of a concept and it will still be more meaningful for them and help them to construct their own knowledge.
Educators felt that the use of laptops enhanced their ability to assess students. Teachers were better able to do formative assessment with their students and they were able to give students more choice in demonstrating their understanding of a concept. Although it may not be as easy, there are many assessment strategies available to teachers that are effective and do not require technology. Teachers can have students create a mathematics journal in which they can write down their thoughts about their learning. Teachers can then read this journal and give students feedback on their learning. Teachers can also create exit slips that help them to gauge the level of understanding of a topic. Although it was very easy for the teachers in this study to synchronize their computers to their students’ computers at any time and gain access to their math notes and homework and leave comments, this kind of information can be gathered in other, non-technological ways.

Students can also be given choice with assessment methods in a non-laptop environment. Again, if computers are redistributed so that classrooms are as close to one-to-one as possible, then there will still be some computers available for the students who might choose to create videos or audio recordings to show their learning. As Frank and Aaron found in their classrooms, when students are given choice, some will gravitate towards using technology and others will not. As long as there are some computers available, those students who want to use it can. If all students want to use technology then you would have to set up the computers as a station and students would have to take turns.

Finally, most of the teachers in this study acknowledged that the laptops had a positive influence on the mathematics teaching and learning in their classrooms because
they made teaching in a more constructivist manner easier. For example, the teachers were able to offer more variety in their lessons, they were able to be more creative, offer more choice, create more engaging lessons and activities for their students, and offer more problem solving tasks. All of these things can still be done in a non-laptop environment; they will just be harder. Giving teachers professional development that shows them how to offer more choice or how to create effective problem solving tasks will give them ideas on what they can do to transform their classrooms. Although technology helps create a more student-centred learning environment, it is not the only way to do this. Teachers can be very student-centred in a non-laptop classroom; they may just need some professional development in order to get there.

A key point for educators to remember is that all of the participants felt quite strongly that technology was just a tool. The laptops were a fantastic resource that did influence their teaching, but they were still tools. Teachers are still the most important factor in creating a more reform and student-centred classroom. If teachers are given ample support and the freedom to try new things, then the classroom environment can be transformed. Although technology can assist in this process, it is not the key piece. The teachers are.

**Limitations of the Study**

This study investigated the influence of laptop classrooms on the teaching and learning of mathematics. There are a few limitations of this study that are as a result of the limited sample that was examined. To begin, the classrooms that were visited were all independent schools. Independent schools were chosen because, in Ontario, they are the most experienced with having laptop classrooms, and many of these schools have been
one-to-one environments for a number of years. Of course, because the environment of an independent school is very different from one of a public school, it is natural to raise certain questions. For example, when projected to the public system, how will the findings of this study translate into a different school system? Although there would certainly be challenges with using laptops in a public system that were not faced by the teachers in this study, the results I found show what is possible for mathematics teaching and learning. As laptop classrooms become more common place in public schools, teachers experienced with using laptops, such as the ones used in this study, can be used as exemplars for other teachers. In addition, in this investigation, the laptops played a factor in improved assessment methods and more differentiated instruction. This finding holds great promise for the public system, where the need to differentiate instruction for different learners is extremely important. Mathematics is often seen as a subject that is the “gate keeper” for higher education. Using more varied teaching methods and assessment tools, such as what was described in this study, can help to reach more students and hopefully, make mathematics a more attainable subject for all. In addition, the use of technology for more exploration and investigation can help to make mathematics a more engaging and interesting subject to pursue.

Another limitation of the study is that all of the teacher participants are well educated and have taken courses beyond teacher’s college. Many have also completed (or are in the process of completing) their Master of Education degree. It is possible that the exposure that these teachers have had to higher education was a factor in their frequent technology implementation and their willingness to be open to new ideas. Thus, as has already been mentioned in the discussion, it is very important that any school going one-
to-one must give teachers ample professional development and support any interest teachers might have in taking courses to further their education.

