INSTRUCTORS' ATTITUDES TOWARD THE USE OF TECHNOLOGY IN THE TEACHING AND LEARNING OF MATHEMATICS IN NEWFOUNDLAND AND LABRADOR POST-SECONDARY INSTITUTIONS: A MIXED METHODS STUDY

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Instructors' Attitudes Toward the Use of Technology in the Teaching and Learning of Mathematics in Newfoundland and Labrador Post-Secondary Institutions: A Mixed Methods Study

by

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Abstract

According to the literature, contemporary educational technology may enhance students' understanding of mathematics and consequently increase students' achievements in the subject. The goal of this research was to investigate to what extent technology was being used by instructors of undergraduate mathematics in Newfoundland and Labrador post-secondary institutions, and why some available technological applications were not being implemented in their teaching of mathematics.

This thesis presents an interpretive mixed methods study. Firstly, a questionnaire was administered to thirteen post-secondary mathematics instructors in order to clarify their backgrounds, teaching styles, professional views on, and experiences with technology. Secondly, eight of these same instructors were selected for an interview to further discuss in more detail their attitudes toward teaching mathematics with technology.

This research reveals that instructors are mostly using technology for organizational and communication purposes. The use of mathematics specific technology for tutorial, exploratory, and creative activities with students takes place mostly on an individual basis and only occasionally, and depends on the topic.

Four major themes emerged from the data: (1) how teaching has changed over time due to the increasing capability and availability of technology for students' and instructors' use, (2) how does the presence of technology influence mathematics curriculum and pedagogy, (3) what are various purposes, advantages, and challenges faced during the process of incorporation of technology in teaching, and (4) what is the relationship between students' use of technology and students' knowledge of the fundamentals of mathematics.

While seeing the values and benefits that technology may offer in teaching, instructors were concerned about the associated costs such as the amount of time, effort, specialists support, and pedagogical knowledge required to the successfulness of its implementation. Instructors worry about possible disadvantages that may follow from improper implementation of technology. They also point out the importance of focused instructional development, collegial support, and departmental initiatives for individual instructors to proceed with technological innovations.

The implications of this study for the post-secondary educational system in Newfoundland and Labrador are also discussed.

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Chapter 1

Introduction

It has been observed that "educational technology, especially computers and computer-related peripherals, have grown tremendously and have permeated all areas of our lives" (Valdez, 2005, p. 1). It is widely understood that with globalization, and humanity's technological advancements, the increasing use of technology in the teaching of mathematics is inevitable (Klopfer, Osterweil, Groff, & Hass, 2009; Wu, 1995). The president of Stanford University, John Hennessy, "recently predicted that a technology 'tsunami' is about to hit higher education" (Hieronymi, 2012).

However, for an individual instructor the extent of the use of technology depends on both their pedagogical and professional training. Within the Newfoundland and Labrador educational system, teachers in the grade school system are trained in specific pedagogical approaches. At the post-secondary level, instructors receive extensive, professional training in a specific subject; at the same time their pedagogical background may vary significantly (Bates, 2011). This lack of standardized pedagogical training has been commented on in an interview by Associate Professor Robert Conry of the University of British Colombia who has stated that "the percentage of people who begin a university or college teaching career with any form of preparatory work in teaching or instruction, or any of the skills that underlie effective teaching, is infinitesimal - about one percent" (TAG UBC, 2010). This opinion is also discussed by Schrum, Burbank, Engle, Chambers, and Glassett (2005). Specifically, the authors state,

> many post-secondary educators, and community college faculty members in particular, have had little preparation to be educators, and teaching expertise is not always a requirement for employment ... The need for ongoing professional development for post-secondary faculty is well documented, and this is especially true for faculty members at community colleges. (pp. 279, 288)

In view of recent technological advantages, particular attention should be given to the instructional approaches that incorporate educational technologies. Conry however "is optimistic that there is more awareness of the need for such training at the post-secondary level since improvement centers have sprung up on campuses over the last decade" (TAG UBC, 2010).

For the purpose of this research, technology can be defined broadly as any assistance to the teaching and learning of mathematics. Some examples of technologies that are potentially useful for an instructor of mathematics include: (1) manipulatives (concrete and virtual); (2) calculators; (3) computers; (4) specialized software (such as Maple or GeoGebra); and (5) the Internet. This list may be extended, but not limited by, adding interactive white boards, clickers, iphones, and so on.

This research distinguished between basic and influential technologies. Basic technologies are those used by instructors in every day practice (e.g., photocopiers, printers, LCD projectors). Influential (math-specific) technology can be defined as those technologies designed to improve student learning in mathematics.

This research aimed to investigate the extent of the use of technology in the teaching and learning of of mathematics at the post-secondary level in Newfoundland and Labrador. It focused on instructors' attitudes toward the use of technology and the types of technologies they were currently using in their teaching and research activities. In addition, the degree of instructors' professional development and familiarity with the literature that discussed the benefits of teaching mathematics with technology is discussed. Instructors' perceived advantages and disadvantages of the use of certain types of technology in teaching are presented. These data helped to explain why the instructors do not use certain technologies and what may stimulate individual instructors towards technological implementation in the teaching of mathematics.

It should be noted that the majority of results presented in this thesis have been obtained from the Department of Mathematics and Statistics at Memorial University of Newfoundland (MUN). To obtain a sense of why this topic is important, the researcher provides his personal experiences.

1.1 Background of the Study

1.1.1 Related Personal Experience

As an instructor of first-year mathematics at MUN, the researcher was not unfamiliar with the quality and capability of first-year students. In the researcher's experience, the class average of first-year mathematics courses is approximately 60%; which is common amongst the majority of first-year mathematics classes at MUN. However, according to the Registrar's Office at MUN, over the past 10 years, the average passing rate (i.e., the percentage of individuals who pass) in first-year math classes is between 71% and 84% depending on the first-year class (G. Genge, personal communication, October 11, 2012). One possible solution that could be used to improve students' achievement is to teach mathematics using technology. Since the literature that was reviewed in this research highlighted many advantages of teaching mathematics with technology, especially increased student achievement, there was a view that there existed a need for instructors to pursue alternate teaching approaches. In the researcher's short time as an instructor of post-secondary mathematics, he has not had a chance to integrate technology into his teachings due to time constraints, as he was also a full-time student. In addition, overall lack of departmental encouragement is an issue.

It was not until taking two graduate courses in mathematics education that the author considered pedagogical practices and the use of technology in mathematics. One such course was *Technology and the Teaching and Learning of Mathematics* with Margo Kondratieva; a joint-appointed professor with the Department of Mathematics and Statistics and the Faculty of Education at MUN. This course focused on various types of technologies such as the Texas Instruments graphing calculator, dynamic geometry software (e.g., GeoGebra or Geometer's Sketchpad), computer algebra systems (e.g., Maple or Mathematica), and their applications in the teaching of mathematics.

As a former mathematics student at MUN, the author has firsthand knowledge of the extent of technology use in the teaching of mathematics. The topic of this thesis was chosen in an attempt to investigate and better understand why the author's instructors, now colleagues, are not using more influential math-specific technology in the teaching of mathematics, while the literature clearly demonstrates how the use of such technology in the teaching of mathematics brings many advantages to both the student and instructor. Similar to the author, the majority of other instructors in the Department of Mathematics and Statistics at MUN use basic technology such as HTML or Desire2Learn to maintain course webpages, word processing programs to compile course materials, overhead projectors, and/or Doc Cams and microphones on a regular basis. Additional computer software that are available within the Department of Mathematics and Statistics are the mathematical/statistical software: R, Matlab, Maple, Minitab, and Mathematica. Other departments on the MUN campus may offer different software which suit the specific needs of that department.

1.1.2 An Overview of the Use of Technology by Instructors in the Department of Mathematics and Statistics at MUN.

Over the past several decades there have been numerous attempts to integrate technology into the teaching of mathematics at MUN. The first such attempt was in the mid-1980s when Herb Gaskill and Richard Charron used Texas Instruments graphing calculators. The initiative was aimed at differential and integral calculus classes. First, the instructors insisted that students enrolling in the special "Calculator Calculus" class would complete both courses with the same instructor. That gave the instructors more latitude in managing the curriculum. The instructors also agreed to cover the same combined syllabus as the regular sections of the courses. The students still worked on basic algebra as they would in a regular calculus class, but the calculator was a means of validation, which could be coupled with algebraic manipulation. The calculator was presented as a tool to allow students to check their answers and overall progress. Charron commented that he "viewed the calculator result as nothing more than an aid allowing the student to validate the algebraic (pencil & paper) result" (R. Charron, personal communication, July 11, 2012). The nature of the Texas Instruments user interface made it a natural tool for that task.

The students fared no worse than any other section of the same course. Overall, Charron provided indication that fewer students failed or dropped out. However, it is possible that the students were more "skilled" than the average student - they were after all self-selecting to do an experimental course. From a teaching perspective, Charron did enjoy "tackling" the course material this way citing,

> the "Calculator Calculus" effort allowed me to do a better job as a teacher,

> and gave my students a different way of approaching some basic math, presented and encouraged a type of mindset they had not been exposed to before. I think the things we did were generally well received by the students. (R. Charron, personal communication, July 11, 2012)

The second attempt to integrate technology into the teaching of mathematics was by Richard Charron in 1989 with the creation of the course then titled, *Introductory Numerical Techniques*. This course was implemented "as an attempt to familiarize students with computerized support of numerical implementations of mathematical methods" (Kondratieva & Radu, 2008, p. 190). The primary goal of this course was to develop students' skills in mathematical writing techniques. The course work was based on four projects, each involving a different problem to be investigated. Working individually or in groups, students tried to comprehend the problem at hand by understanding the underlying mathematics. This was typically a task completed by hand or by writing a computer program to generate data. Once the problem had been considered solved by the student, a "formal report" discussing the problem (typically in the areas of history, methodology, results, and conclusions) was to be professionally prepared using the typesetting and graphics tools associated with the word processing system LaTeX. This course is still ongoing and has become a requirement for a degree in mathematics from MUN.

The next attempt to implement influential math-specific technology in mathematical instruction was in the late 1990s, when Bruce Watson integrated the Texas Instruments 89 symbolic graphing calculator into his teaching of differential and integral calculus. The program *Derive* (which was a part of the calculator itself, and allowed for symbolic calculations such as integration), was also used in a laboratory component for each course. Due to the "power" of the Texas Instruments 89, Watson gave a two-part final exam. One part with the calculator and the other without. This technology was only adopted for one semester by Watson in two different classes, and was not absorbed by any other members of the department. Watson commented that his sections of the courses did slightly better overall as compared to other sections of the same course (B. Watson, personal communication, February 10, 2012).

In 2009 Margo Kondratieva, with then doctoral student Oana Radu, conducted a two year project in which they implemented the on-line support component, *MyMathLaboratory*, in teaching Pre-calculus. Every year more than 1200 students take this course, with a failure rate of approximately 30%, which increases in other first-year courses (G. Genge, personal communication, October 11, 2012; Kondratieva & Radu, 2009). These high failure rates indicate that there is a definite need for instructional change. Kondratieva and Radu (2009) cited numerous reasons for students' underachievement in mathematics such as "students' weak algebraic and arithmetic skills, low reasoning ability with formal concepts, failure to check answers and validate solution processes, negative attitudes, low motivation, or poor time management skills" (p. 1). The authors also conclude that extra help is required for students' progress in this course, especially in large classes; this is where the implementation of *MyMathLaboratory* would be beneficial (Kondratieva, 2012; Kondratieva & Radu, 2009). This technology was only adopted for the duration of this project and was not directly absorbed by the department for this course, partly due to financial restraints. However, some positive changes in student achievement led to the consideration of a similar technology called *WebAssign* for differential calculus classes. It should be noted however that "there is little objective information available as to which of these products, if any, is a useful teaching tool" (Krantz, 1999, p. 22).

The most recent instance of the implementation of technology in the teaching of mathematics was in the Spring of 2010. The Department of Mathematics and Statistics piloted the online support component, *WebAssign*, in the teaching of a single section of differential calculus. *WebAssign* was then formally incorporated into all sections of differential calculus beginning in the Fall 2010 semester. *WebAssign* was implemented by the department for three major reasons. Firstly, differential calculus is a course in which most students will benefit from repetitive drills, and especially from early feedback on their performance (given the very cumulative nature of the course). Secondly, by offering a common suite of problem sets in all sections of differential calculus, it would bring greater consistency to all offerings of the course. Thirdly, since repetitive drills would largely be handled via *WebAssign*, instructors would be able to concentrate written assignments on a smaller subset of such problems (as well as on those types of questions that cannot be adequately assessed via *WebAssign*), easing the burden on instructors and student markers. However, opinions on this issue vary.

A brief analysis of one instructor's sections of differential calculus (S. Sullivan, personal communication, August 23, 2012) found that the overall grade of students who passed the course trended upwards based on the implementation of *WebAssign* by approximately three-to-five percent, while the overall mark of students who failed the course trended downwards (because these students often ignore *WebAssign* and earn little-to-no marks for that component of the course). Passing rates have been effectively stable, which suggests that those students who put the requisite effort into the course are benefitting from the inclusion of *WebAssign*. The researcher attributed this loss or gain in grades due to the fact that five percent of the final grade (normally included on the final exam) was attributed to the *WebAssign* portion of the grade (making the final exam worth five percent less). However, this has only led to the "good" students doing better and the "bad" students doing worse.

It was noted by Kondratieva and Radu (2009) that "many pedagogical practices confirm that students enjoy doing mathematical problems if they know how to approach them" (p. 1). It is also worth noting that students' reaction to *WebAssign* has been consistently more positive as it becomes an accepted part of the differential calculus course. The department membership has been highly satisfied with *WebAssign* and it is planning to introduce a similar program for Math 1090 (Algebra and Trigonometry) beginning in the Fall 2013 semester. However, there were mixed opinions on this point.

Over the past several years, in several statistics, geometry, and numerical methods courses, technology or software such as Matlab, Minitab, FORTRAN, and GeoGebra had been implemented. These technologies or software serve different purposes including data collection, data analysis, and exploration. The use of GeoGebra has been employed in the teaching of Euclidean Geometry by Margo Kondratieva in 2010 and 2011; although it has not been used by any other instructors. Kondratieva (2011) listed the benefits of teaching geometry with emphasis on *basic geometric configurations* which "can be enhanced by the employment of applets produced with a dynamic geometry software" (p. 46). She also commented how "further research is required in order to highlight details and nuances of synchronization of the heuristic and logical components of students' work within the innovative practice" (p. 53).

In conclusion, there have been attempts to implement technology in the teaching of mathematics at MUN. However, the majority of attempts are isolated, and there is minimal continuity between instructors.

A personal reason for this investigation is to more fully understand the need for the integration of technology in the teaching of mathematics, and a possibility for step-by-step proper integration of influential math-specific technologies yielding maximum results. In addition, this research can provide mathematics departments of post-secondary institutions in Newfoundland and Labrador (and elsewhere) with beneficial information to further inform and encourage their instructors to integrate influential math-specific technology into their curriculums. This would improve teaching practices, and would have an impact on both students' attitudes and achievement in first-year mathematics. Furthermore, the author hopes that this work will contribute to the agenda of "promoting research in tertiary mathematics teaching and strategies for the integration of technology in the university mathematics classroom" (Jarvis, Buteau, & Lavicza, 2010, p. 2).

1.2 Statement of the Research Problem

Declining student achievement and passing rates in undergraduate mathematics are concerns of both administrators and educators (Fey, 2003). According to the literature, contemporary educational technology may make a difference in this situation and enhance students' understanding of the subject (Pritchard, 2002). The influence of technology on student achievement has been the topic of investigation for various researchers (Fogarty & Taylor, 1997; Koop, 1982; Leder, 1985; Palmiter, 1991; Rich, 1990; Schacter, 1999; Texas Instruments, 2006). However, Jarvis et al. (2010) commented on the lack of research in this area at the post-secondary level and that the promotion of teaching and strategies for the integration of technology in the teaching of post-secondary mathematics is needed.

The use of technology in the teaching of mathematics has been the subject of considerable debate in a variety of fora for many years, including the Department of Mathematics and Statistics at MUN (E. G. Goodaire, personal communication, May 9, 2012). Despite repeated efforts to teach mathematics using technology, there is still tension between traditional (chalk and blackboard) and new teaching approaches which presents an important issue for mathematics educators (Pundak, Herscovitz, Shacham, & Wiser-Biton, 2009). Educators express a concern that an improper use of technology may make students lazy and contribute to a development in their technological dependence, which is undesirable. On the positive side, Valdez (2005) stated that,

> the value of technology is to add productivity to learning. If you think

> about what the tractor did for farming, this is what technology can do for learning and it's become a necessary productivity tool for the future. If you look at 21st century skills, they're going to be requiring the use of technology very effectively. (p. 35)

Possible reasons for instructors not using influential math-specific technologies included instructors' beliefs (Lavicza, 2010), insufficient technical support, resistance to change, negative attitudes, and lack of accessibility (Bingimlas, 2009). As well, limited instructor knowledge about the technologies that were available and the advantages they may bring to their teaching approaches was also identified as a major barrier. Lack of time (Goos & Bennison, 2008), lack of effective training (Chin & Hortin, 1994), and a lack of systematic policy (Cuban, 2000) were also influential factors. Identifying these limitations and responding to instructors' needs can eventually lead to further integration of technology into the teaching of mathematics, altering the methods of instruction, assessment, and communication between students and instructors. It is important to study the barriers preventing the integration of particular technologies into the teaching of mathematics because the knowledge gained could provide necessary information to improve integration methods (Bingimlas, 2009, p. 236). According to the British Educational Communications and Technology Agency (2004), even though there is literature on the barriers of certain technologies, there is a need for more studies on barriers that are present in specific subject areas.

The purpose of this study was to identify and discuss why some post-secondary mathematics instructors in Newfoundland and Labrador institutions were using influential math-specific technology in their teachings, and why others are reluctant to use such technology even though the literature indicates there are many benefits to doing so.

Initiating a discussion of potential uses of technological assistance in teaching and encouraging instructors to share their ideas and practices on a regular basis has the potential to produce a significant change in instructional approaches to teaching mathematics (Klopfer et al., 2009). Increasing instructors' understanding of how educational technology improves student learning of mathematics can positively affect students attending undergraduate mathematics classes across Newfoundland and Labrador. It is the author's view that in the future the following long-term objectives can be fulfilled.

1. To help instructors of mathematics share their best teaching practices incorporating the use of influential math-specific technology.

2. To promote research in post-secondary mathematics teaching and strategies for the integration of technology in mathematics.

Hieronymi (2012) said certain forms of technology

> enable new forms of communicating. They represent information in incredibly understandable and previously unimaginable ways. They even interact with students; correcting assignments for which there are clearly delineated standards of error and success. They can greatly expand the power of the multiple choice quiz; they can learn which drills remedy which errors. (para. 7)

The major objectives of this thesis were:

1. to determine and describe the use of technology in the teaching of post-secondary mathematics,
2. to summarize and deliver suggestions based on information collected from this research, and
3. to identify mathematics instructors' needs in the use and exploration of influential math-specific technology.

1.3 Need for the Research

One goal of this research was to determine and describe the use of technology in the teaching of mathematics in post-secondary institutions in Newfoundland and

Labrador. A review of current literature suggested that there are several gaps in this area of research. Firstly, there are many questions that must be investigated in terms of data collected by other researchers (Goos & Bennison, 2008, p. 14). For example, what are the relationships between attitudes towards technology, frequency of technology use, experiences with professional development, access to technology, and confidence with technology? Addressing these questions will aid in "the support of mathematics instructors' efforts to incorporate educational technologies into classroom practice" (p. 14). Secondly, to address unexplained differences in computer use "future research should focus on additional factors that may affect a teacher's decision to integrate computers" (Wozney, Venkatesh, & Abrami, 2006, p. 196). For example, "(a) personality differences among teachers, (b) levels of computer anxiety, (c) student characteristics, (d) levels of peer-support and administrative support, and (e) the extent to which prior experiences with computers has affected teacher attitudes" (p. 196). Thirdly, "future research that specifically uses qualitative methods is needed to validate and elaborate quantitative findings" (Cavas, Cavas, Karaoglan, & Kisla, 2009, p. 29). Fourthly, "little is known about the current extent of technology use and mathematicians' practices in university teaching" (Lavicza, 2010, p. 108). Fifthly, Lavicza (2010) and Buteau, Marshall, Jarvis, and Lavicza (2010) cited,

> over the past two decades a considerable imbalance has developed in favour

> of school-level research against university-level research. However, several changes in universities, such as students declining mathematical preparedness and demands from other sciences and employers, necessitate closer attention to university-level research. (p. 105)

Of the above mentioned gaps in the literature, this thesis addresses several issues. Firstly, due to the wide range of backgrounds and ages of instructors, this thesis investigates their attitudes towards the use of technology. Secondly, instructors' frequency of use and access to technology both in their teaching and outside their teaching is also discussed. Thirdly, due to instructional development opportunities, which are offered to instructors at many post-secondary institutions, this thesis discusses instructors' professional development experiences. Lastly, levels of peer and administrative support and prior experience with technology are also discussed.