Despite some of these limitations, the current research did answer the research questions that were posed and many examples of laptop classrooms having a positive influence on the teaching and learning of mathematics were found. Although the results might be different in a public system, the teachers studied can serve as exemplars for other teachers wishing to make changes in their teaching practices. The next step in the investigation of the influence of laptops on the teaching and learning of mathematics would be to extend the sample to include teachers in the public system.

**Recommendations for Future Research**

This study describes the influence of laptops on mathematics teaching and learning in the intermediate mathematics classroom. All of the teachers studied were teaching in a laptop environment at the time of the research. Although I asked them to describe their teaching prior to having laptops, I was not able to observe this. There is a need for longitudinal research to be done that looks at teachers and their practices pre-laptop and then examines these same teachers post-laptop. This type of research would be able to examine the role that laptops played in any teaching changes. It would also describe what the process of going from non-laptop to laptop is like.

In their research on the effects of computer technology on mathematics reform, Ross et al. (2002) found that “the computer was an amplifier providing additional means for teachers to accomplish their instructional goals. It was not a reorganizer that challenged existing ways of teaching” (p. 98). Although this research shows that mathematics teachers that teach in a laptop environment do have more student-centred
and reform oriented classrooms, it is hard to say whether the laptops played any role in changing their beliefs and whether the laptops enabled teachers to challenge their existing ways of teaching. There are some examples of teachers in this study challenging the existing way of teaching. For example, the addition of laptop technology to the classroom allowed Earl to experiment with using a flipped classroom structure.

All of the teachers indicated that they did teach in a more reform way post-laptops. Many of them also mentioned that this was partly because laptops made it easier to do things like differentiate instruction, create problem solving tasks, and assess in more varied ways. Did the laptops truly get them to challenge how they previously taught and make changes or did they just make things easier? Further research needs to be done that looks at whether laptops help teachers challenge existing beliefs. Based on the findings of the current study, I would say that they do, but this is hard to show. To seek an answer to this question, it would probably be best to work with a group of teachers who have low scores on the Attitudes and Practices to Teaching Math Survey and then see if the laptops have any effect on changing their beliefs and changing their practices.

In addition, many teachers in this study expressed an interest to start investigating the use of communication tools such as blogs, wikis, and online journals. It would be very interesting for future research to investigate the how digital communication tools affect the classroom environment and the understanding of students. Adolescents today communicate with their friends digitally through texting, Facebook, and other social media. It would be interesting to see if communicating with their classmates digitally would improve the quality and level of classroom communication and whether it would deepen understanding.
It was very interesting to me, as a female mathematics teacher, to note that no female educators volunteered to take part in this study. Reasons for the lack of female participation are unknown. Thus, it would be interesting to do further research which looked at the integration of laptop technology in classrooms of female mathematics educators. Was it just a coincidence that no female educators volunteered to take part in my research, or is there something more happening that is worthwhile to research and investigate?

Finally, this research revealed an interesting debate about the use of a traditional laptop versus the use of a tablet laptop in the classroom. A few of the teachers felt that a tablet laptop was necessary in a mathematics classroom, and they felt that it was the tablet laptop that was the key to the frequent use of computers in the mathematics classroom. In addition, the study by Maninger and Holden (2009) was done in a tablet environment. It was one of the few studies that did not mention a lack of technology use by math teachers. Could this be because of the use of tablets instead of laptops? Future research needs to look at the differences between a laptop classroom and a tablet laptop classroom to see which one leads to more changes in the teaching and learning of mathematics.

**Closing Reflections**

This research has shown that laptop classrooms hold great promise for mathematics teaching and learning. One-to-one student access to laptops can be the catalyst that teachers need to make significant changes in their approach to teaching mathematics. The positive examples provided in this thesis show that mathematics teachers can be effective implementers of laptop technology.
Teaching in a laptop environment can influence mathematics teaching and learning in many ways. Teachers in this type of environment can more easily play the role of facilitator and, as a result, their classrooms can become more student-centred. Laptop classrooms are more exploratory in nature because teachers can design lessons that use programs such as Geometer’s Sketchpad, Graphmatica, Explore Learning Gizmos, virtual manipulatives, and other dynamic applets. Although a one-to-one laptop teaching environment does have its drawbacks, such as distractibility for students, and extra time to plan for teachers, the teachers in this study showed that these are challenges that can be overcome.

Using the Ten Dimensions of Mathematics Education (McDougall, 2004) as a framework, many aspects of mathematics teaching and learning were influenced by the presence of one-to-one laptops. The teachers in this study felt that they were better able to meet the individual needs of their students. This is in large part because it was easier for the teachers to customize their lessons because they had access to multiple resources. The presence of laptops also influenced Manipulatives and Technology, the seventh dimension. The participants indicated that they were able to experiment with new resources, such as the virtual manipulatives, and they were no longer limited by access. Finally, the teachers in this study felt that the presence of laptops significantly changed the way that teachers assessed their students. The participants indicated that they were able to create new assessment pieces that better matched the strengths of their students and that they were able to experiment with using alternate assessment methods beyond a traditional test.
The teachers in this study were very adamant, however, that technology alone will not cause a shift in how mathematics is taught. In order for a shift to occur, teachers must be supported. This support can come from two sources. First, teachers must be given on-going professional development that focuses on technology integration and constructivist teaching methods. Second, schools must employ information technology integrators who can assist teachers with integrating technology into their lessons. As was shown with this research, with the proper support structure in place, one-to-one laptop classrooms have the potential to significantly change the teaching and learning of mathematics.
REFERENCES


APPENDIX A
Teacher Interview Questions
Semi-Structured Interview Questions (Teachers): Interview 1

1. When did you first start thinking that you wanted to teach? Why?
2. What made you want to become a math teacher?
3. How long have you been teaching math? How long have you been at your present school?
4. Describe your experience as a math student.
5. How did you feel about mathematics?
6. Did any teachers in particular stand out (good or bad)
7. What did you take in University? Have you completed any post-graduate education?
8. What does it mean to be a good teacher?
9. What positive attributes do you possess that make you a good math teacher?
10. How do you feel about your math teaching at this point in time?
11. What challenges have you faced in your teaching? Have you overcome your challenges? Do you face any challenges that you have not yet overcome?
12. What type of classroom environment do you try to create for your students?
13. Describe a typical lesson.
14. How do you plan your lessons or come up with lesson ideas?
15. In a typical lesson, how much time do you spend on the following:
   (a) Activities using manipulatives
   (b) Activities using a calculator/computer
   (c) Students working in small groups
   (d) Students working in pairs
   (e) Students working individually
   (f) Whole class discussions
   (g) Going over homework
   (h) Students explaining their mathematical thinking
   (i) Students voicing their own ideas about mathematical concepts
   (j) Students asking each other questions about mathematics
   (k) Teacher explanations of material
16. Do you build in time in your lessons for students to discuss their ideas with one another? How? How important do you feel this is?
17. What is your comfort level with technology?
18. How long have you been teaching math in a laptop environment?
19. What are some of the pros of a laptop environment?
20. What are some of the cons of a laptop environment?
21. Do you feel your teaching style has changed as a result of having laptops in the classrooms? Explain.
22. What professional development (and/or support) have you been given with respect to using laptops in the math class?
23. What supports do you wish were there for you?

Semi-Structured Interview Questions (Teachers): Interview 2

Questions about Laptop Integration

1. What were the first things you did as a teacher when trying to integrate laptop technology into your teaching?
2. What aspects of your program and/or your teaching have been enhanced as a result of laptop technology?
3. What has your school done to ensure successful implementation of laptops in the classroom? (also what has your department done)
4. What barriers or challenges have you faced when trying to implement laptop technology in the classroom?
5. What advice would you give a teacher that is new to using laptops?