1.4 Research Questions

The following research questions are investigated in this mixed methods study.

1. How frequently and what types of technologies are being used by instructors in their teaching of mathematics?

2. What are mathematics instructors' teaching experiences, professional develop-

ment experiences, familiarity with pedagogical literature on the use of technology, and accessibility to technology and support?

3. What are instructors' opinions of teaching mathematics with technology in relation to students' needs?

In addition to these, all interviewees were asked a series of questions about their *classroom management* and the *evaluation methods* used in their teachings. It is the author's long-term goal, beyond the scope of this thesis, to bring suggestions to respective departments to formulate some individual and departmental change related to the integration of more influential math-specific technology in the teaching of post-secondary mathematics.

1.5 Overview of the Study

In order to answer the research questions of this research, a mixed methods approach was used. Creswell (2008) defines *mixed methods* as "a procedure for collecting, analyzing, and 'mixing' both quantitative and qualitative research and methods in a single study to understand a research problem" (p. 552). More specifically this research employs an *explanatory mixed methods* design, in which quantitative data is first collected, followed by the collecting of qualitative data to help elaborate the quantitative findings. Benefits of such an approach come from the fact that "future research that specifically uses qualitative methods is needed to validate and elaborate quantitative findings" (Cavas et al., 2009, p. 29).

The participants of this study were chosen based on one criteria: they were post-secondary mathematics instructors in Newfoundland and Labrador, either currently working or recently retired. The participants had various levels of education, with some combination of a B.Ed, B.Sc, M.Ed, M.Sc, and PhD. Their backgrounds were also varied. Some purely taught post-secondary, others taught grade school prior to teaching in the post-secondary system, while another came from an administrative background before teaching. The data collection was completed through a questionnaire, accompanied by a follow-up interview.

Data were collected during the period of January 2012 and March 2012 inclusive. The quantitative portion of the research involved one questionnaire consisting of four sections: (1) Professional Views on Technology; (2) Teaching Style, Background, and Resources; (3) Experience With Technology; and (4) Process of Integration. The expected duration for completion of the questionnaire was approximately one hour. The qualitative portion of the research involved one interview containing five sections: (1) Background; (2) Classroom Management; (3) Technological Instruction; (4) Instructor Support; and (5) Evaluation. The length of each interview depended on the length of responses offered by each interviewee. Interviews ranged in duration from 35 to 80 minutes.

In addition to the introductory chapter, this thesis is divided into four chapters: literature review, methodology, research findings and discussion, and conclusions. First, the review of relevant literature provides a synopsis of the major themes previously considered in this area. Second, the methodology chapter includes descriptions of the methodological approach, population and sample selection, ethical procedures, data collection procedures, data analysis, and reliability of the data. The next chapter presents the findings of the study. Finally, the thesis is concluded with the main results and the limitations of the study, as well as recommendations for future research, and individual and departmental change.

Chapter 2

Literature Review

This chapter reviews the major themes of research related to the integration of influential math-specific technology in post-secondary mathematics. The first section briefly described specific instances of teaching mathematics with technology since the 1940s. Section two deals with instructors' attitudes towards the teaching and learning of mathematics with technology, and the importance of technological training and development. The third section described the effects of increased instructor collaboration with the use of influential math-specific technologies in teaching and learning. Section four focused on how technology may address the issue of student's unpreparedness for tertiary mathematics. In section five, the possible effects of technology in teaching and learning are described. The final section delivers some concluding results in regards to the current state of the literature.

2.1 Past Examples of Technology Use

Throughout the history of mathematics education there have been many instances of using technologies to assist in the teaching and learning of mathematics (Brahier, 2005; Papert, 1993). Instructors may have different aims in using technology in the teaching of mathematics, which include (1) visual demonstrations of mathematical facts; (2) experimentations, explorations, and search for new mathematical relations; (3) tutoring students and allowing them to practice and receive instant feedback; (4) assessing students' knowledge and skills; and (5) exchanging information with students using blogs or WIKI, creating course WebPages, sending messages via e-mail, and so on (Grabe & Grabe, 2007).

One of the first theoretically justified attempts to teach mathematics with technology was inspired in the 1940s by Jerome Bruner. He theorized that there were three stages of the learning process: enactive, iconic, and symbolic. According to Brahier (2005), Bruner's theory "has led to the extensive use of hands-on materials - manipulatives - in mathematics classrooms" (p. 36), along with other types of technologies. One such technological tool was the computer. During the 1940s, mathematicians had pioneered the first computer in order to perform certain calculations in time pressured situations (Papert, 1993, p. 157). As the computer permeated more areas of study, it was bound to find its way into educational applications. Papert (1993) stated that "the important and lasting side of what we did was planting the seed of a specifically educational computer culture" (p. 160).

In the 1960s, researchers from other fields of study (e.g., philosophy and psychology, physics, and university administration) joined in the development of computers, with a major breakthrough in the 1970s when the microcomputer was invented (Papert, 1993, p. 161). By the 1980s, the number of people devoting the major part of their professional careers to the development of computers and education had increased from a few hundred to tens of thousands (Papert, 1993). Of course during this time there had been many attempts by instructors and educators, using the available technologies of their time, to assist in student learning.

It was not until the 1980s when it became common practice for mathematics instructors to extensively use electronic technology in the teaching of mathematics; this was in part due to a growing concern of student performance. This was based on the assumption that students would benefit more from each lecture with the addition of technology. Consequently, technology is currently in widespread use in numerous post-secondary institutions in the teaching and learning of mathematics, by instructors and students alike, with growing evidence suggesting that these tools increase student performance (Fey, 2003, p. 1).

Today students and instructors have access to smart phones, tablets (e.g., Ipads), clickers, and various types of other instructional gadgets. With new technologies, students can be in constant contact with other individuals from all over the world, whether it be through a phone call, Skype, or within a virtual social network (e.g., Facebook). An abundance of information can now be found on the Internet and in electronic libraries very quickly. Students can purchase e-books, which have lower prices than an actual textbook, are more convenient to access, and often are supplemented by applets that assist with visualization or exploration. Technologies such as Ipads allow students to take notes in class more easily, transform hand written notes into typed text, videotape, or record lectures. Instructors can upload learning materials on-line and even offer entire on-line courses.

Pundak et al. (2009) indicated that "one of the major goals of science and technology education today is to promote students' active learning as a way to improve students' conceptual understanding and thinking skills" (p. 226). Although there is clear evidence of constructivist teaching approaches (von Glasersfeld, 1995), such as promoting active learning, most lecturers in higher education still adhere to traditional teaching methods. According to Pundak et al., "most academic instructors tend to adhere to traditional teaching approaches, according to which the principal function of the instructor is to convey knowledge" (p. 218). However, there is still much deliberation between these approaches, with traditional teaching still being more widely applied.

At the beginning of the 21st century technological growth increased, resulting in significant improvements in the characteristics of existing technologies, the emergence of new types of technology, and accessibility for a wider population. This phenomenon affected mathematics education at all levels. In order to understand the influence of this process on mathematics education, more research is currently being conducted. It has been found, and well noted in the literature, that some forms of technology positively affect the teaching and learning of mathematics (Jarvis et al., 2010), however "this has not been widely realized in schools and institutions" (Buteau et al., 2010, p. 2).

This literature review provided evidence that there has been a large amount of research conducted in the area of teaching mathematics with technology at the grade school level, but not as much at the post-secondary level. This was verified by Jarvis et al. (2010) and Lavicza (2010). However, some studies have encouraged "mathematicians to engage in educational research and collaborate with educational researchers, though such research activity is still limited compared to that conducted at the school level" (Lavicza, 2010, p. 108).

This lack of research at the post-secondary level is highlighted by Buteau et al's. (2010) analysis of the literature involving the use of computer algebra systems at the secondary/tertiary level and the use of technology in mathematics learning at the post-secondary level. In their research they found 204 papers, which were recovered from two well-regarded journals and the proceedings from two conferences that focused on technology. Their review included papers published over a 20 year period from 1990 to 2010.

Lavicza (2010) commented how "conducting educational research at the university level is even timelier than ever. In addition, understanding technology integration without knowledge about the tertiary level is clearly incomplete" (p. 106). More specifically, Goos and Bennison (2008) comment that "research is needed to examine the nature and extent of teachers' actual use of ... technologies and identify factors that support or inhibit effective integration of technology into mathematics classroom practice" (p. 2).

This research aims to further add to existing data, documenting the contemporary situation concerning the use of technology in the teaching and learning of post-secondary mathematics. It should be noted that some data comes from the secondary school system, but has high relevance to the topic at hand.

2.2 Instructors' Attitudes and the Value of Technology Training

Lavicza (2010) commented that in the second half of the 20th century, technology was intended to open new doors and provide rapid changes in the teaching and learning of mathematics. However, the process of integrating these technologies in the teaching and learning of mathematics has been much slower than was originally expected, which can reflect teachers' beliefs and perceptions about technology use in teaching. This slow pace of technology integration in mathematics pedagogy was one of the reasons why the topic in question was chosen for study by the researcher. Also, it was determined by Lagrange, Artigue, Laborde, and Trouche (2003) and corroborated by Laborde (2008), that much of the research literature has paid little attention to teachers and teaching, hence establishing a need for such research. At this point in time, it was becoming evident that "teachers play a key role in technology integration and examining their beliefs about technology and technology-assisted teaching is important for the understanding of technology integration into mathematics teaching" (Lavicza, 2010, p. 107).

As indicated earlier, many instructors still adhere to traditional methods of teaching which is why studying instructors' attitudes and beliefs in regards to the use of technology in the teaching and learning of mathematics becomes extremely important. Teo (2006) observed two reasons why teachers' attitudes play such an important role: first, "student learning with computer technology will depend largely on the attitudes of teachers, and their willingness to embrace the technology"; and second, "any initiatives to implement technology in an educational program depends strongly upon the support and attitudes of the teachers involved" (pp. 413-414). These two issues have been encountered by the author and other members of the Department of Mathematics and Statistics at MUN during the implementation of the *WebAssign* system indicated in Chapter 1 Section 1.1.2.

The literature provided evidence that whether at the post-secondary or grade school level, instructors hold positive views and strong desires to integrate technology in the teaching of mathematics (Bingimlas, 2009; Cavas et al., 2009; Lavicza, 2010). However, instructors need to be trained in such technologies before they can be integrated into the curriculum, since many of them "do not regard themselves fully-equipped, comfortable and sufficient in using [certain technologies] in educational settings, and they feel more confident with their traditional teaching styles" (Cavas et al., 2009, pp. 21-22). Instructors agree that some forms of technology can be extremely beneficial to a student's future studies and career. Mathematicians assume that certain technologies "will eventually become an integral part of the undergraduate mathematics curricula" (Lavicza, 2010, pp. 111-112); however, teachers continue to encounter many barriers in regards to the implementation of technology in their teaching. Such barriers include a lack of confidence, competence and accessibility "which have been found to be the critical components of technology integration in schools" (Bingimlas, 2009, p. 235). In order to overcome such deficits, Bingimlas (2009) suggested that the following would need to be provided to teachers in order to be successful in the area of technology integration: (1) relevant software and hardware; (2) sufficient technical support; (3) effective professional development; and (4) adequate time in preparing themselves in such technologies (p. 235).

Goos, Stillman, and Vale (2007) found that math teachers need a working knowledge of a variety of technologies and that an "excellent teacher" can use such technologies effectively to make "a positive difference to the learning outcomes, both cognitive and affective, of the students they teach" (Australian Association of Mathematics Teachers, 2006 as quoted in Goos et al., 2007, pp. 74-75). Goos et al. noted that in order to be an effective user of technology in the teaching of mathematics, "teachers need to make informed decisions about how and why to integrate different types of technology into their classroom practice in order to support students' learning of mathematics" (p. 75). Appropriate professional development may produce a change in teachers' ability to make these informed decisions. Hieronymi (2012) stated that "as information breaks loose from bookstores and libraries and floods onto computers and mobile devices, that training becomes more important, not less" (para. 3).

According to Bates (2011) most Western countries do not require any teaching background to work in a university. He says,

> what counts is a post-graduate research degree. Indeed, at UBC post-graduate students interested in experimenting with learning technologies were often deliberately discouraged by their supervisors from doing so as it would detract from their research. Some post-graduate students who act as student instructors may get a briefing on how to manage large lecture classes, and may have a volunteer faculty member as a mentor, but that is all. Teaching in post-secondary education is now about the only profession where pre-service training is not mandatory. (p. 2)

Wozney et al. (2006) stated that numerous studies have looked at the attitudes of teachers towards computer technology. However, the authors pointed out that what the literature is missing "are investigations, which apply broad motivational frameworks for examining the relationship between teachers' beliefs about computer technology and their classroom practice" (p. 177). The goal of this research is to partly close this gap.

2.3 Collaboration

Compiling course material is very time consuming, especially if an instructor is teaching more than one new course. An easy way to overcome this issue is to ask a more experienced colleague for reference material, as well as any other guidance they could provide. Buteau, Jarvis, and Lavicza (in press) note that mathematicians have an "interest in collaborating with colleagues" (p. 14) on course development that involves technology.

Klopfer et al. (2009) commented on the benefits that can evolve from collaboration with friends, colleagues, and/or new instructors. The authors recommended that an individual in pursuit of using technology to improve their teaching practices converse about technologies of interest with colleagues. They also recommended establishing a method in which instructors are able to "bounce ideas off one another" so that instances of success and failure could be shared. Weathers and Latterell (2003) argued that if nothing else,

> a forum of collaboration reminds instructors of the value of thoughtful, persistent communication about issues we face in the classroom. Beyond serving as a type of support group, it helps us focus on pervasive issues and provides us with a better basis for deciding what issues need to be addressed. (p. 359)

If instructional resources addressing how to use certain technologies for a specific purpose are shared, then perhaps more mathematicians would be willing to integrate technology into their teaching (Buteau et al., in press). The exchange of ideas on the use of various types of technology can be best obtained through seminars and publications. Buteau et al. (2010) suggested that "more collaboration between mathematicians and mathematics educators is necessary, and that this change would serve to increase the number, quality, and depth of such publications written by practitioners" (p. 65).

In their study of the implementation of the on-line support component *MyMath-Laboratory*, for an Algebra and Trigonometry course at MUN, Kondratieva and Radu (2009) addressed the need to improve students' learning of mathematics through the use of technology, and suggested that it could be beneficial to have a core group of instructors dedicated to the overseeing of the on-line component. Such dedication might include, but not be limited to, instructor belief of the technology's usefulness and experience with such technology.

Therefore, the reviewed literature provided a view that with further collaboration, more math instructors would be open to the idea of integrating technology into their teaching.

2.4 Student Unpreparedness

In the author's experience teaching first-year mathematics, the class average of a typical first-year math class is 55%-65%. It is rare for instructors to have the class average beyond this range (G. Genge, personal communication, October 11, 2012). It is the researcher's view that these low passing rates can be connected to the unpreparedness of students entering post-secondary institutions.

Kondratieva and Radu (2009) noted that the increasing number of students attending post-secondary institutions has also resulted in a greater diversity in students' level of preparedness, especially in first-year mathematics. To try and address this phenomenon at MUN, incoming students are required to complete a mathematics placement test. Students who fail this test are labeled "unprepared" and placed in non-credit mathematics foundation courses. This test "helped to provide suitable instruction matched to the student's level of competence and consequently to reduce first year courses' failure rates" (Kondratieva & Radu, 2009, p. 4). The use of technology is one solution to help overcome this low student preparedness for tertiary mathematics (Buteau et al., 2010; Lavicza, 2010).

Considering the low level of technology currently being used in math pedagogy at MUN, and the benefits of teaching mathematics with technology as outlined in the literature, through this research the researcher investigates why more instructors are not teaching with technological aids to try and improve students' academic performance. It has been noted by the National Council of Teachers of Mathematics (2000) that technology can play an essential role in teaching and learning mathematics. Technology has been known to influence mathematics, while enhancing students' learning. Lavicza (2010) observed that educators "have turned their attention to pedagogical issues" (p. 108). The vast amount of easily available technology, combined with the low level of students' mathematical preparedness, has caused instructors and educators "to experiment with innovative teaching" (p. 108). However, more research is needed regarding the use of technology at the university level (Lavicza, 2008).

Another issue the researcher saw a need to address was what happened when students are being taught with technologies in grade school not being used in post-secondary institutions. The transition to post-secondary education is already a complicated undertaking. Collaboration between grade school educators and post-secondary officials is needed to make this transition easier for students, especially as the use of technology in learning steadily increases. Also, one observation that emerged from this literature review was that teachers within the grade school system and post-secondary instructors alike need to collaborate on ways to better motivate students to learn mathematics so that students arrive with the proper attitude to be successful in their future studies (Buteau et al., 2010).

With students' observed low levels of mathematical preparedness, and the current level of available, influential math-specific technology, math instructors need to turn their attention to pedagogical issues. Such has been noted in Buteau et al. (2009). Moreover, Lavicza (2010) has seen the integration of technology into post-secondary mathematics as a way to improve current teaching practices and assist students with their current level of mathematical preparedness.

2.5 Possible Effects of Technology on Teaching and Learning

The idea that the addition of technology to teaching "would not simply improve learning but support different ways of thinking and learning" was realized in the 1980s (Papert, 1993, p. 168). Since this time, several studies have discussed students' attitude, achievement, and learning, in regards to the integration of technology in math pedagogy. Presumably, the implementation of technology in the teaching of mathematics improves students' attitudes toward the subject by encouraging them to learn and think in alternative ways. Technology allows for independent learning and "by potentially increasing their motivation to learn" (Buteau et al., 2010, p.

60).

With the addition of technology to the teaching of mathematics, Goos et al. (2007) commented that technology (a) assists learning by providing instant feedback; (b) aids students in understanding patterns; (c) allows students to see multiple ways to solve a problem; (d) supports "inductive thinking by allowing students to quickly generate and explore a large number of examples, and make conjectures about patterns and relationships" (p. 79); and (e) allows students to work with more complicated sets of data. However, according to Gómez-Chacón and Haines (2008) "there have been enthusiastic claims regarding the positive impact of technology on the teaching and learning of mathematics" (p. 102).

Kondratieva and Radu (2009) suggested that

> students must be taught traditional mathematical techniques within a number of toy problems which do not require the use of technology and focus on developing mental mathematics, logic and abstract thinking. But students will be less motivated to learn certain skills, especially involving routine and tedious calculations if they are aware of the fact that this task can be solved by a technological tool. Also, students previously exposed to a more open interactive way of teaching will find it challenging to learn from a strict fact delivery in a lecture format. (p. 15)

2.5.1 Technology and Students' Attitudes

In relation to studies of attitudes towards technology in mathematics pedagogy, the following themes were identified: (1) qualitative instead of quantitative measurement instruments (Hannula, 2002); (2) problems linked to measuring attitude (Kulm, 1980); (3) the definition of attitude (Di Martino & Zan, 2001, 2002); (4) questions of the nature of attitude (Ruffell, Mason, & Allen, 1998); and (5) relationships between positive attitude and achievement (Leder, 1985). Although the literature suggests that technology promotes positive attitudes among mathematics students, there are still some instructors and educators who disagree.

2.5.2 Technology and Practice with Instant Feedback

Many instructors believe that the more examples a student works through, the better they will understand mathematical concepts (Kondratieva, 2012). Therefore, a system that generates as many examples of a specific problem as required, along with an instantaneous response to an in-putted answer, "presumably forces the student to review the incorrect answer until it is accepted by the system" (Kondratieva, 2012, p. 2). It should be recognized that such online tutorials may affect students positively, as well as negatively (Radu & Seifert, 2010). Authors generally conclude that the use of software may reduce failure rates (Kondratieva, 2012, p. 3).

It has been established that current technology offers new avenues in which teaching and learning can be improved (Bingimlas, 2009, p. 235; Buteau et al., 2010, p. 60; Fogarty, Cretchley, Harman, Ellerton, & Konki, 2001; Leitzel, 1989). Such technologies also have "the potential to support education across the curriculum and provide opportunities for effective communication between teachers and students in ways that have not been possible before" (Bingimlas, 2009, p. 235). Adams (1997) stated that "the power of technology and its application in mathematics can be realized when computers and calculators are used as tools for teaching and learning" (p. 483). Adams commented how every mathematical topic can be enhanced with the use of computers and calculators. However, in a survey of American schools, Coley, Cradler, and Engel (1997) illustrated that even though some computer-based instruction can promote learning, there is still concern that the integration of technology in the teaching of mathematics can be problematic.

Thomas and Holton (2003) commented that "now more than ever we appear to be in a position where students can experience the entire process of doing mathematics. This position has been reached with the ready availability of technology that can produce non-trivial examples extremely quickly and manipulate" (p. 386).