Questions Related to Technology and its Impact on the 10 Dimensions

Program Scope and Planning
1. How has laptop technology impacted how you implement the mathematics curriculum?
2. How has the planning of your lessons changed as a result of having access to laptop technology?
3. Have you been able to be more creative with your use of a variety of resources as a result of laptop technology? If so, how?
4. What challenges have you faced in your planning as a result of laptop technology?

Meeting Individual Needs
1. Has your ability to meet the individual needs of the learners in your classroom changed as a result of having laptop technology?
2. How has the use of laptop technology changed how you group your students?

Learning Environment
1. How has the learning environment changed as a result of laptop technology?
2. Do you find yourself doing more or less cooperative activities as a result of the laptop technology?
3. Has how you structure your lessons changed as a result of laptop technology?
4. Has laptop technology brought challenges to the learning environment?

Student Activities and Tasks
1. How often do you use open-ended or rich tasks in your teaching? Has technology had an impact of your ability to use more of these tasks?
2. Has technology impacted your ability to offer more real-life activities within your teaching?
Constructing Knowledge
1. Has having laptop technology changed your beliefs about how students learn mathematics?
2. Has having laptop technology changed your approach to how you teach your students mathematics?

Teacher’s Role
1. What do you believe is the teacher’s role in the classroom?
2. Has your role changed since you have been teaching in a laptop environment?

Mathematical Tools
1. Has laptop technology allowed you to be more creative with your use of manipulatives and other tools to support learning?
2. Do you find yourself using manipulatives more often as a result of having laptop technology in the classroom?

Student Interaction
1. Has having laptop technology enabled you to design more activities which require student communication?
2. How much student communication and collaboration takes place in your classroom?
3. Has this increased, decreased, or not changed as a result of having laptops in your classroom?

Assessment
1. Has laptop technology impacted the way that you assess your students? If so, how?
2. How has having access to technology changed the types of assessments you offer?

Teacher’s Conception of Mathematics
1. Over your teaching career, has your conception about mathematics changed (eg. Fixed rules vs. dynamic integrated topics)?
2. Has laptop technology impacted the way you view mathematics in any way?
APPENDIX B
Director of Information Technology Interview Questions
Semi-Structured Interview Questions (Directors of Information Technology)

1. What support does your school provide to teachers in your 1:1 laptop environment?
2. What professional development is given to the teachers at your school with respect to teaching using laptop technology?
   i. Is it a one time thing or ongoing?
   ii. Is there follow up?
   iii. Is it focused on how to use technology or how to integrate technology in the classroom?
3. Do you feel that laptop technology has had a positive impact on the teaching and learning at your school? Explain.
4. Do you feel that teacher beliefs about teaching and learning changed?
5. Do you feel that classrooms with laptop technology more student-centred? Explain.
6. Do you feel that teachers have made more of an effort to create lessons that encourage student to student interaction as a result of having laptop technology?
7. What are some of the biggest changes you have seen in classrooms pre and post laptop technology?
8. Do you think laptop technology is a catalyst for change – a change that moves teachers away from a transmission based, teacher centred delivery to a dynamic, student-centred delivery? If so, how can administrators and IT personnel ensure that this happens in their school? If not, why?
9. How do you get reluctant teachers on board?
10. What qualities does a teacher have to have to be able to successfully integrate technology?
11. What were the challenges that your school initially faced when it went 1:1? How did you overcome these challenges? Are there still challenges that you face?
12. What are some of the barriers to successful integration?
13. What advice would you give to schools that were starting the process of going 1:1?
APPENDIX C
Attitudes and Practices to Teaching Math Survey
ATTITUDES AND PRACTICES TO TEACHING MATH
(McDougall, 2004, pp. 87-88)

Using the 1 to 6 point scale, indicate the extent to which you disagree or agree with each statement. Answer each question by writing the appropriate number in the box provided.