2.5.3 Technology, Engagement, and Motivation

As found in the literature, technology has been implemented in the teaching of mathematics for several reasons, the first of which was to improve student in-class engagement. Liu and Stengel (2009) demonstrated that with the addition of clickers, in lieu of traditional teaching methods, the results of "student retention and examination performance compared favorably to other sections of the same course" (p. 51). Students and the instructor reported increased levels of motivation, that they were able to focus more on content, which in turn promotes active learning and "incorporates immediate feedback, which is effective in promoting learning" (p. 51). Another reason technology has been implemented is because other researchers looking at active learning have noted improvements in the following areas: conceptual understanding, test achievements, reduced dropout rates, student satisfaction, team work, and problem solving (Pundak et al., 2009, p. 218).

2.5.4 Technology and Visualization

A major impact of including technology in the teaching and learning of mathematics, as noted by Goos et al. (2007) is its influence on visualization:

> Students can observe changes in numbers, see patterns, and view images of geometric figures, relationships and data. Visualization as a means of

> learning mathematics has gained more prominence through the use of technology and visual reasoning has become more widely acknowledged as acceptable practice for mathematicians in the mathematical discovery process. (pp. 83-84)

According to Goos et al. researchers, therefore agree that certain technologies are essential in students' lives "in order to participate successfully in contemporary social, economic and cultural life" (Goos et al., p. 74). Valdez (2005) commented that "technology can also help teachers respond to students' diverse learning styles by creating rich environments that engage students' tactile, visual, and auditory senses" (pp. 4-5).

It should be noted however that "less is known about how students actually use technology to learn mathematics in specific classroom contexts or about how the availability of technology has affected teaching approaches" (Goos et al., 2007, p. 90). Although the use of technology in the teaching of mathematics can positively affect students' learning, educators should realize that the integration of such technologies into the curriculum could have unanticipated results (Goos et al.). This research will partly address this question by interviewing math instructors about the effects of technology on their teaching approaches and about unanticipated results of the implementation of technology.

Since one of the major benefits cited for the use of technology in mathematics learning is that of visualization, it is surprising that relatively little use appears to have been made of computers in the teaching of geometry at the tertiary level (Thomas & Holton, 2003).

2.6 Summary

In summary, through the analysis of available literature, it can be concluded that teaching mathematics with technology, at the post-secondary level, has the potential to increase student (1) interest; (2) attitude; (3) motivation; (4) achievement; (5) learning; (6) ability to think abstractly (Jarrett, 1998); and (7) problem solving abilities. However, it is clear that the technology must be implemented properly for students and instructors to fully benefit. Valdez (2005) concluded that "effective use of instructional technology is possible only if sufficient attention is given to the following:" (p. 13)

1. curriculum uses;
2. instructional pedagogy used;
3. sufficiency of technology and access to the Internet; and
4. ability of the teacher, especially, to model uses of technology.

This literature review has provided a positive picture of the use of technology in the teaching and learning of post-secondary mathematics in regards to improved student learning. Although there are many challenges to doing so, there are still a variety of factors that determine whether or not an instructor uses technology (see Thomas and Holton, 2003).

According to Wozney et al. (2006), teachers are more likely to use certain technologies if they see their value and real potential in the classroom, have high expectations for success of using it, and if "these benefits outweigh the perceived costs or implementation" (p. 177). In addition, several results generally consistent with the national results given in Buteau et al. (in press) illustrate that at the undergraduate mathematics level, only 11% of instructors use computer algebra systems frequently, 27% occasionally, and 62% never use technology in their teaching. From this section onwards, this thesis focuses on the extent that mathematics instructors at post-secondary institutions in Newfoundland and Labrador are familiar with the above mentioned benefits, and how their practices correlate with the themes identified within this literature review.

Chapter 3

Methodology

This research aimed to investigate the attitudes of post-secondary mathematics instructors in Newfoundland and Labrador towards the teaching and learning of mathematics with the inclusion of technology. Data were collected in order to address the following questions: (1) How frequently and what types of technologies are being used by instructors in their teaching of mathematics? (2) What are mathematics instructors' teaching experiences, professional development experiences, familiarity with pedagogical literature on the use of technology, and accessibility to technology and support?; and (3) What are instructors' opinions of teaching mathematics with technology in relation to students' needs? This chapter contains details regarding the design of the study, population and sample selection, ethical procedures, data collection, data analysis, and the reliability of the data.

3.1 Design of the Study

Quantitative and qualitative research are two distinct and commonly used types of educational research. Creswell (2008) defines *quantitative research* as "a type of educational research in which the researcher decides what to study; asks specific, narrow questions; collects quantifiable data from participants; analyzes these numbers using statistics and conducts the inquiry in an unbiased, objective manner" (p. 46). *Qualitative research* is "a type of educational research in which the researcher relies on the views of participants; asks broad, general questions; collects data consisting largely of words from participants; describes and analyzes these words for themes; and conducts the inquiry in a subjective, biased manner" (p. 46).

The research methodology chosen for this study is a mixed methods research design. According to this approach (Creswell, 2008), researchers collect and analyze data by "mixing" both qualitative and quantitative methods in one study in order to better understand a problem. Creswell gives the rationale of this approach as "the quantitative data and results provide a general picture of the research problem; more analysis, specifically through qualitative data collection, is needed to refine, extend or explain the general picture" (p. 560). This design was chosen for two reasons.

First, since the author was skilled in quantitative data analysis the collection of quantitative data was appealing. The collection of qualitative data was included because the literature review revealed that there is a necessity for more research that yields qualitative results (Goos & Bennison, 2008). Second, both types of data should present a clearer picture of the problem at hand than either type on its own (Creswell, 2008), building upon the strengths of both the quantitative and qualitative data.

More specifically, this research employed the most popular of the mixed methods designs (Creswell, 2008), the *explanatory mixed methods design.* In an explanatory mixed methods design, the researcher first collects quantitative data (called *Phase One* of the study). Once the quantitative data has been analyzed, the researcher then collects qualitative data (called *Phase Two* of the study) to further explain the results of the quantitative findings. This design provides the advantages associated with both forms of data collection. That is, "to obtain quantitative results from a population in the first phase, and then refine or elaborate these findings through an in-depth qualitative exploration in the second phase" (Creswell, 2008, p. 560). The disadvantages of such a design are: (a) it can be difficult to decide which quantitative portions of the study the researcher needs to carry over to the qualitative portion of the study; and (b) depending on the number of participants, the design can be labour intensive in terms of the time and expertise needed to collect both forms of data (Creswell, 2008).

For an in-depth review of the development of mixed methods research, the reader is directed to Creswell and Plano Clark (2007), Datta (1994), and Tashakkori and Teddlie (1998).

3.2 Population and Sample Selection

The participants in this study are post-secondary mathematics instructors from institutions across the Province of Newfoundland and Labrador. Of the 36 individuals who were asked, a total of 13 instructors (12 male and 1 female) completed the questionnaire portion of the study, as this was the total number of respondents. Eight of the participants hold doctoral degrees; four have a pure mathematics background, and four have an applied mathematics or statistics background. The teaching experience of these eight instructors (one of whom was recently retired), was exclusively at the post-secondary level. The remaining five instructors (one of whom was also recently retired) were hired specifically to teach first-year mathematics. These instructors have various levels of education, but all hold some combination of a B.Sc, B.A, B.Ed, M.Ed, and M.Sc. Two were former grade school teachers, one an administrative professional, and the other two were exclusively post-secondary instructors.

Of the initial sample of 13 participants, individual follow-up interviews were conducted with eight of the instructors upon the completion of the analysis of the questionnaire data. The researcher determined that saturation was reached with eight interviewees and concluded no more were necessary. Participation in this research was voluntary, with all interviewees conducted in the St. John's area.

3.3 Ethical Procedures

The Interdisciplinary Committee on Ethics in Human Research and the Department of Mathematics and Statistics at MUN provided the approval for this study (see Appendix A). All participants were informed that: (1) participation in this study was voluntary; (2) they could withdraw from the study at any time; and (3) a decision to participate or to withdraw from the study would in no way affect their employment.

Before the commencement of the study, the researcher explained to each participant the importance of free and informed consent, and the instructors were provided with a description of the research and their anticipated role in the study. Each participant was then provided with a copy of a consent form, including a confidentiality and anonymity statement, which was completed before participation (see Appendix B).

The transcription of both data types was completed by two third parties. Both signed a consent form (see Appendix C) indicating that no information related to the project was to be released to any other persons. Each participant was assigned an identification number (from P1 to P13) and any information that might potentially identify a participant was omitted during the transcription process. All collected data are currently being kept in a secure location known only to the research team consisting of the author of this thesis and the research supervisors. It was explained to each participant that this information would eventually be destroyed after a period of five years, as per MUN policy.

3.4 Data Collection

The data collection period for this research occurred between January 2012 and March 2012, and began with an advertisement (see Appendix D) that was mailed to the post-secondary institutions that taught mathematics in the Province of Newfoundland and Labrador. The advertisement gave a brief description of the study, emphasized confidentiality, and invited instructors willing to participate to contact the researcher. Following the advertisement, a sufficient number of participants were willing to participate in this research study and a letter of thanks was sent to each participant (see Appendix H). All participants filled out a questionnaire, but only eight participants participated in an individual follow-up interview due to saturation of the data. Participants were encouraged to ask questions about the data collection process throughout the study.

3.4.1 Quantitative Data: Questionnaire

During Phase One of the study, the 13 participants completed a questionnaire comprised of 64 multiple-choice questions categorized in the following four sections: (1) Professional Views on Technology; (2) Teaching Style and Background; (3) Experiences with Technology; and (4) Process of Integration. The questionnaire used in this study (see Appendix E) is a modified version of a questionnaire used by the Centre for the Study of Learning and Performance at Concordia University in Montreal, Québec (see Appendix G), from whom permission was granted to use their questionnaire. One of the goals of the Centre for the Study of Learning and Performance is "to study classroom processes through an active association with teachers, students and administrators" (Centre for the Study of Learning and Performance, 2001, p. 1). This questionnaire was first constructed to better illustrate the reasons why teachers were integrating computer technology into their classrooms. In order to obtain an accurate understanding of these reasons at the post-secondary level, a modified version of this questionnaire was provided to the participants. The original questionnaire and information regarding its development are outlined by Wozney et al. (2006).

Each section of the modified questionnaire employed a Likert-style response format for all its items. Section one consists of 30 items regarding instructors' views on technology, with options including (1) Strongly Disagree, (2) Moderately Disagree, (3) Slightly Disagree, (4) Slightly Agree, (5) Moderately Agree, and (6) Strongly Agree. In each of these 30 items there was a mixture of positively and negatively worded items which were grouped into three categories: those measuring perceived expectancy of success, perceived value of technology use, and perceived cost of technology in the teaching of mathematics. Sections two and three addressed teaching style and general use of technology respectively, each consisted of three items that have five to nine choices (inclusive). Section four consisted of 26 items regarding the implementation of technology, each with options including (1) Never, (2) Practically Never, (3) Once in a While, (4) Fairly Often, (5) Very Often, and (6) Almost Always. The final two questions (not assigned to a section), addressed the amount of professional development received by an instructor (five choices), and their current level of technology integration (six choices).

3.4.2 Qualitative Data: Interviews

Phase Two of the study consisted of an in-depth, individual one-on-one interview with eight instructors selected from those who participated in Phase One of the study. The eight instructors were selected from the city of St. John's due to the importance of face-to-face communication and convenience. The semi-structured interview consisted of a list of interview protocols (see Appendix F) which were used to develop a more detailed understanding of the questionnaire results. The qualitative phase of this study provided an opportunity for the instructors to voice and elaborate on their attitudes towards the application of technology in the teaching and learning of mathematics.

An introductory portion of the interview protocols were adopted from Matchem's (2011) M.Ed thesis, which focused on teachers' attitudes toward problem solving approaches in teaching mathematics. The additional protocols were designed based on the key subject areas identified within the literature, as well as the author's own experience, combined with that of the author's supervisor, who is an experienced post-secondary mathematics instructor. The final version of the protocols was approved by the researcher's supervisors and consisted of the following sections: (1) Background; (2) Classroom Management; (3) Technological Instruction; (4) Instructor Support; (5) Evaluation; and (6) Conclusions. The interview protocols were divided into sections so that participants could think about specific topics. Although the questionnaire also asked questions regarding the participant's background, each interview began with background questions to establish a feeling of comfort. The interview then proceeded into more probing, open-ended questions, followed by those of a more general nature.

Contact was made with the participants via e-mail to arrange in-person interviews. Of the eight interviews conducted, all except one was completed at MUN's St. John's campus. The duration of the interviews varied from 35 to 80 minutes. The interviews were recorded using the researcher's laptop with an external microphone. Notes were also taken during and immediately following the interview to report on items of significance.

This was the researcher's first experience conducting interviews. Before conducting interviews, research was completed on interview preparation and the role of the interviewer. The researcher believes that knowing the interviewees on a personal basis (as a colleague or former instructor), created a comfortable atmosphere, further encouraging valuable and truthful responses. Each interview was then transcribed by a professional transcriber.

3.5 Data Analysis

Data collected for this thesis consisted of responses to a questionnaire administered to all participants ($N = 13$) and eight transcribed interviews. The questionnaire data became the object of the data analysis for the quantitative portion of this study. Whereas, the interview data became the object of the data analysis for the qualitative portion of this study. The objective of the data analysis was to answer the research questions of this thesis (see Chapter 1 Section 4).

The first phase of the analysis involved the data obtained from the questionnaire. The questionnaire consisted of 64 items for a total of 832 data entries. It should be noted that there were nine pieces of missing data. A participant's reasoning for not answering a question could include discomfort in answering the question, not understanding the question, or failure to remember to readdress the question at a later time. The missing data were left as such due to the advice of the Research Computing Specialist at MUN who analyzed the data using the Statistical Package for the Social Sciences (SPSS). Also, since the author used positively and negatively worded statements in the questionnaire, some statements were recoded. That is, statements that were negatively worded were rephrased to have a positive meaning. The data was in-putted into SPSS and specific clusters of questions were analyzed to help address the research questions. For example, questions 36-62 (inclusive) and

64 from the modified questionnaire were analyzed to address the research question: how frequently and what types of technology is being used by instructors in their teaching?

The second phase of the analysis involved preparing verbatim transcripts of the interviews. This took 27.5 hours and the task was completed by a professional transcriber. The 112 pages of transcribed interview data were then analyzed by hand to give the author a more in-depth understanding of the data. This means that the author "read the data, mark it by hand, and divide it into parts" (Creswell, 2008, p. 246). Next, the author coded the data, isolating the specific ideas (themes) that arose. The researcher then interpreted the data. This took several readings of the interviews, while trying to correlate the ideas with the themes. A more in-depth look at the themes can be found in Chapter 4.

3.6 Reliability

Within the questionnaire used in this study, three categories of items were measured: (1) perceived *value* of technology use; (2) perceived *expectancy* of success; and (3) perceived *cost* of technology use. The Cronbach's alpha (a measure of internal consistency) for items falling within the three categories of belief statements ranged from moderate to high. The creators of the questionnaire (for which a modified version was used in this study), advised future researchers using the questionnaire to "rephrase strongly skewed statements to increase the variability of responses, and hence increase the internal reliability of each of the three broad categories of belief items" (Wozney et al., 2006, p. 197). Consequently, for this research project three questions were removed from the original questionnaire, while some others were rephrased to agree with the above recommendations.

Through statistical analysis using SPSS, it was determined that the Cronbach's alpha for each category was 0.961 (value), 0.765 (expectancy), and 0.739 (cost). The Cronbach's alpha for the cost category was originally 0.602, but when two questions (5 and 17) were removed from the researcher's modified questionnaire (see Appendix E), there was an increase in the internal consistency of the questions. These two questions were removed as they were determined to not contribute to the research questions. The values of the Cronbach's alpha from Wozney et al's. (2006) study produced values of 0.86 (value), 0.61 (expectancy), and 0.73 (cost). Hence, it can be seen that the researcher's modifications based on the advice of the original authors of the questionnaire improved the internal consistency within the three categories.

To ensure reliability of the interview data, the data was analyzed in detail and quotes from the respondents were supplied to support conclusions. The dependability of the study was affirmed by using a sufficient number of participants (Radu, 2011) and through the use of clear and concise interview questions. In addition, the results of this study are in agreement with those found in the literature (see Chapter 2).

Chapter 4

Research Findings and Discussion

The goal of this research is to better understand various attitudes of post-secondary mathematics instructors in the Province of Newfoundland and Labrador towards the use of technology in the teaching and learning of mathematics. Specifically, the purpose of this study is to collect information concerning mathematics instructors' use of technology in their teaching, and to discuss why some instructors are reluctant to use more influential technology despite the overwhelming evidence of the positive effects. This chapter presents the findings and a detailed discussion of the collected quantitative and qualitative data, in an attempt to describe the opinions of the participants involved and address the research questions. The response rate (13 out of 36) and the majority of positive feedback from interviewees suggests that instructors are interested in this study, the various types of technologies, and their applications to the teaching and learning of mathematics. The following research questions were investigated in this mixed methods study.

(RQ1) How frequently and what types of technologies are being used by instructors in their teaching of mathematics?

(RQ2) What are mathematics instructors' teaching experiences, professional development experiences, familiarity with pedagogical literature on the use of technology, and accessibility to technology and support?

(RQ3) What are instructors' opinions of teaching mathematics with technology in relation to students' needs?

The following three sections present the data related to each of the research questions respectively.

4.1 Instructors' Purposes for Using Technology

As Lavicza (2010) following Buteau et al. (2009) has observed, "little is known about the current extent of technology use and mathematicians' practices in university teaching" (p. 108). This section reports on what types of technologies are being used by a selection of instructors in Newfoundland and Labrador post-secondary institutions, how frequently, and for what purposes.

It was found that instructors mostly employ tools of their choice. However, sometimes there are departmental initiatives to employ certain technologies in certain courses. For example, *WebAssign* was employed by the Department of Mathematics and Statistics at MUN in the teaching of calculus in the Fall of 2010 to provide students with extra practice, which constituted a minor portion (5-10% of the total grade) of the students' assessment.

In terms of other technologies, the most popular among the instructors are those that make their job more efficient. These included (1) word processors (e.g., LaTeX; Microsoft Word); (2) D2L or other means of maintaining course websites; and (3) Excel for keeping and managing students' grades. Most instructors, especially those who teach big classes were using classroom equipment such as big drop screens and projectors (overhead or computer-connected). Lecture Capture was used by a few instructors as well.

Less frequently, and depending on the instructor and course material, other types of math-specific technology were mentioned. These included computer algebra systems (Maple and Mathematica) and dynamic geometry software (Geogebra and Geometer Sketchpad).

Data about the different uses of technology has been collected from section four of the questionnaire. Section four of the questionnaire asked instructors how frequently they were using technology for a variety of activities in their teaching practices. These activities included (1) instruction; (2) communication; (3) organization; (4) analytical/programming purposes; (5) recreation; (6) expansion; (7) creativity; (8) expression; (9) evaluation; and (10) informative purposes. The Likert type scale used for these questions was "1-Never" to "6-Almost Always".

4.1.1 Instructional

Table 4.1: Tutorials for self-training

Scale	Freq	%
Never	4	30.8
Practically Never	1	7.7
Once in a While	4	30.8
Fairly Often	2	15.4
Very Often	2	15.4
Almost Always	0	0

Table 4.2: Tutorials for remediation

Scale	Freq	%
Never	7	53.8
Practically Never	3	23.1
Once in a While	2	15.4
Fairly Often	1	7.7
Very Often	0	0
Almost Always	0	0

Table 4.1 illustrates that instructors are likely to use tutorials they have access to to guide students in their learning of the course material. However, Table 4.2 illustrates that instructors are highly unlikely to have students use technology to help improve basic mathematics skills.

4.1.2 Communicative

Most instructors regularly use e-mail for communication with students. However, 3 out of 13 use e-mail only "Once in a While" (appendices Table J.2). This is comparable to the fact that 2 out of 13 use e-mail only, "Once in a While", to stay in contact with other instructors (Table J.1).

Table J.3 illustrates that 7 out of 13 instructors use an LCD projector in class, which is especially relevant in teaching big classes. Table J.4 illustrates that 4 out of 13 instructors use PowerPoint presentations in the classroom. This could be attributed to the statistician participants since their course notes are often supplied to them from book publishers in the form of PowerPoint.

Tables J.1, J.2, and J.3 show that instructors do use technology the majority of the time for communicative purposes.

4.1.3 Organizational

Tables J.5 and J.6 show that instructors do use technology the majority of the time for organizational purposes. It was found that all instructors use technology for the compilation of course materials (Table J.6), and 10 out of 13 instructors use technology for the compilation of students' grades (Table J.5).

4.1.4 Analytical/Programming

Tables J.9 and J.10 illustrate that 9 out of 13 instructors, at least "Once in a While", use technology for analytical/programming purposes. This could be attributed to research methods of the instructor and not necessarily pedagogical reasons.

4.1.5 Recreational

Table 4.3: Have students play games

Scale	Freq	%
Never	9	69.2
Practically Never	2	15.4
Once in a While	2	15.4
Fairly Often	0	0
Very Often	0	0
Almost Always	0	0

Table 4.4: Reward for good behaviour

Scale	Freq	%
Never	11	84.6
Practically Never	2	15.4
Once in a While	0	0
Fairly Often	0	0
Very Often	0	0
Almost Always	0	0

Tables 4.3 and 4.4 show that 11 out of 13 instructors "Practically Never" use technology for recreational purposes in relation to their students' needs. What is surprising is that two instructors "Once in a While" let their students play games in class. The researcher has no reasoning or evidence to support this claim.

4.1.6 Experimental

Three out of 13 instructors, at least "Once in a While", have students use 3D modeling software (Table J.12). Whereas 7 out of 13 instructors, at least "Once in a While", have students conduct experiments (Table J.11). The researcher believes that this difference is attributed to the level of courses instructors teach. For example, as mentioned in Chapter 1 Section 1.1.2, one instructor implemented GeoGebra in the teaching of Euclidean geometry for the purposes of experiential learning.

4.1.7 Creative

Table J.13 illustrates that 8 out of 13 instructors do not use drawing or paint programs. The researcher attributes this to the fact that knowledge of such programs would require special professional development, which instructors are lacking. Whereas, Table J.14 illustrates that 8 out of 13 instructors are using pictures and diagrams (probably drawing them by hand) and using a scanner, which is a basic piece of technology, to put pictures on a webpage.

4.1.8 Expressive

The researcher finds it interesting that one person responded "Never" and one person responded "Practically Never" to the use of word processors (Table J.15).

This is because the author is aware that all the instructors who participated in this research study used a word processor to compile course materials, but not necessarily all their course materials.

According to Table J.16, 4 out of 13 instructors, at least "Once in a While", maintain an online discussion board. P3 mentioned in his/her interview that he/she always maintained a discussion board on a webpage so that students could post their questions and other students, as well as the instructor, could post a response. Similar ideas can be done with D2L, but instructors do not seem to be doing such things. However, discussion boards could promote student interaction through technology and perhaps initiate face-to-face interactions and collaborations between students.

4.1.9 Evaluative

Since instructors are not using much influential math-specific technology in their teaching practices, it would be highly unlikely that they would use technology to assess student learning. However, Table J.17 shows that 7 out of 13 instructors, at least "Once in a While", do test student learning using technology, but the author attributes this to the fact that some instructors are using WebAssign in their teaching of calculus (not by choice) which is worth a small portion of a student's final grade.

4.1.10 Informative

The researcher found that 9 out of 13 instructors, at least "Once in a While", search the Internet for information for a lesson (Table 4.5).

Table 4.5: Search the Internet

Scale	Freq	%
Never	2	15.4
Practically never	2	15.4
Once in a While	3	23.1
Fairly Often	1	7.7
Very Often	3	23.1
Almost Always	2	15.4

It is interesting that despite instructors having taught their courses numerous times before, and have memory banks of examples in which instructors can pick and choose to compile their course materials, some of them still search the Internet for material for a lesson plan.

4.1.11 Summary

Within the traditional teaching approach, the only technology that is consistently used in the teaching of all mathematics at MUN are overhead projectors and their modern version Doc Cams, combined with a microphone. These are especially needed when the class sizes are large and the use of the whiteboard is inadequate.

Encouraging instructors to consider influential math-specific technologies in many cases means simultaneously inviting them to review their teaching beliefs and strategies (Mishra & Koehler, 2006). This is a challenging but important task considering that the students' education is taking place in the technological age. By asking instructors to articulate their teaching positions, needs, and attitudes regarding the use of technologies, as well as to share their best practices with technology, it is the author's long-term goal that this research will facilitate changes in the teaching of mathematics with technology in Newfoundland and Labrador post-secondary institutions. In the next two sections a more detailed analysis of the interview and questionnaire data is provided to discuss the reasons for instructors' current use of technology.

4.2 Instructors' Background

In this section, the question "what are mathematics instructors' teaching experiences, professional development experiences, familiarity with pedagogical literature on the use of technology, and accessibility to technology and support?" is discussed. Answering this question serves to support instructors' pursuits in the incorporation of more influential math-specific technologies in their teaching, as demonstrated in Goos and Bennison (2008). In order to answer this research question, this section has been separated into four subsections. The first subsection addresses instructors' own experiences as students, and what they learned from their instructors. Subsection two deals with instructors' professional development related to technology and why they are not always taking full advantage of available opportunities. Subsection three presents data on instructors' familiarity with research on technological advantages in teaching. The final subsection discusses instructors accessibility to technology and accompanying support. It should be noted that this section contains data immediately dealing with technological instructions. Additional data reflecting participants' overall background, career paths, and pedagogical views are presented in Appendix I.

4.2.1 Teaching Practices and Experiences with Technology

All participants said that in their teaching practices, they attempted to emulate the "good" instructors they had as students. P2 commented that his/her instructors were just scratching the surface of the course material and that is why he/she always provided students with a "deeper treatment" of the course material. P4 noted that

> some of the things that I learned as a student way back in high school from one of my old geometry teachers ... who would challenge us with challenging problems, and he would do it ... say, you know, because I was good

> at geometry he'd give me harder ones, and some of my colleagues and friends who weren't so good, he would just let them do the stuff in the book, but he'd always find problems for me and my buddies and me to do, and he always challenged us to think, you know, a little more and to ... and I've tried to do that as well during my career.

This being said, instructors are using forms of technology in their teaching practices (e.g., word processors and e-mail) that were not available to many of their instructors when the interviewees were students. This indica tes that the use of basic technology is continually being integrated into everyday teaching practice. Therefore, although interviewees are emulating what they considered to be the best aspects of their former instructors, they are also incorporating new and improved techniques that have become available over time.

In many studies experience with technology is considered an important factor influencing instructors' use of technology in their teaching (Cavas et al., 2009, p. 27). An instructor's lack of knowledge and experience with technology seems to make them reluctant to allow students to further expand upon the application of such technology (Goos et al., 2007, p. 91). Question 36 of the questionnaire asked the instructors about their technological proficiency level and the results in Table 4.6 show that the majority of responses were "Beginner" or "Average" which supports

Goos et al.

Table 4.6: Technology proficiency level

Scale	Freq	%
Unfamiliar	0	0
Newcomer	0	0
Beginner	4	30.8
Average	6	46.2
Advanced	2	15.4
Expert	0	0

Question 35 of the questionnaire asked instructors "how many hours per week they spent using technology for personal use outside of teaching activities". The results are summarized in Table 4.7.

Table 4.7: Technology use outside teaching

Scale	Freq	%
None	1	7.7
Less than 2 hours	2	15.4
2 hours or more, but less than 4 hours	1	7.7
4 hours or more, but less than 6 hours	0	0
6 hours or more, but less than 8 hours	2	15.4
8 hours or more, but less than 10 hours	1	7.7
10 hours or more	5	38.5

Question 34 of the questionnaire asked instructors "how often they integrated technology into their teaching activities". The results are summarized in Table 4.8.

Table 4.8: Frequency of technology integration

Scale	Freq	%
Not at All	1	7.7
Rarely	2	15.4
Occasionally	8	61.5
Frequently	1	7.7
Almost Always	0	0
All the Time	1	7.7

Although two individuals considered themselves to be at an "Advanced" level of technological proficiency, both were only "Occasionally" integrating technology into their teaching practices. This could be attributed to the fact that instructors are applying many technologies in their research responsibilities that are not applicable in their teaching. Table J.9 and J.10 illustrate that the majority of instructors, "Once in a While", use technology for research purposes.

Of the five participants who used technology most frequently outside of teaching activities, they were all "Occasional" or "Frequent" users of technology in their teaching practices. Although two individuals were more than "Frequent" users of technology in their teaching, they were still of "Average" proficiency in terms of technological applications. This could be attributed to the fact that some instructors use in-class technologies all the time in their teaching. Therefore, the researcher concludes that there is no direct correlation between the amount of technology being used by instructors outside their teaching and the amount of technology being used in their teaching.

Of the eight interviews that were conducted. only one individual actually implemented influential math-specific technology into his/her teaching, with an additional laboratory component. The students were given exams that tested their pencil and paper knowledge, as well as an exam specially designed to test their abilities using the technology. It was noted by P3 that his/her section of the course did better than the other sections being conducted at the same time without technology, and as compared to similar sections in the past where he/she did not use the technology. P3 said "having a second approach to the material aided in student comprehension of the material." Even with the obvious benefit from the implementation of this technology, it was still not absorbed into the curriculum by the Department of Mathematics and Statistics at MUN.

Similarly, Hawker (1986), Heid (1988), and Judson (1988) find that an alternate approach to course material aids in improved student comprehension of the material. With reference to the work of Pundak et al. (2009), the researcher conjectures that the reluctance of instructors to use more technology in their teaching practices can be related to the amount of professional development they receive. This is discussed in more detail in the next section.

In conclusion, teaching practices are largely influenced by instructors' own experience when they were students, but they also adapt to changing conditions and incorporate novelties available for their use; technology is one of them. Also, instructors may use technology outside their teaching activities (Q35) and posses a certain level of confidence with them (Q36), however this does not necessarily imply that they will be using technology in their teaching practices (Q34). Further investigations would be needed in order to further discuss this phenomenon.

4.2.2 Professional Development Experiences

In the previous subsection, the researcher speculated that the reluctance of instructors to use more technology in their teaching practices can be related to the amount of professional development they receive. At MUN, the Instructional Development Office provides support to the University's faculty members and graduate students in the enhancement of their teaching knowledge and skills. The Instructional Development Office espouses a collaborative, responsive, and pragmatic approach to developing services and programs related to teaching and learning, including those that deal with technology. However, in the author's experience, the professional development offered to instructors at MUN is generally not specific to mathematics, and is often geared more towards Arts rather than Sciences. P6 said "I'm always a little skeptical about these workshops because they seem targeted to a pretty broad audience. You know, I'm concerned it's going to be a lot of, you know, obvious stuff that I think I already know." P3 commented that

> they're trying to do the best they can, but the stuff we need is different. Math support in the classroom - getting math symbols up on the screen is different from what the English Department might need, or the Political Science Department maybe ... I haven't seen anything that's too math specific, alright, apart from the occasional spreadsheet thing.

However, there is funding available from different sources throughout the university for full-time faculty, and even for per-course instructors, in terms of professional development that is related to his/her field of study. In particular, instructors have an opportunity to apply for local grants and can explore technologies potentially useful for their teaching assignments. Despite this, it seems that not many math instructors at MUN are doing so. P5 attributed this to the fact that what is being offered is "inapplicable to me because of the nature of what I have to teach and the time frames I have to teach with." Several instructors agree that they do not know enough of what is out there, hence cannot ask for specific types of workshops, but would support anything that would help with the development of teaching and learning. Therefore, instructors first need to be informed of what types of influential math-specific technologies are available, and the benefits of applying these technologies in teaching. Once this is known, they could then ask for workshops that deal with these specific technologies in order to ensure their successful application. For example, 8 out of 13 instructors "Practically Never" use drawing programs in their teaching, even though their courses involve many visual aspects (Table J.13), which would be significantly benefited by visual aids.

In response to Question 63 of the questionnaire, the majority of instructors have received less than one full day of technological training in their entire career. The results are presented in Table 4.9.

Table 4.9: Technology training

Scale	Freq	%
None	6	46.2
A full day or less	5	38.5
More than a full day and less than one-semester course	1	7.7
A one-semester course	0	0
More than a one-semester course	1	7.7

Klopfer et al. (2009) recommend establishing a method in which instructors are able to "bounce ideas off one another" so that instances of success and failure can be shared (p. 17). P1 commented

> what I really think the university would benefit from ... unfortunately, over the years teaching has been marginalized at Memorial, as I think it has

> been at most universities, and so I don't think that there is the sense of a teaching community that we often have, you know, whereby instructors would just as a matter of course sit down and - you know, the instructors within a department or within a faculty or whatever - sit down and discuss issues pertinent to teaching, and I think that would be beneficial, you know, because we have lots of research colloquia and seminars and so forth, so research is always a hot topic of conversation, as it should be, and I would want to see teaching gaining some of that stature, you know.

It should be noted that instructors are in contact with each other on a regular basis, but not necessarily for this purpose (Table J.1).

In order to use technology in the teaching of mathematics, the instructor must have an abundance of pedagogical knowledge. While technology can be used in powerful ways, it can be distracting and become detrimental to student learning (Coppola, 2004, p. 4). Goos et al. (2007) claim that math teachers need a working knowledge of a variety of technologies and that an "excellent mathematics teacher" can use such technologies effectively to make "a positive difference to the learning outcomes, both cognitive and affective, of the students they teach" (Australian Association of Mathematics Teachers, 2006 as quoted in Goos et al., 2007, pp. 74-75).

The researcher concludes that insufficient professional development is one of the main causes of a lack of technological integration into teaching. Therefore, post-secondary mathematics instructors must always be revising their teaching, even if obtaining proper professional development requires high demands of their time in addition to their teaching and research responsibilities (Schrum et al., 2005, p. 279). Based on interview data, the researcher concludes that if instructors had more encouragement and support in terms of professional development opportunities in the use of technology in their teaching, they would feel more comfortable and possibly integrate more influential math-specific technology into their teaching. However, some educators "may need additional constructive feedback that will enable them to take risks using technology in even more ways" (Valdez, 2005, p. 21). In order to provide students with the highest quality of education, educators need to be properly trained in the most recent pedagogical processes and theory. This will not happen if the current departmental focus is weighted more heavily on research than improved teaching.

4.2.3 Instructor's Familiarity With Current Pedagogical Literature Regarding Benefits of Technology Use in Teaching Mathematics

Thomas and Holton (2003) comment that "it is easy, even for dedicated teachers, to proceed with teaching as if it hasn't been essentially altered by the technology; to fail to acknowledge the presence of technology and hence to miss its advantages" (p. 380). This is the attitude that needs to be shared amongst more instructors. No matter an instructor's academic position, the level of instruction offered should be of high quality and being familiar with the literature is one way to aid in this process.

During the interview process, the eight participants were asked "to what extent are instructors familiar with the literature that describes the benefits of teaching mathematics using technology?" The opinions ranged from "not familiar at all" (P2, P4, P6), "not very much" (P7, P8), to "somewhat familiar" (P1, P3, P5). P1 commented that "I won't say I've done a whole lot of reading. I've more relied on talking with people who do have some familiarity with that, so it's not something that I could speak to with any degree of authority." P3, P5, and P8, who had some degree of familiarity with the literature represented an interesting cohort of instructors. P3 had taught at all levels in the post-secondary system and was the most experienced interviewee, both in teaching and implementing technology in teaching. This individual was the most enthusiastic towards the use of technology in mathematics pedagogy, and was the only participant who conducted current recreational research on improvements in teaching. P3 said,

> I'll try something just so I can look at you in the eye and say, "Look, either this works or it doesn't work." If you're an advocate of a certain approach using technology I'll try it, you know, assuming it's not completely off the wall. No, it's unprofessional to do anything otherwise - you know, to ignore it - I mean, you got to do it.

Krantz (1999) said "I would encourage others to be open to at least trying some of the different ways that [technology] can be used in the classroom" (p. 24). P5 commented that

> at one point I was quite familiar with the literature because, as I said, I did my master's in education, and I was quite familiar with that technology and philosophy at the time, and I don't ... so right now I'm probably not up on the current literature, but I'm really not sure if the philosophy has been changed; and, again, my philosophy back then was technology properly done can be a great asset in certain areas. Technology poorly done, like anything else, shouldn't be done, yeah, but I think in many ways like I would not want to go back to ... like every now and then the computer breaks down in the

classroom and I got to go back to using the chalkboard.

In conclusion, individuals whose goal was to teach at a post-secondary institution at the beginning of their career (especially those with a PhD, as opposed to a degree in education) are less inclined to use technology in the teaching of mathematics (However, even though P3 fell in this cohort of instructors he/she was still somewhat familiar with the literature). This could be attributed to certain job restrictions (number of classes they teach, number of graduate students they supervise, number of committees on which they serve, amount of research they conduct, lack of interest, or lack of time). Those whose background had a more pedagogical nature (i.e., those with a degree in education), were more familiar with methods of improved teaching.

Similar to the situation with professional development, it has been found that instructors generally have insufficient familiarity with current pedagogical literature regarding the use of technology in teaching post-secondary mathematics. The researcher conjectures that a lack of familiarity with the literature may also inhibit instructors from using familiar technology in their teaching.

4.2.4 Accessibility and Instructional Support of Teaching with Technology

4.2.4.1 Support for Teaching Innovation

Due to academic freedom, the approach an instructor takes to teaching is the choice of the instructor. Therefore, there is no set support structure within the Department of Mathematics and Statistics at MUN in terms of either general or specific teaching advisement. However, there are instructors who are willing to offer their opinions. As Wozney et al. (2006) demonstrate, future research in the area of technology integration should look at levels of peer-support and administrative support (p. 196). P1 commented that

> on an informal basis I think there are lots of people that ... you know, if you said, "Well, you know, I'm thinking about trying this. Has anybody ever tried something like this before," but a lot of people who would be quite happy to offer their experiences; or even if they don't have any experiences, just debate, you know - "What's the best way to do that? What do you think of that ... about this?" So I think on an informal basis the department does have a good community of support for that kind of thing.

In terms of their current teaching approaches, instructors were/are receiving full teaching support. However, P2 and P4 did not know if they would receive support in terms of a new teaching approach, but could not foresee why the department would not support them in new teaching practices. P4 and P5 said they did not need support in the way they teach, while P3, P5, and P8 said they were sure the department would support them if their new teaching approach was within reason. The researcher concludes that similar to professional development, instructors need to be informed of the existing, influential math-specific technologies and their benefits. Other than being informed, instructors would also need access to these technologies, be properly trained in using such technologies, and have access to technological support if a problem should arise.

4.2.4.2 Technical Assistance

Technical assistance is integral in order for instructors to be able to successfully use influential math-specific technology in their teaching. P5 mentioned that if all instructors were using vast amounts of technology in their teaching it would be unfeasible and disastrous, saying

> do I get the support I need? Yes. Do I need a lot of support? No, because once the initial bugs are out of the system either caused by me or the system, it's working very well. From my point of view, it's perfectly seamless, right?

> If I have a problem with the equipment it's solved quickly; but if we want a whole new approach and it was going to be heavily technology based, and there was going to be a lot of technology and direction at the individual level, I think the first year, like anything, would be absolutely madness, especially if the senior/older people learned it. A couple of years down the road it'd probably be fantastic, but it's that initial year wouldn't be fun, I think.

All of the instructors who were interviewed indicated that they had access to adequate resources in their teaching. There are books arriving from publishers each semester that offer a wide variety of examples. Since most instructors had taught courses multiple times, they have a copious amount of examples at their disposal that they can pick and choose to form assignments and work-sheets. Similar to the author, the majority of other instructors in the Department of Mathematics and Statistics at MUN use basic software such as HTML (Table J.16) or D2L to maintain course webpages (Table J.8), printing, photocopying, and scanning equipment (Table J.14), word processing programs to compile course materials and maintain student grades (Tables J.5, J.6, J.15), overhead projectors, and/or Doc Cams and microphones on a regular basis (Table J.3). Additional computer software available in the mathematics computer laboratory (and not necessarily in classrooms around the university) are the mathematical/statistical software: R, Matlab, Maple, Minitab, and Mathematica.

Other computer labs on the MUN campus offer software that suit the specific needs of that department.

P7 had technology (e.g., Maple) as part of several final exams, and has never had a problem receiving the technological support needed to conduct examinations. However, these classes were of 30 or less. P7 said that

> the benefit is that students all have access to the same type of software (such as Maple, or a toy example of a cryptosystem). So it's possible to incorporate some things into the exam that would otherwise be beyond the level of reasonable expectation were the exam to be held outside of a computer lab. A downside is the reliance on the technology. A power outage, or network trouble, or a server failure, etc., can all wreak havoc with what might be planned. I don't think that has actually happened with any of my exams (well, unless you count a fire alarm once during an AMAT 2120 final exam) but the potential is real.

However, as discussed later, there are more basic technological support issues (e.g., no chalk in a classroom) that need to be addressed before the implementation of more complicated technology can occur. As can be seen in Table J.17, 6 out of 13 instructors "Practically Never" use technology when testing their students. Those that do use technology for student testing are most likely referring to the mandatory use of *WebAssign* in some calculus courses.

To conclude, in order to overcome inaccessibility to technology, Bingimlas (2009) suggests that instructors need relevant software and hardware and sufficient technical support in order to successfully integrate technology. Even though the interviewees of the Department of Mathematics and Statistics at MUN have access to the basic technologies, as listed above, they do not have access to more influential math-specific technologies (as per Bingimlas) that would be of major benefit to student learning. The basic technologies are primarily used to help students carry out otherwise long winded pencil and paper calculations with large data sets or to manipulate complex expressions. Also, the implementation of any of the available technology is only realistic in classes of 40 or less. As a result, the majority of first- and second-year classes could not be exposed to many influential math-specific technologies. In addition, "it is essential for success to have a core group of instructors dedicated to working with the on-line component" (Kondratieva & Radu, 2009, p. 11) and other forms of technology. Such dedication should include, but not be limited to, instructors' beliefs of the usefulness of technology and experience with such technology.

4.2.5 Summary

In conclusion, post-secondary mathematics instructors at MUN, who participated in this study, can be regarded as "Frequent" to "Occasional" users of technology in their teaching, and consider themselves to have a proficiency level of technology from "Beginner" to "Average". There was no direct correlation between technology used outside of teaching to technology used in teaching. These instructors are lacking in mathematics specific professional development that would allow them to improve their teaching habits in relation to the use of technology in their teaching practices. Professional development experiences that allow instructors to understand both the technological processes as well as the underlying pedagogical theory are two key components required to improve student learning. Thomas and Holton (2003) stated that "there are gains to be made in student learning, we believe, if technology is employed in a way that takes into account current theories of learning, student attitudes to learning and faculty perspectives" (p. 387). Although technical support may be available at MUN, the broad and extensive use of influential math-specific technology is problematic. Even though having access to technology that benefits student learning is a step in the right direction, instructors need proper professional development, technological assistance, access to technology, and access to technological support, if they are to successfully implement technology into their teaching.

4.3 Instructors' Views

In this section, the question "what are instructors' opinions in regards to teaching mathematics with technology in relation to students' needs?" is discussed. As Wozney et al. (2006) have observed, future research in the area of technology integration should look at the extent to which prior technological experiences has affected teachers' attitudes. In order to address this research question, this section has been separated into two parts. Part One consists of five subsections based on themes that emerged from the interview data. The first subsection deals with instructors' perceived changes in teaching and learning during their academic career. Subsection two discusses instructors' experiences implementing technology in their teaching. The next subsection talks about the importance of fundamental knowledge for the learning of mathematics. The fourth subsection addresses curriculum and pedagogical changes resulting from the implementation of technology. The final subsection discusses the barriers instructors encounter with the implementation of technology in teaching. Part Two gives a detailed analysis of the instructors' opinions towards the value, expectancy, and cost of the implementation of technology in teaching in relation to the qualitative data.

4.3.1 Emergent Themes of the Interview Data

4.3.1.1 Changes in Teaching and Learning Over Time

Of those interviewed, P1, P3, and P5 believed that there has not been significant change in the teaching and learning of mathematics during their teaching careers, especially in relation to the current level of available technology. Five participants (P2, P3, P5, P6, and P8) believed that there has been an increase in the amount of technology now being used in the teaching of mathematics; however, P1 and P7 commented that more technology in the teaching of mathematics does not necessarily imply an improvement in learning. Although, regardless of the method of instruction, students will often adapt to the situations they encounter in their studies. P7 remarked,

> for example, when technology is forced upon students, they will adapt and their learning techniques will adapt accordingly. So if you were taught first- and second-year calculus without calculators you learn to sketch things and draft things ... whereas if you're taught first- and second- year calculus with a mandatory graphing calculator in hand ... that changes things a little bit. You don't have to rely entirely on pencil and paper. There's still a lot of pencil and paper in hand, but you've got the benefit of being able to refer to this aid, and that does change how things are timed, how things are

learned, not necessarily for the better.

However, it has been noted in Thomas and Holton (2003) that technology cannot simply be "thrown" at post-secondary mathematics students with the hope of some benefit; students' experiences have to be thoroughly considered.

4.3.1.2 Integrating Technology

According to Table 4.8, the majority of instructors "Occasionally" integrate technology into their teaching activities. As discussed earlier, all instructors used forms of technology in the compilation of course materials (Table J.6), but nothing out of the ordinary in terms of influential math-specific technology. This corroborates with the data of Table 4.6 since an instructors' comfort level with technology ranged from "Beginner" ($N = 4$), to "Average" ($N = 6$), to "Advanced" ($N = 2$).

Over time at MUN, there has been an attempt to integrate numerous technologies into the teaching of mathematics. These technologies have been discussed in detail in Chapter 1 Section 1.1.2. This section discusses the technologies which came about through the interview process: Derive, *WebAssign*, and Lecture Capture.

In the interview process, P3 discussed the integration of the computer algebra system *Derive* into the teaching of a special section of calculus at MUN for the sole purpose of improved student learning. P3 said that an alternate approach aided in student comprehension and increased student achievement. Similar findings were found in Weida (1996, p. 4), as well as an increase in student attendance/retention due to increased student comprehension. As for P1 and P2, they remarked that they would only integrate technology into their teaching practices when it makes sense to do so. For example, instructors would implement a new technological method for a specific topic if students have always had difficulties in this area through regular lecturing methods. P2 said,

> I think it would have to be tried and tested; and if the outcome ... you know, I mean, you could always have like a control room. If the outcomes from, say, of a lecture delivered the old-fashioned way compared to a lecture delivered by technology ... if the outcomes were the same, then, you know, it's okay; but I think it would have to be, you know, tried and tested before it is just accepted as the way to do it.

As part of a recent departmental initiative at MUN, a drill and practice online random problem generator, called *WebAssign*, was introduced into differential calculus classes. The system was implemented because most students may benefit from repetitive drills, and especially from early feedback on their performance (given the very cumulative nature of the course). Despite the departmental encouragement for this initiative, the system has negatively affected some students. For example, P2 commented,

> I'm afraid of students not getting as good a knowledge of mathematics from the use of technology because quite often it's multiple choice - just feeding in an answer; doing their rough work on scrap paper, and just feeding into the computer, for example, just the numbers, so they're not particular in how they develop their solutions, and it's their organizational skills that will be suffering there because they don't have to be particular as to how they develop it as long as they get it done and they get an answer that's logical, reasonable and feed it into the computer. I'm scared of that because I think that a lot is lost if a student doesn't know how to develop a solution to a problem nice and ... but, you know, one line should flow over into the next one clearly. I think that's lost if you're just doing multiple choice or fill in the blanks or just feed in a number. I think that's some skills, knowledge that are not acquired if they take that approach and they use that kind of technology.

WebAssign has also been considered a hassle by both the instructors, since it interferes with their teaching pedagogy, and especially the students who are not properly trained in how to use the technology. P2 also remarked that the introduction of *WebAssign* did not improve his/her overall class performance. It should be recognized that such online tutorials may affect students positively, as well as negatively (Radu & Seifert, 2010).

One interviewee used Lecture Capture, which recorded the class lectures. The lectures were then posted on D2L where the students could view them if necessary. When asked if P5 thought this would decrease class attendance he/she said,

> I don't know ... that probably answered your question back further, which means if a student misses a class or needs further information, they can go back up until the last day of their exams and review all my lectures, see the full lecture, so I think that at least gives a student who misses a class a possibility of reviewing a lecture; but what it means too is if they fall behind in notes, they can just get the page, or I'll tell them if it gets really complicated, "Listen, learn and go back on the screen. After, at your pace take down the notes."

In terms of how the interviewees were taught as students in relation to the amount of technology employed in their teaching, the instructors commented that very little technology, if any, was used when they were students. For the more experienced instructor, they would have been in their post-secondary pursuits beginning in the mid-to-late 1960s, thus their instructors would have been in a similar situation long before that with even less available technology. The beginning of the interviewees' teaching careers would have been approximately 5-10 years later. This was still a time when influential math-specific technology was scarce and what was available was extremely expensive. When many influential, affordable, math-specific technologies became available, these instructors had already found what worked best for them and had been applying their pedagogical techniques for many years, hence did not feel the need to integrate available technology to help aid their teaching. This implies that their past exposure to technology has not influenced the way they teach, which is very significant because in today's world technology is used on so many levels in everyday life.

The interviewees pointed out that different types of technology have different modes of applications in the teaching of mathematics. However, "it is clear that we do not yet know all the answers, nor have we realized all the potential" (Krantz, 1999, p. 27). P1 noted that,

> no I don't think that there's a way that works best with all technology, or for all courses for that matter. I think it is something that you have to look at on a case-by-case basis - sort of, "I want to use this piece of technology, you know, this particular topic or this particular course." Then you need to figure out what is the best way to do that, but that might be completely different on how you'd use another piece of technology in a

different course.

For example, as seen in Table J.4 9 out of 13 instructors "Practically Never" use PowerPoint in their teaching activities. P2, who observed several lectures delivered using PowerPoint said,

> I found that the presentation of the material was too fast. That certainly could be remedied. But the worst thing was that students didn't seem to like it and were leaving during the presentation. I didn't expect that and didn't know what to do. I was at the back of the lecture theatre and I didn't feel like interrupting the lecturer to stop them. I think they got lost very quickly and after 10 minutes they didn't know what was going on. I'm not sure that I would use it. I prefer writing the notes as I explain them and at the same time the students were engaged. They've told me that they liked that kind of presentation because they could often get ahead of me when working through solutions of examples. This gave them confidence in their ability to learn whatever it was that we were doing.

The researcher concludes that although there have been attempts in the Department of Mathematics and Statistics at MUN to integrate technology into teaching practices, only one, WebAssign, has been absorbed by the department; it however, has been looked upon negatively by some instructors. The author attributes this to the fact that this was the only instance of technological integration which could be labeled as a "departmental initiative", while all other attempts were individually based, and were unfortunately not adopted by other instructors.

4.3.1.3 The Fundamentals

Throughout the interview process many of the instructors commented on the necessity of knowing and understanding the fundamentals, the basic mathematical skills which every individual should possess and use in everyday life. Palmiter (1991) says, "possibly paper and pencil computations are necessary for understanding the ideas of calculus. If computer algebra systems replace pencil-and-paper computations, might they also remove essential elements from the learning of calculus?" (p. 151). Similar questions may be posed regarding the learning of mathematics in general. P4 observed that having basic computational and logical skills is essential in order for a student to have the ability to solve problems:

> students have no problem solving skills now coming from school in my experience. It's gone downhill every year since I've been teaching here, so I think that there has to be a balance between drill and practice and problem solving. You can't solve problems if you can't do basic computation skills or basic mathematics, and a lot of students have no idea of basic mathematics

> so sometimes it frustrates me and intrigues me that they have absolutely no problem solving skills or don't know how to approach it, but then I realize that they have no basic mathematical skills anyway, so you can't solve a problem if you don't have the skills to do it.

Students inability to do basic calculations is often attributed to the improper use of calculators in grade school. As Fey (2003) remarked,

> the worriers feared a further erosion of students' abilities to calculate with, and reason about, numbers and arithmetic; they warned of a growing population of high school graduates who, without their calculators, would not be able to read the newspaper, multiply a number by 10, or make change for a dollar. (p. 97)

One instructor (P6) pointed out that students having issues with basic pencil and paper mathematics will be further hindered by the addition of technology. Goos et al. (2007) stated that, "technology is a servant if used by teachers or students only as a fast, reliable replacement for pen and pencil calculations" (p. 91). But technology is more than that. Kondratieva and Radu (2009) observed that "the use of technology opens a whole new cluster of questions and problems along with new approaches available for students to solve creatively and to get involved in mathematical investigations" (p. 15). The question of whether technology should be introduced only after the students learn the fundamentals, or the fundamentals should be learned with appropriate technology and pedagogy, is an important issue in contemporary mathematics education. It is very complex and delicate and is beyond the discussion of this thesis. However, the researcher notes that the observed attitude of the instructors was that students need to learn the fundamentals before technology can be introduced into their learning. This is illustrated in Tables 4.3, 4.4, J.11, and J.12 which shows that the majority of instructors are highly unlikely to use technology for student learning.

4.3.1.4 Curriculum and Pedagogical Changes

All the interviewees stated that teaching mathematics with technology works in principle, and as a result, is slowly permeating into the curriculum. For example, technology can be beneficial for certain aspects of learning especially providing students with more immediate feedback. However, students need to be exposed to technology earlier so that any problems can be immediately identified in order to maximize student benefit. Therefore, the pros and cons of applying a specific technology in the teaching of mathematics needs to be considered. P1 commented how

> technology provides a more immediate way of providing feedback to students, however there are challenges accompanying that. There are psychological

> challenges. You're going to be doing mathematics online or, you know, on a computer of any sort ... and, actually, you're going to get to the point where you only need to be able to take in complex expressions, and that's something that's especially ... when your students have poor notational skills, it can be very challenging, and students have to be willing to use the technology in the manner that it was designed. So with technology there's a pretty big onus on the student to use it in an optimum manner. You know, in some ways it's very easy through apathy, through lack of effort, to take something that should be very beneficial and turn into, really, a hindrance, or at least an irritation.

Additionally, Thomas and Holton (2003) said "the use of technology could provide a wider range of experiences for students, including enactive ones, on which they can build a firmer basis for subsequent developments" (p. 386) in the post-secondary mathematics curriculum. Technology can also allow students to explore the behaviour of solutions and gain greater insight into certain ideas, as well as increase student motivation and allow for more insight in a shorter period of the time.

Three instructors (P1, P3, and P4) commented how the curriculum will not change, but adapt to technology. However, technology may have a greater influence in other disciplines as one of the many ways that may improve their teaching habits. P1 said,

> apart from introducing technology to complement the existing curriculum, the existing modes of evaluation, I don't think that's going to introduce any changes. I think any changes that we make to our curriculum will stem from good pedagogical practices, and that's really independent of technology.

Three instructors (P2, P5, and P8) thought the curriculum would change, but were unsure how, in what aspects, and to what degree. However, the instructors recognized ongoing changes in the use of technology in the teaching of mathematics at the post-secondary level. Compared to 10 years ago a drastic change can be noted in how material is presented in the classroom. P7 commented,

> I think there's a pendulum kind of behaviour at play, and I see this not just with technology but other kinds of teaching and pedagogical ideas. Let's teach Topic X this way, and that happens for three to five to 10 years, and then people decide, "Let's teach Topic X no longer this way; let's teach it that way," and that happens for three to five to 10 years, and then people ... they're, "Okay, let's now teach Topic X this way" - maybe not the original of this, but do this. I think it's swinging back and forth and here and there. It's still the same content, but how it gets taught, there's

> ... it's always adapting, but it's not adapting in the sense that it's always going in a direction as if ... "Okay, let's always introduce and integrate more and more technology," for example, because I've ... like right now we got a departmental policy that's about to come into play of no calculators in freshman math, whereas 10 years ago there were some of our sections where it was required that you had a calculator, okay, so there's the pendulum, right? Okay, come back in five to 10 years. Somebody five to 10 years from now will have objected and succeeded in repealing the no calculators allowed rule that's now coming into play.

It can be concluded that instructors believe that the content in the curriculum will not change due to technology, however the way the material is being presented in the classroom has already begun to change in the direction of using technology to better relate the material to the students to help improve learning. Schrurrer and Mitchell (1994) reported that "using the available technology to apply mathematics in a meaningful way requires a revision of the current curriculum as well as a modification of the method of delivery" (p. 1). Although opinions vary, P7 gives a relevant example specific to MUN. In Chapter 1 Section 1.1.2, it was discussed that in the late 1980s and early 1990s MUN had calculus classes based around the calculator (with calculators still allowed in other math classes); however, in 2011, the department removed calculators from these and other courses. Therefore, there does seem to be a pendulum effect in pedagogical approaches. However, there was a reason for that outside of pure pedagogy: calculators were recently removed from certain math courses at MUN for exam security. P1 commented,

> I think first of all what needs to be borne in mind is that the decision to remove calculators in the classroom was not a pedagogical decision. It was a question of exam security because these days there are an increasing number of calculators on the market which incorporate Smart Phone technology, and if as instructors we can't be assured that students - be it two students in the same exam room or a student inside the exam room and a student outside the exam room - aren't communicating, then that's a real problem, and then it becomes a huge question of fairness to the students who wouldn't engage in that type of activity. So that decision was made purely on the basis of the academic integrity of our tests and exams.

However, the calculator was viewed as a "crutch" for the students by many instructors (P1, P5, and P8). Thus six of the interviewees (P1, P2, P4, P5, P6, and P8) thought the removal of the calculator was a great idea, and the overall response (of the removal) from the students has been positive. P6 said,

> there's really not much reason to have a calculator in these courses. I mean,

> the calculations that people are doing are not that difficult; and if people are having trouble doing these certain basic arithmetic operations, then it's really something they ought to be practicing to improve because I think a certain facility with arithmetic is important in mathematics, right? You got to be able to sort of do these things, or at least develop an intuition for ... you know, if you multiply a 100 by, you know, 22 or, you know, 110 by 22, you should have a rough idea what that is, you know; and if you work it out by hand and it looks approximately right, you should be able to recognize that, you know. You shouldn't have to punch it into a calculator. So, I mean, I think it's positive. I think it's fine.

The most technologically savvy interviewee thought the removal of the calculator from these mathematics courses was "silly". P3 remarked,

> I mean, the kids, they all come in here with a Texas Instruments 83 or 84 you know, one of the graphic calculators, and so all of a sudden we don't let them use it. Geez, I mean, the person I feel sorry for is the Undergraduate Officer who has to answer the phone when a parent says, "I just spent a 130 bucks on this calculator for my kid and so and so won't let him use it in the class. What's going on?"

It may then be beneficial "that school teachers talk to tertiary educators in order to know what is actually needed 'after' grade school and, that since technology is "not used" in post-secondary classrooms, secondary teachers should cease using technology in their own classrooms" (Buteau et al., 2010, p. 65). Kondratieva and Radu (2009) as well commented on the importance of the consistent use of technology at the secondary and post-secondary levels, as specifically applied to MUN.

4.3.1.5 Barriers to Teaching With Technology

When teaching mathematics with technology, it is not uncommon to encounter barriers. The interviewees commented that some obstacles in teaching mathematics with technology can result from malfunctions of the technology, security issues, non-familiarity with the technology, misuse of the technology, and a more technologically savvy student body. P7 commented that there are current problems in classroom support that need to be addressed before more advancements can be implemented saying,

> what is the cost to the institution to ensure that instructors have it, are trained in its use, that it's properly integrated in the classroom infrastructure cost; to the students - do they have it? Do they have it as their individual purchase? Is it bundled into their tuition? There are issues of reliability. If it's more complicated than a graphing calculator; if it is ... everybody

> has to have a fancy computer; there's an operating system that does something spiffy, or if there's a special ... I don't know. Imagine a classroom with magic whiteboards all over the walls because that's the technological advancement, right? Where's the support staff to make sure it's all working? Who do you call when magic whiteboard #3 won't turn on? How does that affect your lecture when you plan to have it being on that day? There's issues like that. It's even more basic than that. We can't go to a classroom around this campus without bringing our own chalk. You want to talk about technological innovation. A piece of chalk is better than writing in the sand. That is technology, and it fails when there's no chalk brush in the room, which happens on a regular basis around here. Also something that fails on a regular basis around here is having no batteries or no working batteries in the microphone system, and who do you call when it fails?

Hence, the idea of integrating more influential math-specific technology into teaching activities is something which P7 suggested will require a lot of work. If current practices are not working to their full potential, instructors cannot expect to have further advancements without encountering problems. Pundak et al. (2009) commented that studies conducted at two American universities showed "that students' learning by team work in small groups during the lessons is much more valuable and fruitful than learning in traditional lectures halls" (p. 218). Although this could be feasible, and a change from normal lecture proceedings, due to classroom restrictions and the size of many mathematics classes at MUN this is near impossible.

Another issue related to the implementation of technology is that it decreases the personal side to teaching. P4 noted that

> if you don't have that personal appeal to be able to stand there and help students sort of strategize and show them, you know, little sort of nuances about the mathematics and little sort of ways of going about different approaches, and mathematics is not just done one way. There's many ways of doing mathematics. So if I'm there and the student is not getting it, I can say, "Well, what about this; what about that," and technology is still ... even though it's getting pretty interactive now, right - you know, phones talk to you. Maybe if they can get a computer program that can think and strategize and ... might be helpful, but I don't know. I still think that personal touch is there with the experienced instructor.

4.3.1.6 Summary

In conclusion, the major themes that emerged from the interview data were: first, instructors believe that there has not been significant change in the teaching and learning of mathematics during their teaching careers especially in relation to the current level of available technology; even though some instructors have seen more technology now being used in math pedagogy. Second, instructors said that the choice and implementation of technology depends on the course and topic, and needs to be considered on an individual basis. Of the three forms of technology discussed, Derive and Lecture Capture have been regarded as influential. Third, according to the participants, fundamental knowledge for the learning of mathematics is key in order to be successful in mathematics, and should be learned before the implementation of technology can begin. Fourth, most participants think that the mathematics curriculum will change but not because of technology. Technology will only affect the methods of delivery of some topics, and this has already begun to happen. Fifth, there are current barriers that instructors encounter with existing technology and basic classroom support, and the implementation of more influential math-specific technologies to teaching may cause an additional hinderance.

4.3.2 Quantitative Results

To further elaborate the findings stated earlier, results from the collected quantitative data are presented. The first section of the questionnaire addressed instructors' professional views on technology. The section consisted of thirty questions, 11 of which were negatively worded, and 19 positively worded. The questions in this section were separated into three categories: value (items assess the degree to which instructors perceived the innovation or its associated outcomes as worthwhile; 14 questions), cost (items assess the perceived physical and psychological demands of implementation operating as a disincentive to applying the innovation; 9 questions), and expectancy (items probe instructor perceptions of the contingency between their use of the strategy and the desired outcomes; 7 questions). The Likert type scale used for these questions was "Strongly Disagree (1)" to "Strongly Agree (6)".

4.3.2.1 Value Category

The Value questions had a Cronbach's alpha of 0.961. Generally, instructors disagreed with 10 out of the 14 value statements (overall Mean = 3.312, SD = 1.6109). The data is displayed in Table 4.10, where $N = 11$.[1] The individual questions and their accompanying tables can be found in Appendix K.

[1] Since two of the participants did not answer all the questions in this category results were based on only a sample size of 11 even though all interviewees may have answered a specific question(s).

Table 4.10: Value statements

Question	Mean	SD	Agree	Disagree	N
Q1	3.3636	1.62928	6	7	11
RQ2	3.0909	1.51357	8	5	11
Q4	3.0909	1.57826	6	7	11
Q6	2.7273	1.55505	4	9	11
Q7	4.0909	1.92117	10	3	11
Q9	2.5455	1.50756	4	9	11
Q11	3.2727	1.42063	6	7	11
Q14	3.4545	1.91644	9	4	11
RQ15	3.8182	1.72152	4	8	11
Q16	3.5455	1.29334	11	2	11
Q19	3.5455	1.57249	7	5	11
Q20	3.3636	1.43337	8	4	11
Q24	3.0909	1.57826	6	6	11
Q30	3.3636	1.91169	7	6	11

The majority of instructors (10 out of 13) agreed that the use of technology is a valuable instructional tool (Q7). This is the highest agreement among questions presented in Table 4.10. This result corroborates the interview data revealing that all instructors use basic technology in their teaching practices. At the same time, most of the instructors (9 out of 13) do not think that the use of technology promotes the development of communication skills (Q6). This result requires further clarification which is beyond the scope of this thesis. Perhaps, instructors are specifically considering WebAssign, where only a numerical answer is required with no communication of the step-by-step solution. However, existence of technologies such as e-mail and iphones, for example, specifically designed for the communication purpose makes this negative opinion surprising for the researcher since these technologies are now in widespread use.

As well, most instructors (9 out of 13) disagreed that technology makes them more competent as educators (Q9). This result can be linked to the fact that many instructors admitted having insufficient professional development regarding the use of technology in teaching, as well as the fact that technology in not always reliable and may fail during a lecture.

4.3.2.2 Expectancy Category

The Expectancy questions had a Cronbach's alpha of 0.736. One question was removed from this category as the researcher later deemed the question unnecessary, which in turn increased the internal consistency of the questions. Generally, the instructors agreed with 4 out of the 6 expectancy statements (overall Mean = 3.423, SD = 1.5015). The data is displayed in Table 4.11. The individual questions and their accompanying tables can be found in Appendix K.

Table 4.11: Expectancy statements

Question	Mean	SD	Agree	Disagree	N
Q3	3.77	1.589	9	4	13
Q10	3.92	1.441	10	3	13
Q12	4.31	1.974	9	4	13
Q18	4.15	1.463	10	3	13
Q26	2.38	1.387	3	10	13
Q28	2.00	1.155	1	12	13

The majority of instructors (9 out of 13) agreed that the use of technology is only successful if technical staff regularly maintains the technology (Q12); also the majority of instructors (10 out of 13) agreed that the use of technology is effective if instructors participate in the selection of the technologies being integrated (Q18). These questions had the highest correlation within the questions presented in Table 4.11. This result corroborates the interview data revealing that several interviewees were concerned that with the implementation of new influential math-specific technology on a large scale, there would be a need for more extensive technical support. The obvious question that rises from this is: how easily will instructors have access to this new support? According to the interviews (see quote 1 in Section 4.3.1.5), there is currently inadequate classroom support. In addition, instructors need to be informed of what types of influential technologies exist in order for them to choose which of these they believe can be of the most benefit to their students. At the same time, most of the instructors (10 out of 13) do not think that the use of technology is only effective when extensive technological resources are available (Q26). This result corroborates the interview data revealing that the technologies that students are currently exposed to are benefiting the students. Also, instructors (12 out of 13) do not think that the use of technology is only successful if the technology is part of the students' home environment (Q28). This result substantiates the interview data since P7 commented that students will often adapt to the situations they are put in.

As well, most instructors (10 out of 13) agreed that technology is successful only if there is adequate instructor training in the uses of technology for learning (Q10). This result can again be linked to the fact that many instructors admitted insufficient professional development regarding the use of technology in teaching.

4.3.2.3 Cost Category

The Cost questions had a Cronbach's alpha of 0.739. Two questions were removed from this category as the researcher deemed the questions unnecessary, which in turn increased the internal consistency of the questions. Generally, the instructors disagreed with 6 of the 7 cost statements (overall Mean = 3.055, SD = 1.390). The data is displayed in Table 4.12. The individual questions and their accompanying tables can be found in Appendix K.

Table 4.12: Cost statements

Question	Mean	SD	Agree	Disagree	N
Q8	3.15	1.463	6	7	13
Q13	3.00	1.291	6	7	13
Q21	2.46	1.506	4	9	13
Q22	2.69	1.437	5	8	13
Q23	2.85	1.405	6	7	13
Q25	2.92	1.188	4	9	13
Q29	4.31	1.437	10	3	13

The majority of instructors (10 out of 13) agreed that the use of technology requires extra time to plan learning activities (Q29). This is the highest agreement among questions presented in Table 4.12. This result corroborates the interview data revealing that the demand technology requires of an instructors' time is a reason why more instructors are not using more influential math-specific technology in their teaching activities. As was mentioned earlier, instructors were using many technologies in their research, but were not implementing them in their teaching practices because they were not suitable to teach the course material. At the same time, about one half of the instructors (7 out of 13) do not think that the use of technology demands that too much time be spent on technical problems (Q13) and technology requires software-skills training that is too time consuming (Q23). This result corroborates the interview data as already presented in this section.

As well, most instructors (8 out of 13) agreed that technology limits their choices of instructional materials (Q22). This result can be linked to the fact that since instructors are not aware of available technology, it is plausible that they present materials using one type of technology, even when a second piece of technology can be used to present the same material with more of an impact on student learning.

4.3.3 Summary

Part one of this section discussed the qualitative results in relation to instructors' opinions of teaching mathematics with technology. The themes which emerged were (1) how teaching and learning have changed over time; (2) integrating technology; (3) the importance of the fundamentals; (4) curriculum and pedagogical changes; and (5) barriers faced when trying to integrate technology. Part two of this section considered instructors' opinions in regards to the value, cost, and expectancy of technology use in the teaching of mathematics. The quantitative data confirm that on one hand instructors seem to be struggling between seeing the values and benefits that technology may offer in teaching, and on the other hand the realization of related costs such as the amount of time, effort, specialists support, and pedagogical knowledge required to the successfulness of its implementation.

Chapter 5

Conclusions

The research intent was to better understand the various attitudes of post-secondary mathematics instructors in Newfoundland and Labrador towards the teaching and learning of mathematics using general purpose and influential math-specific technology. How frequently and what types of technologies are being used by instructors in their teaching of mathematics? What are mathematics instructors' teaching experiences, professional development experiences, familiarity with pedagogical literature on the use of technology, and accessibility to technology and support? What are instructors' opinions of teaching mathematics with technology in relation to students' needs? To address these research questions, the author collected data from a questionnaire and face-to-face, one-on-one interviews.

To best find the answers to the research questions, the author conducted a mixed methods study. Phase One of this study involved the collection of the quantitative data. This task was completed through the use of a single questionnaire administered to 13 participants. Phase Two of this study involved the collection of the qualitative data. This task was completed through one-on-one interviews with eight of the 13 participants from Phase One of this study.

This chapter is separated into three sections. The first section discusses a synopsis of the main findings of the research. Section two addresses the limitations of this research study. Section three looks at the future of similar research and discusses recommendations for departments if they wish their instructors to benefit from employment of more influential math-specific technology in their teaching. It should be noted that a paper based on this research has been written: Jesso and Kondratieva (unpublished), on the use of technology in undergraduate post-secondary mathematics teaching.

5.1 Synopsis of the Study

The qualitative results obtained from the interviews of eight people included instructors' opinions of teaching mathematics with technology. The themes which emerged were (1) how teaching has changed over time due to the increasing capability and availability of technology for students' and instructors' use in practice; (2) how does the presence of technology influence mathematics curriculum and pedagogy in principle; (3) what are various purposes, advantages, and challenges faced during the process of incorporation of technology in teaching; and (4) what is the relationship between students' use of technology and students' knowledge of the fundamentals of mathematics. The quantitative results considered instructors' opinions in regards to the value, cost, and expectancy of technology use in the teaching of mathematics. This section summarizes the key points that emerged from the collected data.

It was found that the majority of instructors regularly use technology for organizational and communication purposes. The use of influential math-specific technology such as CAS for instructional, exploratory, and creative activities with students takes place mostly on an individual basis, only occasionally, and seems to be topic specific.

Many factors may influence an instructor's use of technology in the teaching of mathematics. First, different instructors may have various levels of familiarity and experience with technology outside of teaching, possessing different teaching philosophies and approaches. Second, the usefulness of technologies may only apply in certain topics, which are inapplicable in other courses. Third, due to the rapid development of technology, instructors may not always know what is available to them and in which way the technology can be implemented into their courses.

However, how does one motivate an instructor to use technology in the teaching of mathematics? If instructors know that certain mathematical topics presented using current techniques are ineffective to student learning, then instructors should look for a more beneficial pedagogical approach. If an instructor is familiar with a technological tool, that in their view may help students in a challenging situation, then they may consider employing it. In general, an instructor would need to teach the same course several times before he/she could determine if their pedagogical practices are being effective and whether or not the implementation of a new technique with or without technology is necessary.

Although instructors may be aware of the benefits of student learning with technology, they are also aware of possible disadvantages. For example, low engagement during Power Point lectures, inability to organize their solutions when learning from solving multiple choice problems generated by the tutoring system WebAssign, developing dependency on the tool when working with graphing calculators, or due to poor arithmetic skills and understanding of fundamentals, the failure of learning of higher mathematics using CAS. An instructors' reluctance of technological employment could also be attributed to the (1) requirement for extra planning time; (2) potential failure of technology; (3) lack of consistency in using technology at the departmental level; and (4) instructors' belief in the dominancy of the human element in learning. The quantitative data revealed that on one hand instructors seem to be struggling between seeing the values and benefits that technology may offer in teaching, and on the other hand the realization of related costs such as the amount of time, effort, specialists support, and pedagogical knowledge required to the successfulness of its implementation.

The findings of this research add some details which resemble the situation outlined in the literature with the use of technology in the teaching and learning of mathematics. However, the question remains: What could be done in order to increase the use of technology by instructors for a variety of instructional purposes enhancing students' learning of mathematics? In view of the expectancy-value theory discussed in Wozney et al. (2006), in order for the current situation to be successful, instructors' expectations of success should be stronger than their concerns associated with technological implementation. But how can this situation be achieved?

One possible solution gained through this research is to extend instructors' pedagogical knowledge by way of proper instructional development and familiarity with pedagogical publications. This could possibly enhance instructors' views on teaching mathematics with technology and address any issues raised by the instructors during the interviews. However, participants of this research felt that mathematics instructors need training specific to mathematics teaching. A general presentation given by either a teaching specialist speaking about constructivist approaches in learning or a software developer explaining the advantages of their educational products would probably have some effect in terms of changing instructional beliefs. However, the presentation of these ideas by an expert possessing the related expertise in teaching mathematics courses may be of a greater benefit in terms of changing the attitudes of instructors towards teaching mathematics with more influential math-specific technology.

This research found that instructors have at least some knowledge and experience with teaching mathematics with technology. For example, they possess (1) certain technological skills used in their research; (2) individual classroom experiences successful or otherwise; and (3) some teaching ideas, philosophies, observations, as well as questions generated by their practices. However, the instructors who participated in this study do not currently have a forum where they could share such knowledge, successes, and concerns. Such a forum could allow for the discussion and support of each other's initiatives, the opportunity to invite external speakers and experts from other universities, learn about new technological approaches, and develop teaching resources. Weathers and Latterell (2003) argue that if nothing else,

> a forum of collaboration reminds instructors of the value of thoughtful, persistent communication about issues we face in the classroom. Beyond serving

> as a type of support group, it helps us focus on pervasive issues and provides us with a better basis for deciding what issues need to be addressed. (p. 359)

Analysis of interview data suggests that introducing such fora in mathematics departments in the form of face-to-face regular meetings or seminars supplemented by on-line postings will bring instructors to more informed choices of technologies that assist their teaching. Kondratieva and Radu (2009) observed that when implementing new technology in teaching "it is essential for success to have a core group of instructors dedicated to working with" this technology (p. 10). The forum may lead to the emergence of such groups and become a means of their productive function. In addition, given the importance of collegial support and departmental initiatives, for individual instructors to proceed with technological innovations such regular seminars may play a critical role in changing instructors' attitudes towards using technology in the teaching of mathematics.

5.2 Limitations of the Study

The sample size of $N = 13$ for Phase One and $N = 8$ for Phase Two maybe considered a limitation in this study. However, as previously mentioned, the researcher believed that the saturation point was reached after the eight interviews. That is, enough data had been collected in order to support the data from Phase One of the study. The research is limited in generalizability either because post-secondary institutions may currently be at a different level of technology use, class sizes may be smaller/larger, or the type of post-secondary institution might affect the funding of such an institution.

It should be noted that this study may have primarily attracted instructors with strong opinions on teaching mathematics with influential math-specific technology. Also, the researcher's previous relationships with the interviewees (either as a former instructor of the researcher or a current colleague) may have influenced the participation of some participants, or their responses based on their knowledge of the researcher's opinions on the subject at hand. In addition, the use of self-reported measures of technology use, proficiency levels, and stages of integration could have affected the reliability of the analysis.

5.3 Recommendations and Future Work

One major motivation of writing this thesis was a concern about insufficiently high student achievement in the first and second year undergraduate mathematics courses and a hypothetical possibility to address this concern by the employment of more technology helping students to better learn the material. Instructors' views on such a possibility to implement technology in their teaching were collected and analyzed. The following ideas and recommendations for improving the situation with students' low achievements emerged throughout this analysis.

First, due to the vast amount of technology permeating peoples' daily lives Valdez (2005) says "educators must prepare for a technology-rich future and keep up with change by adopting effective strategies that infuse lessons with appropriate technologies" (p. 1). This is why in order for instructors to change their pedagogical practices and employ more influential math-specific technology for improving students' learning, instructors need to receive proper (i.e., mathematics teaching specific) professional development in a timely fashion.

Second, during the interviews, some participants mentioned that they offered their respective departments several recommendations both general and specific in nature, but were seemed to be "ignored" (possibly due to the nature of their position). This situation needs to be changed. Instead, it would be beneficial for the departments to solicit more recommendations from experienced instructors for courses' directions and to invite relevant workshops or presentations for the enhancement of teaching practices. In particular, successful experiences of using technology in teaching mathematics should be collected and shared with other instructors teaching the same courses.

Third, instructors teaching a course for the first time may benefit from having course materials that meet the standards of the respective department. Serving as a guideline, these materials would allow new instructors to understand the level of difficulty of examples, what material should be covered, and what kind of technology could be incorporated in the course in order to enrich students' experiences.

Fourth, both the literature review and the interview data suggest that administrative support and leadership are essential for creating the atmosphere where teaching gains more importance and where experiments with incorporation of appropriate technological tools in teaching are encouraged and inspired.

These are possible avenues of furthering this research. For example, the fact that most of the interviewees do not think that "the use of technology promotes the development of communication skills" requires further clarification. Other important questions are: How do departments and instructors themselves become empowered in order to take advantage of available technology? What is required in order for technology to be integrated into the curriculum and not just simply added on? What kinds of new advantages and challenges will the integration of technology in the teaching of mathematics give to instructors and administrators? Searching for answers to these and similar questions is unavoidable for the success of the process of technological assistance in mathematical learning. It is hoped that this thesis has made a contribution in advancing human knowledge and understanding in this direction.

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Appendix A

Request for Permission to Conduct Research

Andrew Jesso, B.Sc (Honours), M.Sc
M.Ed Candidate
Faculty of Education
Memorial University of Newfoundland
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January 15, 2012

Dr. Edgar Goodaire
Interim Head of Department
Department of Mathematics and Statistics
Memorial University of Newfoundland
St. John's, NL
A1C 5S7

Dear Dr. Goodaire,

I am currently completing my Master's of Education (Post-Secondary Studies) from Memorial University (MUN), and I am proceeding to conduct research on my thesis.

In my capacity as a graduate student, I wish to invite the Department of Mathematics and Statistics to participate in my study entitled: *Instructors' Attitudes Toward the Use of Technology in the Teaching and Learning of Mathematics in Newfoundland and Labrador Post-Secondary Institutions: A Mixed Methods Study.*

The purpose of this study is to determine and describe mathematics instructors' attitudes toward the teaching and learning of mathematics with technology. To carry out this study, I will need to interview between eight and ten mathematics instructors, inclusive, for approximately one and a half hours, those of whom are selected randomly from post-secondary institutions across Newfoundland and Labrador. I will also administer a questionnaire to all interested instructors. The completed questionnaire will be expected to be returned within three (3) weeks of receipt. These data will richly add to this research study and will be held in the strictest of confidence within the guidelines of MUN.

In this report, the names of the participants will be referred to by pseudonyms. In addition, instructors will not be identified by any affiliation other than mathematics instructors.

A transcribers and I will transcribe the interviews and analyze the data collected by the questionnaire. We will comply with the TCPS guidelines for ethical research. The raw data, in the form of the recorded interviews and the corresponding transcribed documents, will not be heard or seen by other participants or anyone except the researcher, transcriber, and my academic supervisors, each of whom will adhere to the ethical guidelines outlined in this document. The same will apply to the data collected from the questionnaire. The data file for this research will be stored in a secure location.

Participation in this study is voluntary, and a participant is free to withdraw at any time. The proposal for this research has been received by the Interdisciplinary Committee on Ethics in Human Research and found to be in compliance with Memorial University's Ethics Policy. If participants have ethical concerns about the research (such as the way they have been treated or their rights as participants), they may contact the Chairperson of the ICEHR at icehr@mun.ca or by telephone at (709)-864-2861.

Should you wish further information on this study, do not hesitate to contact me or my thesis supervisors:

Dr. Margo Kondratieva
Faculty of Education and Department of Mathematics and Statistics
Telephone: (709)-864-8074
e-mail: mkondra@mun.ca

Dr. Dale Kirby
Faculty of Education
Telephone: (709)-864-7623
e-mail: dkirby@mun.ca

Please find enclosed:

1. Participant Consent and Disclosure Form; and
2. Interdisciplinary Committee on Ethics in Human Research Approval.

Thank you very much for your attention and consideration of this research project.

Sincerely,

Andrew Jesso, B.Sc (Honours), M.Sc
e-mail: andrewj@mun.ca

Appendix B

Consent Form

Researcher

Andrew Jesso, B.Sc (Honours), M.Sc, M.Ed (Post-Secondary) Candidate
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Dr. Dale Kirby
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You are invited to take part in a research project entitle "*Instructors' Attitudes Toward the Use of Technology in the Teaching and Learning of Mathematics in Newfoundland and Labrador Post-Secondary Institutions: A Mixed Methods Study.*"

This form is part of the process of informed consent. It should give you the basic idea of what the research is about and what your participation will involve. If you would like more details about something mentioned here, or information not included here, you should feel free to ask. Please take the time to read this document carefully and to understand any other information given to you by the researcher.

It is entirely up to you to decide whether to take part in this research study. If you choose to take part in this research study or if you decide to withdraw from the research once it has started, there will be no negative consequences for you now or in the future. Participation is independent of your employment and a decision not to participate or to withdraw from the study will in no way affect your employment.

What you will do in this study

This study will involve, on your part, one interview, at a time and place to be mutually agreed upon, and the completion of one questionnaire, to be completed and returned to the researcher within three (3) weeks of receipt. The interview, approximately one-to-two hours in duration, will deal with your experiences as a mathematics instructor. The interview will be tape-recorded and later transcribed by a third party, with all items being stored in a secure location. The questionnaire will also be analyzed by a third party, with all items being stored in a secure location. I will use both data types as part of my thesis submission.

Possible Benefits

While there are no immediate benefits, participation in this study may provide the opportunity for the participants to personally reflect on areas of practice and promote constructive professional dialogue. It is the hope of the researcher that Newfoundland and Labrador post-secondary mathematics departments will consider implementing some forms of influential math-specific technology in their classroom instruction in the future.

Possible Risks

I am unaware of any risks that you will personally experience as a result of this study.

Confidentiality and Anonymity

Only I, Andrew Jesso, the transcribers, and my supervisors will have access to the tape-recording and transcription of both your interview and questionnaire. Your name, however, will only be known to me. In other words, I, Andrew Jesso, will be the only person who knows you to be a participant. The signing of this consent form gives your permission to be included as part of this mixed methods study.

Recording of Data

The study will involve the participant to be tape-recorded. The participant agrees to be tape-recorded.

____

Participant's Signature

Reporting of Results

This interview and questionnaire will be used as part of my thesis submission. In my report, when using any participant's quotations, whether direct or summarized, the participants will be referred to by pseudonyms.

Questions

You are welcome to ask questions at any time during your participation in this research study. If you would like more information about this study, please contact the researcher, the research supervisors, the chairperson of the ICEHR or The Faculty of Education (Graduate Programs) at (709)-864-3402.

Consent

The proposal for this research has been reviewed by the Interdisciplinary Committee on Ethics in Human Research and found to be in compliance with Memorial University's ethics policy. If you have ethical concerns about the research (such as the way you have been treated or your rights as a participant), you may contact the Chairperson of the ICEHR at icehr@mun.ca or by telephone at (709)-864-2861.

Your signature on this form means that:

- You have been able to ask questions about this study.
- You are satisfied with the answers to all of your questions.
- You understand what the study is about and what you will be doing.
- You understand that you are free to withdraw from the study at any time, without having to give reason, and that doing so will not affect you now or in the future.

If you sign this form, you do not give up your legal rights, and do not release the researchers from their professional responsibilities.

The researcher will give you a copy of this form for your records.

Your Signature

I have read and understood the description provided. I have had an opportunity to ask questions and my questions have been answered. I consent to participate in the research project, understanding that I may withdraw my consent at any time. A copy of this Consent Form has been given to me for my records.

________________________ ________________________

Signature of Participant Date

Researcher's Signature

I have explained this study to the best of my ability. I have invited questions and given answers. I believe that the participant fully understands what is involved in being part of the study, any potential risks of the study, and that he/she has freely chosen to be in the study.

________________________ ________________________

Signature of Researcher Date

Appendix C

Confidentiality Form

Privacy and Confidentiality Agreement

Electronic files associated with this research project will not contain personal, identifiable information of the participants.

Since research assistants will be involved with the organization of data to create the working dataset, they will have access to participant surveys and data files marked with pseudonyms. Research assistants will be informed of, and expected to adhere to, the ethical obligations of confidentiality if they come in contact with any personal information of the participants. To ensure confidentiality of individual records and to protect the individuals who have provided this data, members of the research team who have access to the data will sign a pledge of confidentiality.

Having read and understood the above statement regarding protection of privacy and confidentiality, I, the undersigned, agree to use my best efforts to protect the privacy and confidentiality of this research projects participant questionnaires and data files, and to prevent this confidential information from falling into the public domain or into the possession of unauthorized persons.

Name:____________________ Signature: ____________________

Witness: ____________________ Signature: ____________________

Date: ____________________

Appendix D

Advertisement

Andrew Jesso an M.Ed Candidate in the Faculty of Education at Memorial University is conducting a research study on the use of technology by post-secondary mathematics instructors in Newfoundland and Labrador. All members of the Department of Mathematics and Statistics at Memorial University are cordially invited to participate in this research study whether or not they are currently using technology in their teaching.

The purpose of the study is to determine and describe instructors' needs, attitudes toward the teaching and learning of mathematics with technology. According to the study's design, as many instructors as possible will be invited to respond to a questionnaire that will take a maximum of one hour to complete. In addition, between eight and ten (inclusive) post-secondary mathematics instructors will be randomly selected and interviewed for approximately 1-2 hours. Instructors are invited to participate in one or both portions of this study. These data will richly add to the research study and will be held in the strictest of confidence within the guidelines of Memorial University. In the research report, the names of the participants will be referred to by pseudonyms. As well, instructors will only be identified as mathematics instructors.

If you are interested in participating or not, please contact Andrew Jesso with a response. Thank you.

Andrew Jesso, B.Sc (Honours), M.Sc, M.Ed (Post-Secondary Studies) Candidate
e-mail: andrewj@mun.ca

Appendix E

Questionnaire

Instructions

This questionnaire has four (4) sections and consists of six (6) printed pages. Please record **ALL** of your responses by placing the appropriate letter after each question. After you have completed your responses, please return the answered questionnaire to the researcher in the envelope provided.

Your Professional Views on Technology

Using the scale provided, please rate the extent to which you agree or disagree with the following statements regarding the use of technology in the teaching of mathematics.

Strongly Disagree	Moderately Disagree	Slightly Disagree	Slightly Agree	Moderately Agree	Strongly Agree
A	B	C	D	E	F

The use of technology in the teaching of mathematics ...

1. Increases academic achievement (e.g., grades).
2. Results in students neglecting important traditional learning resources (e.g., library books).
3. Is effective because I believe I can implement it successfully.
4. Promotes student collaboration.
5. Makes classroom management more difficult.

6. Promotes the development of communication skills (e.g., writing and presentation skills).
7. Is a valuable instructional tool.
8. Is too costly in terms of resources, time, and effort.
9. Makes instructors feel more competent as educators.
10. Is successful only if there is adequate instructor training in the uses of technology for learning.
11. Gives instructors the opportunity to be learning facilitators instead of information providers.
12. Is successful only if technical staff regularly maintains the technology.
13. Demands that too much time be spent on technical problems.
14. Is an effective tool for students of all abilities.
15. Is unnecessary because students will learn technological skills on their own, outside of school.
16. Enhances my professional development.
17. Eases the pressure on me as an instructor.
18. Is effective if instructors participate in the selection of the technologies to be integrated.
19. Helps accommodate students' personal learning styles.
20. Motivates students to get more involved in learning activities.
21. Could reduce the number of instructors employed in the future.
22. Limits my choices of instructional materials.
23. Requires software-skills training that is too time consuming.
24. Promotes the development of students' interpersonal skills (e.g., ability to relate or work with others).
25. Will increase the amount of stress and anxiety students experience.

26. Is effective only when extensive technological resources are available.
27. Is difficult because some students know more about technology than many instructors do.
28. Is only successful if the technology is part of the students home environment.
29. Requires extra time to plan learning activities.
30. Improves student learning of critical concepts and ideas.

Your Background, Teaching Style and Resources Available to You

31. How many years of teaching experience have you completed? (Including both in the K-12 school system and in post-secondary institutions).
    (a) 0. This is my first year teaching.
    (b) 1-10 years
    (c) 11-20 years
    (d) 21-30 years
    (e) 31-40 years
    (f) 41-50 years
    (g) Over 50 years
32. What is your preferred teaching methodology (choose only one)?
    (a) Largely teacher-directed (e.g., teacher-led discussion, lecture)
    (b) More teacher-directed than student-centred
    (c) Even balance between teacher-directed and student-centred activities
    (d) More student-centred than teacher-directed
    (e) Largely student-centred (e.g., cooperative learning, discovery learning)

33. What is your average class size?

    (a) less than 50 students
    (b) between 50-100 students inclusive
    (c) between 101-200 students inclusive
    (d) between 201-250 students inclusive
    (e) between 251-300 students inclusive
    (f) more than 300 students

Your Experience with Technology

34. Please indicate how often you integrate technology in your teaching activities.

    (a) Not at all
    (b) Rarely
    (c) Occasionally
    (d) Frequently
    (e) Almost Always
    (f) All the time

35. On average, how many hours per week do you spend using technology for personal use outside of teaching activities?

    (a) None
    (b) Less than 2 hours
    (c) 2 hour or more, but less than 4 hours
    (d) 4 hours or more, but less than 6 hours
    (e) 6 hours or more, but less than 8 hours
    (f) 8 hours or more, but less than 10 hours
    (g) 10 hours or more

36. Please read the following descriptions of the proficiency levels a user has in relation to technology. Determine the level that best describes you.

(a) Unfamiliar: I have no experience with influential math-specific technology.

(b) Newcomer: I have attempted to use influential math-specific technology, but I still require help on a regular basis.

(c) Beginner: I am able to perform basic functions in a limited number of technological applications.

(d) Average: I demonstrate a general competency in a number of technological applications.

(e) Advanced: I have acquired the ability to competently use a broad spectrum of influential math-specific technologies.

(f) Expert: I am extremely proficient in using a wide variety of influential math-specific technologies.

Your Process of Integration

For Items 37 to 62, please indicate how frequently you use technology for each of the activities listed below.

Never	Practically Never	Once in a While	Fairly Often	Very Often	Almost Always
A	B	C	D	E	F

Instructional

37. Use tutorials for self-training.
38. Have students use tutorials for remediation (in class).

Communicative

39. Use e-mail to communicate with other instructors.
40. Use e-mail to communicate with students.
41. Use LCD projector (a projector connected to a computer) in class.
42. Create PowerPoint presentations to use in class.

Organizational

43. Keep track of student grades or marks.

44. Prepare handouts, tests/quizzes, and homework assignments for students.

45. Create lesson plans.

Analytical/Programming

46. Create charts or graphs.

47. Create a class/school website or put student work on-line.

48. Analyze data.

49. Statistics or data analysis.

Recreational

50. Have students play games (in class).

51. Use time with technology as a reward for completing class work or good behaviour.

Expansive

52. Have students conduct experiments or laboratory exercises (in class/school lab).

53. Have students use 3-D modeling software or simulations (in class/school lab).

Creative

54. Use drawing or paint programs.

55. Scan pictures or images.

56. Use digital video, digital cameras.

Expressive

57. Use a word processor.

58. Maintain an on-line journal (diary) or discussion board.

Evaluative

59. Test or assess student learning.

60. Use digital portfolios.

Informative

61. Search the Internet for information for a lesson.

62. Access CD-ROM reference material.

63. Total amount of training you have received to date on using technology in teaching:
    (a) None
    (b) A full day or less
    (c) More than a full day and less than a one-semester course
    (d) A one-semester course
    (e) More than a one-semester course

64. Please read the descriptions of each of the six stages related to the process of integrating technology in teaching activities. Choose the stage that best describes where you are in the process.
    (a) Awareness: I am aware that technology exists, but have not used it - perhaps I'm even avoiding it. I am anxious about the prospect of using technology.
    (b) Learning: I am currently trying to learn the basics. I am sometimes frustrated using technology and I lack confidence when using it.
    (c) Understanding: I am beginning to understand the process of using technology and can think of specific tasks in which it might be useful.
    (d) Familiarity: I am gaining a sense of self-confidence in using technology for specific tasks. I am starting to feel comfortable using technology.
    (e) Adaptation: I think about technology as an instructional tool to help me and I am no longer concerned about it as technology. I can use many different technological applications.
    (f) Creative Application: I can apply what I know about technology in the classroom. I am able to use it as an instructional aid and have integrated technologies into the curriculum.

Appendix F

Interview Protocols

Background

1. How long have you been teaching at the post-secondary level?
2. In your opinion, in general, how do you believe learning and teaching have changed during this time?
3. Has your own experience as a student influenced the way you teach mathematics?
4. What course levels do you presently teach?

Classroom Management

1. Tell me about your style of teaching and how you conduct a typical class? What do you do to accommodate individual learning styles? What do you do about students falling behind or expressing low interest to the course?
2. What do you feel leads to the success of your students? Do you feel students have more long-term retention of skills using the problem solving technique versus drill and practice?
3. Do you find it difficult to complete the current course content in the courses you teach?

Technological Instruction

1. Do you think technological instruction works in the mathematics classroom? Why?

2. At any point during your teaching career have you used technology in the teaching of mathematics? Why or why not?

3. What obstacles would you perceive in offering technological instruction?

4. How do you feel instructors have modified their practice in terms of technological instruction? What about the department?

5. To what extent are you familiar with the literature that describes the benefits of teaching mathematics with technology?

6. What are your thoughts on the recent removal of calculators from first-year math courses at Memorial?

7. If lessons using methods of instruction using technology were available and already planned, would you attempt to test their usefulness?

8. Do you think that first-time instructors (graduate students, post-docs, etc.) would benefit from already prepared course materials (notes, tests, etc.) which have lessons requiring technological instruction?

9. If you taught smaller classes, would you consider integrating technology?

10. Do you believe there is an ideal way to integrate technology into the teaching of mathematics? If so, what is it?

Instructor Support

1. Do you receive enough assistance from your department in teaching according to a new approach? For example, for the purposes of this project a technological based approach? What can be done to improve this situation?

2. Do you have adequate access to relevant resources?

3. Do you provide students with any supplemental materials if they enquire? Why or why not?

4. Are you familiar with any useful resources that you feel other instructors may not be aware of? Why is using these resources significant?

5. What professional development improvements, in terms of teaching, would you support? Would you take advantage of such opportunities? Do you need more focus on technology specifically for mathematics?

6. What types of technologies are you currently/willing to use in the teaching of mathematics?

Evaluation

1. How do you assess performance in the courses you teach? Is this your choice or that of the department? If you could change it would you? How? What are your thoughts about exploration (like GeoGebra or Maple) versus drill and practice (like *WebAssign*) with technologies and the use of these types of technologies in the evaluation of students performance?

2. How important is homework, in your opinion? How much time do you feel an average student should spend on homework for a given math course? On extra practice? How important is feedback (written comments) on homework/tests?

3. If you had more support on the use of technology in the classroom would you improve your thoughts on the subject of teaching with technology?

4. Do you spend any time preparing students for tests/exams (i.e., review)?

Conclusions

1. Do you think that university math curriculum will be modified soon due to the growing role of technology in our lives? How do you see your own teaching approach changing (or not) in view of that?

Appendix G

Request to Use Questionnaire

To whom it may concern,

My name is Andrew Jesso and I am a graduate student at Memorial University of Newfoundland and am currently conducting research in the field of post-secondary mathematics education. I am writing to request permission for the use of your Technology Implementation Questionnaire.

The purpose of my study is to examine instructors' attitudes toward the use of technology in the teaching and learning of mathematics in Newfoundland and Labrador post-secondary institutions.

Data will be collected using (1) a modified version of the questionnaire to rate instructors' attitudes; and (2) one-on-one interviews with the instructors to further elaborate on the information gained from the questionnaire.

I thank you for your time and consideration of my request, and I look forward to hearing from you in the near future.

Sincerely,

Andrew Jesso, B.Sc (Honours), M.Sc, M.Ed (Post-Secondary) Candidate
e-mail: andrewj@mun.ca

Appendix H

Letter to Interested Instructors

This questionnaire is part of a study being conducted by Mr. Andrew Jesso, a graduate student of Memorial University of Newfoundland, in partial fulfillment of the requirement for the degree of Master's of Education. One of the goals of this study is to learn more about the reasons why instructors do or do not integrate technology in their teachings and if they do, what forms of technology are they using. To gain an accurate understanding of these reasons, it is critical that we hear from both instructors who are using and those who are not using technology. The knowledge we gain from your responses will help in providing services to instructors where needed and requested.

All information you provide will be kept strictly confidential and under no circumstances will your individual responses be released. Participation in this project is voluntary and you are free to discontinue at any time. However, your professional experiences and opinions are crucial to helping Mr. Jesso understand teaching from the educator's point-of-view and, in particular, how resources should be organized to best help you accomplish your objectives. He would greatly appreciate your taking the time to complete this questionnaire.

If you would like to obtain a copy of the report on the findings from this study, please contact him by e-mail.

Thank you for your participation.

Andrew Jesso, B.Sc (Honours), M.Sc, M.Ed (Post-Secondary Studies) Candidate
e-mail: andrewj@mun.ca

Appendix I

Axillary Qualitative Data

This section contains data collected from the interviews that describes participants' career paths and pedagogical views. These data do not contain information on the technological instruction, but they help to better understand participants' backgrounds and positions regarding such points as their teaching styles, students' needs and requirements for students' success, course content, supporting materials for instructors, supporting materials for students, assessment, homework, and course reviews.

I.1 Participants Career Characteristics

The participants of the interview process had varied backgrounds. Their teaching experience, at the post-secondary level, ranged from five to 38 years. Two of the participants had substantial teaching experience in the grade school system before entering the post-secondary system. The participants also had various levels of education; either a doctoral degree, master's degree(s), and/or multiple bachelor's degrees. To obtain a more well rounded representation, two younger instructors (with less than 12 years experience), five instructors with 18-30 years experience (two of which were teaching in their last semester), and one retiree with 38 years experience were selected.

All but one interviewee (P7) taught at the first-year level, while P2, P4, and P5 only taught first-year courses. Five interviewees taught at the second and third year level (P1, P3, P6, P7, P8), while three of these also taught at the fourth year and graduate level (P3, P6, P7). Only one instructor taught foundation courses which was only briefly at the beginning of his/her career (P3). The interviewees' mathematics speciality also varied including pure mathematics, applied mathematics, statistics, and education.

I.2 Teaching Style

All interviewees taught their classes using a lecture-driven approach. The presentation of the material, as well as methods of evaluation, were important (P1, P3, P5), but the material needs to be taught in such a way so that it can be understood by an average student (P1, P2, P5). P5 commented that "I teach to the person that if I do a poor job will get 30; and if I do a great job, they'll get 60. I teach to that student who I feel I can make a difference on." It was stressed by P2, that from day one students should be made comfortable and should be engaged during the lectures. P2 said

> I try to, right from the beginning, get students to feel comfortable in the course to change attitudes ... students feel that they can do rather than, "I've always had trouble with math, and therefore I'm not going to be able to do it." I try to change that attitude, and I try to gear my lecture to more perhaps the average student in the class. That way, I think, you stand a chance of getting your points across to most of your class.

It is important that materials be prepared in advance (P3, P5, P6) as most courses are overloaded with material. All instructors reported that at some point during their teaching career they have used some form of technology in their teaching, however technology has never played a major role in how all the interviewees teach.

I.3 Students' Needs and Requirements for Students' Success

P1, P5, and P8 stated that it is unfeasible for an instructor to tailor themselves to every student at the post-secondary level, so students need to tailor themselves to the instructor. P1 mentioned that

> ultimately, you know, part of the trade-off of teaching lots of students at once is that they kind of got to tailor themselves to you as opposed to the other way around; but that being said, I think where you kind of can make up for that a bit is by being very approachable, by being very accessible.

To help aid in this issue, instructors gave plenty of examples during their lectures (P2, P4, P5, P7, P8), implementing pictures for the visual learner where possible (P2, P6, P8). Goos et al. (2007) noted that

> technology is a partner if it increases the power that students exercise over their learning by providing access to new kinds of tasks or new ways of approaching existing tasks. By displaying things in different ways technology can help you to understand things more easily and that technology may help you approach problems differently in the sense that you can visualize functions. (p. 92)

P6 remarked that he/she does not give as many examples that should be given, but this could be attributed to the fact that he/she teaches high level theoretical mathematics courses. Instructors also commented how first-year math courses are overloaded with material and follow a set curriculum; whereas at a higher level, there is flexibility in the material. It was also suggested that if the current method of instruction of a certain topic does not seem to be working the instructor must modify their teaching style (P1).

In order for students to succeed in their mathematics studies, students must be motivated and engaged in class in terms of asking questions, which is perhaps the only way of doing so due to large class sizes (P1, P3, P5, P8). The quality of their instruction is key as well as the homework and modes of evaluation (P1, P2, P4, P5, P8). There was an unanimous decision in terms of spending quality time on homework and extra practice problems, and going to class in relation to a student's success. P1 commented that

> as long as the instructor is doing a good job both in terms of the lectures that the instructor is giving and the modes of evaluation that are being assigned, and the students are putting in the time to work on those assignments and to understand that lecture material, they'll be fine.

I.4 Course Content

All instructors found it difficult to finish the course content in one or more of their courses, especially in algebra and trigonometry and differential calculus. P1 and P5 commented that if they were to not finish the course content it was due to bad weather and canceled classes, while others fell behind for different reasons. P2 said

> I'm always behind, and I think it's because I get so involved with the sampling, giving them in class in their notes a whole variety of examples, and that always puts me behind, but I get the course done on lecturing right up to the last day.

It should be noted that P2's class grades were always higher than average when compared to other instructors teaching the same courses. This could be attributed to fact that P2 has always been recognized as an exceptional instructor, spending extensive time outside the classroom helping students.

P8 noted that he/she always has had trouble finishing the course content in first-year evening courses because they "lose approximately three and a half weeks of instructional time because of the length of the semester testing, so it's difficult to get those courses covered in time." At the other institution where P8 taught, there were no problems in finishing the course content because there was more lecture time. At a higher level however, instructors did not find it difficult to finish the course content. P7 commented that "upper-level courses, fourth-year courses, graduate-level courses - there's not as strong a requirement to complete a set curriculum because often these courses are terminal."

The researcher comments that if some instructors are currently having trouble finishing the course content, would the implementation of technology make things worse? In-class projectors need to warm up, computer programs need to be "booted up", all of which takes time; and these are just "basic" technologies.

I.5 Supporting Materials for Instructors

There are many advantages for first-time instructors to have already prepared materials: (1) they save time in preparing the materials which can be used to focus more on their teaching; (2) they understand how many examples are sufficient for a given topic; (3) they understand what course material is suppose to be taught so they do not go off track; and (4) it allows for more colleague collaboration. P1 says

> in principle, I think, having prepared material for some instructors is advantageous - that they don't have to go ... and especially if it's a course that they don't have ... that they didn't have firsthand experience in as a stu-

> dent,just so that they don't have to go through and do the incredible amount of work that's involved in putting course materials together for the first time.

However, as a way to integrate more technology in the teaching of mathematics, P1 comments how being a first-time instructor is hard enough without adding technology to the mix. P1 says

> I would worry with technology that for somebody who's never been in a ... classroom before that having to try and balance both this ... "How do I give a regular lecture with ... okay, now I've got to also incorporate this technology in some way." I'm worried that that might actually make things worse instead of better because now there's ... you know, there's just more overhead then. You know, there's more things that they have to understand or something they have to get used to or something they have to worry about; and for some instructors that may be fine, you know, but I would worry that for a lot of instructors that would be just a little over the top, and that would just be, you know, more to keep track of, to get a handle on than they'd necessarily be in position to really master at that stage.

Although there are many advantages of having already prepared course materials, those that incorporate technology into their everyday activities can be hindrance for the first-time instructor. Such materials have their pluses and minuses and would really depends on the person in question.

I.6 Supporting Materials for Students

Of those interviewed, P4 and P7 said they did not give students any supplementary materials in addition to graded work. P7 commented "I try to make the effort to ensure that what is taught in the lectures and the assignments is self-contained, does not require additional supplements." However, P1, P2, P5, and P8 did provide students with extra materials. P5 noted that "for certain parts of the course, yes. So if I don't think there's enough in the text books that they've got for them, I'll put extra on." It was also commented by four interviewees (P3, P4, P6, P10) that they always referred their students to online resources and textbooks for extra examples.

P1, P2, P4, P5, P6, and P8 mentioned how they did not know of any useful resources that other instructors were not already aware of. However, P6 commented how online databases of lecture notes are very beneficial to his students. P3 suggested that the internet is a major resource, saying

> still a lot of people don't realize that kids can Google virtually every problem you give them. You know, they can find some sort of answer or partial answer so, you know, they're probably not aware of the fact that virtually everything you need is out on the web there somewhere.

I.7 Assessment

All instructors commented that the percentage given to a student's term mark and final exam mark is the choice of the Department. While the choice of how the term mark is broken down (e.g., tests, assignments, quizzes, etc.) is the choice of the instructor. P5 said he/she would not change the breakdown between the term mark and the final exam, P4 would opt for a heavier weighted final exam, whereas P1, P6, and P8 would put less weight on the final exam. To try and compare the quality of instruction in a course, some instructors compared their course results to students in previous semesters (P1) or gave their own questionnaire to obtain feedback from the students (P3). Others experimented with the distribution of the term marks. For example, giving one, two, three, or four tests, supplemented with graded assignments, or work sheets not worth marks.

The modes of assessment an instructors uses is extremely important. Written assignments are extremely important for students. They get to do some practice needed in order to learn the material and learn to present it in a logical fashion. Although they will have access to lots of help and there's the possibility of copying, they deserve some credit for doing the assignments, also they will look at marks as motivation to do the assignments. So 10% for written assignments seems fair. Giving two or three term tests (which was the norm amongst most interviewees) made for short term testing and helped in the transition from high school practices to the university setting.

It takes some of the weaker students a while to get their act together. So 40% on term work does not penalize them too heavily. The 60% final on the whole course gives them a chance to demonstrate what they have learned. If they do better on the final on the whole course than they have been doing all semester, there can be an adjustment made in the distribution of the marks in light of the improved performance on the final.

I.8 Homework

All interviewees said that homework was essential in student learning. The written assignment with a good cross-section of examples is absolutely necessary for the students to take home with them and learn. It also makes the student a little bit independent. Students need to be able to develop something on their own, getting their assignment and notes out at home, and see if they can work through the examples. P2 commented

> I think that, you know, students coming in from the high school in the fall - and the same thing in the winter - they're used to seat work. They're used to having somebody explain a topic, and then they spend two or three days doing seat work. Well, they don't get that chance when they come in here. They come to our classes. They come in and they're lectured to for 50 minutes, so it's extremely important that they have something to go home and practice immediately after that.

Four of the instructors (P1, P3, P4, P7) mentioned how students do not learn in a classroom. P1 said,

> in math you cannot learn in a classroom. The purpose of lectures is not so that you will come out of that lecture completely understanding the material. It's that now you have the basic understanding and the basic tools to go away and master this topic, master this technique, master this concept. Mathematics, probably more than any other discipline, is one in which students, having been introduced to a concept in class, have to go away and sit down and practice that. Ideally, all students would recognize this and will just do it of their volition. Of course, that's not the case and, for the most part, especially in introductory course, so homework, assignments are an integral tool to students mastering the course.

The amount of time the average student should spend on homework for a given math course varies by student. The interviewees agreed that anywhere between 0.5 and 5 hours should be sufficient; or until the student masters the topic. P1 said "the old rule of thumb was always that for every hour of lecture you should do three hours at home." However, in reality how much time a student spends on homework will vary by student. The amount of time the average student should spend on review for a test or exam, again depends strictly on the student, with opinions ranging from 1-3 hours. P1 noted that

> it's really hard to put a number on that because it will completely depend on the student and on the topic, you know, but if a student has ... you know, if it takes a student an hour to do an assignment and they do quite poorly on that assignment, then that tells me that they probably need at least two hours outside the assignment to get themselves to the point where they need to be.

Not only is doing one's homework important, but regular feedback on graded work by instructors is also very important. In theory, regular feedback in terms of teacher comments on written homework is effective. P2 (who gave the most feedback on written work) said

> Early in the semester when the assignments came back from the markers, I would do the percents and record them. If a student scored really low on the assignment, I would write a note to the effect that that kind of work would not bring success in the course. I watched that student for a couple more weeks and wrote a note each time the mark was poor (below 50). If there was improvement, I mentioned it. If after three weeks there was no improvement, I stopped making comments. If a student got 50 - 65, I would encourage them to do better, come and see me, and the follow up for them was as for the weaker group. Those who scored above the benchmark (80%) I wrote a brief comment praising their work. I didn't bother to do that very much.

P2 also commented that for the weak group he was not sure if they benefitted from the feedback; perhaps only a few. Some of P2s students would probably take offence to such comments and perhaps that is why they did not bother to do any more assignments with the consequence of failure in the tests and final exam. The others appreciated any comments and corrections. Most students would want to know why the solution is incorrect or why they lost marks on a solution. With the large number of students that P2 taught it was impossible to do many corrections on assignments, but did so on quizzes.

With, due to class sizes being approximately 200-300 students, it is unrealistic to give much feedback. P8 noted that

> feedback is very important, but sometimes it's hard to do. I find really ...sometimes I do make comments on it, but what I tend to do is either e-mail the class or post online the common mistakes. It speeds up my marking process, and what I do tell students sometimes I will a circle a mistake and will tell them they should recognize what that circle means, what that mistake is, and the reason is it's time, just getting ... you know, if you're marking a 125 papers and they got to be back before the drop date, it's hard to write, you know, detailed examples, but it is important. I probably don't do it enough to be quite honest with you. Individually I probably should do more, but because of time, class sizes, it's not practical.

It was well mentioned that feedback is not always necessary and posting solutions for students to find their own errors is part of the learning process. P4 said

> that's why we put the keys online - so that everybody can see, you know, there's absolutely no reason why a student should have any problem with an assignment when they go to their computer and look at the solutions and know exactly where they went wrong because, I mean, I'm sure just about everyone else does supply those keys for them.

Although homework may be extremely important, instructors remarked how assignments are not a good representation of a student's work. P8 noted that "what we get in sometimes is not original work, which is the downside of giving assignments, and I think you ...you know, and you don't really get a good feel of what the student does or doesn't know until he actually writes a test." P1 comments how in large classes giving assignments is unrealistic. P1 stated that "there are logistical issues with that - how do you ... especially in large class sizes - how do you effectively take in and then hand back potentially 330 assignments?"

The purpose of assignments, of homework, is it helps students figure out (1) what they know; (2) what they do not know; (3) what they are doing right; and (4) what they are doing wrong. Therefore, since an assignment is worth approximately one percent, even if they do horribly on an assignment, it does not matter. However, if they do that assignment and realize they do not know anything on the assignment they are going to be in a position where they can go to the instructor, help centre, tutor, their notes or to a text book and bring themselves from a position of knowledge up to the point where now they do understand that material.

I.9 Course Reviews

By the end of the semester the instructors understand how well their students are progressing in the course and can determine whether or not review is necessary. P1 and P8 said they spend no time conducting review, either for a midterm or final exam, as they take it as an admission of poor instruction on their part. P1 commented

> I don't conduct review because in general what I found is that students who show up to those review sessions, they really don't need it. They already have it handled. They're coming because they're responsible students. Students who would benefit from it don't show up. I think it's far better to give students their assignments, the feedback, the notes - that they can prepare themselves for a test or for a final exam than to try to prejudge what issues students might be having.

The other five interviewees did perform some type of final review. P3 remarked that

> at the end of every semester, I would ... a couple of weeks before the end I would give them a practice exam, a practice final - an actual final from previous semesters and not one in the books we sell - and I would say as soon as we finish the course you're going to present these problems on the board in class. I would assign, "You do this. You do this. You do this." They would get all the solutions on the board, and so they'd have a complete set of solutions if they came to that class, you know, and we could do it in one, sometimes two classes. So if I had two classes left at the end, they would have a complete practice exam they work through.

Appendix J

Section 4 of Questionnaire Data

Table J.1: E-mail communication with instructors

Scale	Freq	%
Never	0	0
Practically Never	0	0
Once in a While	2	15.4
Fairly Often	3	23.1
Very Often	4	30.8
Almost Always	4	30.8

Table J.2: E-mail communication with students

Scale	Freq	%
Never	0	0
Practically Never	0	0
Once in a While	3	23.1
Fairly Often	3	23.1
Very Often	2	15.4
Almost Always	5	38.5

Table J.3: Use of LCD projector

Scale	Freq	%
Never	5	38.5
Practically Never	1	7.7
Once in a While	4	30.8
Fairly Often	1	7.7
Very Often	0	0
Almost Always	2	15.4

Table J.4: Use of PowerPoint

Scale	Freq	%
Never	4	30.8
Practically Never	5	38.5
Once in a While	3	23.1
Fairly Often	1	7.7
Very Often	0	0
Almost Always	0	0

Table J.5: Compile student grades

Scale	Freq	%
Never	1	7.7
Practically Never	0	0
Once in a While	2	15.4
Fairly Often	0	0
Very Often	1	7.7
Almost Always	9	69.2

Table J.6: Prepare course materials

Scale	Freq	%
Never	0	0
Practically Never	0	0
Once in a While	0	0
Fairly Often	0	0
Very Often	1	7.7
Almost Always	12	92.3

Table J.7: Create charts or graphs

Scale	Freq	%
Never	3	23.1
Practically Never	1	7.7
Once in a While	5	38.5
Fairly Often	1	7.7
Very Often	1	7.7
Almost Always	2	15.4

Table J.8: Create a course website

Scale	Freq	%
Never	2	15.4
Practically Never	1	7.7
Once in a While	2	15.4
Fairly Often	0	0
Very Often	2	15.4
Almost Always	6	46.2

Table J.9: Analyze data

Scale	Freq	%
Never	2	15.4
Practically Never	2	15.4
Once in a While	4	30.8
Fairly Often	0	0
Very Often	1	7.7
Almost Always	4	30.8

Table J.10: Statistics or data analysis

Scale	Freq	%
Never	3	23.1
Practically Never	1	7.7
Once in a While	5	38.5
Fairly Often	0	0
Very Often	1	7.7
Almost Always	3	23.1

Table J.11: Have students conduct experiments

Scale	Freq	%
Never	6	46.2
Practically Never	0	0
Once in a While	5	38.5
Fairly Often	1	7.7
Very Often	1	7.7
Almost Always	0	0

Table J.12: Have students use 3D software

Scale	Freq	%
Never	7	53.8
Practically never	3	23.1
Once in a While	2	15.4
Fairly Often	0	0
Very Often	1	7.7
Almost Always	0	0

Table J.13: Using drawing programs

Scale	Freq	%
Never	6	46.2
Practically never	2	15.4
Once in a While	3	23.1
Fairly Often	0	0
Very Often	2	15.4
Almost Always	0	0

Table J.14: Scan pictures

Scale	Freq	%
Never	3	23.1
Practically never	2	15.4
Once in a While	4	30.8
Fairly Often	1	7.7
Very Often	2	15.4
Almost Always	1	7.7

Table J.15: Use a word processor

Scale	Freq	%
Never	1	7.7
Practically never	1	7.7
Once in a While	0	0
Fairly Often	3	23.1
Very Often	5	38.5
Almost Always	3	23.1

Table J.16: Maintain an online discussion board

Scale	Freq	%
Never	6	46.2
Practically never	3	23.1
Once in a While	3	23.1
Fairly Often	0	0
Very Often	0	0
Almost Always	1	7.7

Table J.17: Use of technology for student assessment

Scale	**Freq**	%
Never	3	23.1
Practically never	3	23.1
Once in a While	3	23.1
Fairly Often	4	30.8
Very Often	0	0
Almost Always	0	0

Table K.3: Promotes student collaboration

Scale	Freq	%
Strongly Disagree	4	30.8
Moderately Disagree	1	7.7
Slightly Disagree	2	15.4
Slightly Agree	4	30.8
Moderately Agree	2	15.4
Strongly Agree	0	0

Table K.4: Promotes communication skills

Scale	Freq	%
Strongly Disagree	4	30.8
Moderately Disagree	2	15.4
Slightly Disagree	3	23.1
Slightly Agree	3	23.1
Moderately Agree	0	0
Strongly Agree	1	7.7

Table K.5: Valuable instructional tool

Scale	Freq	%
Strongly Disagree	2	15.4
Moderately Disagree	1	7.7
Slightly Disagree	0	0
Slightly Agree	3	23.1
Moderately Agree	3	23.1
Strongly Agree	4	30.8

Table K.6: A more competent educator

Scale	Freq	%
Strongly Disagree	3	23.1
Moderately Disagree	4	30.8
Slightly Disagree	2	15.4
Slightly Agree	1	7.7
Moderately Agree	3	23.1
Strongly Agree	0	0

Table K.7: Facilitator versus provider

Scale	Freq	%
Strongly Disagree	3	23.1
Moderately Disagree	1	7.7
Slightly Disagree	3	23.1
Slightly Agree	4	30.8
Moderately Agree	2	15.4
Strongly Agree	0	0

Table K.8: Effective tool for students

Scale	Freq	%
Strongly Disagree	3	23.1
Moderately Disagree	1	7.7
Slightly Disagree	0	0
Slightly Agree	5	38.5
Moderately Agree	1	7.7
Strongly Agree	3	23.1

Table K.9: Unnecessary since students will learning about technology elsewhere

Scale	Freq	%
Strongly Disagree	2	15.4
Moderately Disagree	2	15.4
Slightly Disagree	4	30.8
Slightly Agree	2	15.4
Moderately Agree	0	0
Strongly Agree	2	15.4

Table K.10: Enhances professional development

Scale	Freq	%
Strongly Disagree	2	15.4
Moderately Disagree	0	0
Slightly Disagree	0	0
Slightly Agree	10	76.9
Moderately Agree	1	7.7
Strongly Agree	0	0

Table K.11: Accommodates student learning styles

Scale	Freq	%
Strongly Disagree	2	15.4
Moderately Disagree	0	0
Slightly Disagree	3	23.1
Slightly Agree	4	30.8
Moderately Agree	2	15.4
Strongly Agree	1	7.7

Table K.12: Motivates students

Scale	Freq	%
Strongly Disagree	2	15.4
Moderately Disagree	1	7.7
Slightly Disagree	1	7.7
Slightly Agree	6	46.2
Moderately Agree	2	15.4
Strongly Agree	0	0

Table K.13: Promotes students' interpersonal skills

Scale	Freq	%
Strongly Disagree	4	30.8
Moderately Disagree	1	7.7
Slightly Disagree	1	7.7
Slightly Agree	4	30.8
Moderately Agree	2	15.4
Strongly Agree	0	0

Table K.14: Improves students' critical learning

Scale	Freq	%
Strongly Disagree	4	30.8
Moderately Disagree	1	7.7
Slightly Disagree	1	7.7
Slightly Agree	4	30.8
Moderately Agree	1	7.7
Strongly Agree	2	15.4

K.2 Expectancy Statements Regarding the Use of Technology in Teaching

Table K.15: Effective if the instructor can implement successfully

Scale	Freq	%
Strongly Disagree	2	15.4
Moderately Disagree	1	7.7
Slightly Disagree	1	7.7
Slightly Agree	4	30.8
Moderately Agree	4	30.8
Strongly Agree	1	7.7

Table K.16: Successful if instructors have proper professional development

Scale	Freq	%
Strongly Disagree	1	7.7
Moderately Disagree	2	15.4
Slightly Disagree	0	0
Slightly Agree	5	38.5
Moderately Agree	4	30.8
Strongly Agree	1	7.7

Table K.17: Successful if technical staff regularly maintains the technology

Scale	Freq	%
Strongly Disagree	2	15.4
Moderately Disagree	1	7.7
Slightly Disagree	1	7.7
Slightly Agree	2	15.4
Moderately Agree	1	7.7
Strongly Agree	6	46.2

Table K.18: Effective if instructors select the technology

Scale	Freq	%
Strongly Disagree	1	7.7
Moderately Disagree	1	7.7
Slightly Disagree	1	7.7
Slightly Agree	4	30.8
Moderately Agree	4	30.8
Strongly Agree	2	15.4

Table K.19: Effective when technological resources are available

Scale	Freq	%
Strongly Disagree	5	38.5
Moderately Disagree	2	15.4
Slightly Disagree	3	23.1
Slightly Agree	2	15.4
Moderately Agree	1	7.7
Strongly Agree	0	0

Table K.20: Successful if technology is part of the students home environment

Scale	Freq	%
Strongly Disagree	5	38.5
Moderately Disagree	5	38.5
Slightly Disagree	2	15.4
Slightly Agree	0	0
Moderately Agree	1	7.7
Strongly Agree	0	0

K.3 Cost Statements Regarding the Use of Technology in Teaching

Table K.21: Costly in terms of resources, time, and effort

Scale	Freq	%
Strongly Disagree	2	15.4
Moderately Disagree	1	7.7
Slightly Disagree	0	0
Slightly Agree	3	23.1
Moderately Agree	3	23.1
Strongly Agree	4	30.8

Table K.22: Too much time spent on technical problems

Scale	Freq	%
Strongly Disagree	2	15.4
Moderately Disagree	3	23.1
Slightly Disagree	2	15.4
Slightly Agree	5	38.5
Moderately Agree	1	7.7
Strongly Agree	0	0

Appendix K

Value, Expectancy, and Cost Statements

K.1 Value Statements Regarding the Use of Technology in Teaching

Table K.1: Increases academic achievement

Scale	Freq	%
Strongly Disagree	3	23.1
Moderately Disagree	1	7.7
Slightly Disagree	3	23.1
Slightly Agree	3	23.1
Moderately Agree	2	15.4
Strongly Agree	1	7.7

Table K.2: Neglects traditional resources

Scale	Freq	%
Strongly Disagree	0	0
Moderately Disagree	3	23.1
Slightly Disagree	2	15.4
Slightly Agree	3	23.1
Moderately Agree	2	15.4
Strongly Agree	3	23.1

Table K.23: Could reduce instructor employment

Scale	Freq	%
Strongly Disagree	6	46.2
Moderately Disagree	0	0
Slightly Disagree	3	23.1
Slightly Agree	3	23.1
Moderately Agree	1	7.7
Strongly Agree	0	0

Table K.24: Limits choices of instructional materials

Scale	Freq	%
Strongly Disagree	4	30.8
Moderately Disagree	2	15.4
Slightly Disagree	2	15.4
Slightly Agree	4	30.8
Moderately Agree	1	7.7
Strongly