1 = Strongly Disagree  2 = Disagree  3 = Mildly Disagree  4 = Mildly Agree  5 = Agree  6 = Strongly Agree

<table>
<thead>
<tr>
<th></th>
<th>Statement</th>
<th>Answer</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>I like to assign math problems that can be solved in different ways.</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>I regularly have all my students work through real-life math problems that are of interest to them.</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>When students solve the same problem using different strategies, I have them share their solutions with their peers.</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>I often integrate multiple strands of mathematics within a single unit.</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>I often learn from my students during math time because my students come up with ingenious ways of solving problems that I have never thought of.</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>It is often not very productive for students to work together during math.</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>Every student should feel that mathematics is something he or she can do.</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>I plan for and integrate a variety of assessment strategies into most math activities and tasks.</td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>I try to communicate with my students’ parents about student achievement on a regular basis as well as about the math program.</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>I encourage students to use manipulatives to communicate their mathematical ideas to me and other students.</td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>When students are working on problems, I put more emphasis on getting the correct answer rather than on the process followed.</td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>Creating rubrics is a worthwhile exercise, particularly when I work with my colleagues.</td>
<td></td>
</tr>
<tr>
<td>13</td>
<td>It is just as important for students to learn probability as it is to learn multiplication.</td>
<td></td>
</tr>
<tr>
<td>14</td>
<td>I don’t necessarily answer students’ math questions, but rather ask good questions to get them thinking and let them puzzle things out for themselves.</td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>I don’t assign many open-ended tasks or explorations because I feel unprepared for unpredictable results and new concepts that might arise.</td>
<td></td>
</tr>
<tr>
<td>16</td>
<td>I like my students to master basic operations before they tackle complex problems.</td>
<td></td>
</tr>
<tr>
<td>17</td>
<td>I teach students how to communicate their math ideas.</td>
<td></td>
</tr>
<tr>
<td>18</td>
<td>Using technology distracts students from learning basic skills.</td>
<td></td>
</tr>
<tr>
<td>19</td>
<td>When communicating with parents and students about student performance, I tend to focus on student weaknesses instead of strengths.</td>
<td></td>
</tr>
<tr>
<td>20</td>
<td>I often remind my students that a lot of math is not fun or interesting, but it’s important to learn it anyway.</td>
<td></td>
</tr>
</tbody>
</table>
### Attitudes and Practices to Teaching Math Survey Scoring Chart

For statements 1–5, 7–10, 12–14, and 17, score each statement using these scores:

<table>
<thead>
<tr>
<th>Response</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
</tr>
</thead>
<tbody>
<tr>
<td>Score</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
</tr>
</tbody>
</table>

For statements 6, 11, 15, 16, 18, 19, and 20, score each statement using these scores:

<table>
<thead>
<tr>
<th>Response</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
</tr>
</thead>
<tbody>
<tr>
<td>Score</td>
<td>6</td>
<td>5</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>1</td>
</tr>
</tbody>
</table>

To complete this chart, see instructions below:

<table>
<thead>
<tr>
<th>Dimension</th>
<th>Related Statements</th>
<th>Statement Scores</th>
<th>Sum of the Scores</th>
<th>Average Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Program Scope and Planning</td>
<td>4, 8, 13</td>
<td>6, 4, 5</td>
<td>15</td>
<td>÷ 3 = 5</td>
</tr>
<tr>
<td>2. Meeting Individual Needs</td>
<td>2, 6, 7, 15, 16</td>
<td></td>
<td></td>
<td>÷ 5 =</td>
</tr>
<tr>
<td>3. Learning Environment</td>
<td>3, 5, 6</td>
<td></td>
<td></td>
<td>÷ 3 =</td>
</tr>
<tr>
<td>4. Student Tasks</td>
<td>1, 2, 11, 15, 16</td>
<td></td>
<td></td>
<td>÷ 5 =</td>
</tr>
<tr>
<td>5. Constructing Knowledge</td>
<td>5, 11, 14, 15, 16</td>
<td></td>
<td></td>
<td>÷ 5 =</td>
</tr>
<tr>
<td>6. Communicating With Parents</td>
<td>19, 9</td>
<td></td>
<td></td>
<td>÷ 2 =</td>
</tr>
<tr>
<td>7. Manipulatives and Technology</td>
<td>10, 18</td>
<td></td>
<td></td>
<td>÷ 2 =</td>
</tr>
<tr>
<td>8. Students’ Mathematical Communication</td>
<td>3, 6, 10, 17</td>
<td></td>
<td></td>
<td>÷ 4 =</td>
</tr>
<tr>
<td>9. Assessment</td>
<td>8, 11, 12, 19</td>
<td></td>
<td></td>
<td>÷ 4 =</td>
</tr>
<tr>
<td>10. Teacher’s Attitude and Comfort with Mathematics</td>
<td>4, 7, 13, 15, 20</td>
<td></td>
<td></td>
<td>÷ 5 =</td>
</tr>
</tbody>
</table>

**Total Score** (All 10 dimensions)

**Overall Score** (Total Score ÷ 38)

**Step 1** Calculate the **Average Score** for each dimension:
1. Record the score for each **Related Statement** in the third column.
2. Calculate the **Sum of the Scores** in the fourth column.
3. Calculate the **Average Score** and record it in the last column.

For example:

<table>
<thead>
<tr>
<th>Dimension</th>
<th>Related Statements</th>
<th>Statement Scores</th>
<th>Sum of the Scores</th>
<th>Average Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Program Scope and Planning</td>
<td>4, 8, 13</td>
<td>6, 4, 5</td>
<td>15</td>
<td>÷ 3 = 5</td>
</tr>
</tbody>
</table>
Step 2 Calculate the Overall Score:
1. Calculate the Total Score of the sums for all 10 dimensions in the fourth column.
2. Calculate the Overall Score by dividing the Total Score by 38.

For example:

<table>
<thead>
<tr>
<th>Total Score (All 10 dimensions)</th>
<th>152</th>
</tr>
</thead>
<tbody>
<tr>
<td>Overall Score (Total Score ÷ 38)</td>
<td>4</td>
</tr>
</tbody>
</table>

Step 3 Interpret the results:

<table>
<thead>
<tr>
<th>Average Score for Each Dimension</th>
<th>Overall Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average scores will range from 1 to 6. The higher the average score, the more consistent the teacher’s attitude and teaching practices are with current mathematics education thinking, with respect to the dimension. A low score indicates a dimension that a teacher might focus on for personal growth and professional development.</td>
<td>The overall score will range from 1 to 6. The higher the overall score, the more consistent the teacher’s attitude and teaching practices are with current mathematics education thinking and the more receptive that teacher will likely be to further changes in his or her practice.</td>
</tr>
</tbody>
</table>
APPENDIX D
Open Ended Response True/False Survey
Open Ended Responses

Please take a moment to select your response to each question. Then, in the space provided, explain why you chose this response.

1. True or false: Laptops (or tablets) can be a catalyst to change teacher beliefs about mathematics teaching and learning.

EXPLANATION:

2. True or false: Laptops (or tablets) can be a catalyst for moving classrooms away from the traditional model (teacher centred) towards the reform model (student centred).

EXPLANATION:

3. True or false: Laptops (or tablets) promote more student-to-student communication in the classroom.

EXPLANATION:

4. True or false: Laptops (or tablets) have had a positive impact on student motivation and participation in the math classroom.

EXPLANATION:
5. True or false: Laptops (or tablets) have had a positive impact on student achievement and understanding.

EXPLANATION:

6. True or false: Laptops (or tablets) better enable teachers to offer a variety of assessment options for students to demonstrate their understanding.

EXPLANATION:

7. True or false: Laptops (or tablets) better enable teachers to meet the individual needs of their students.

EXPLANATION: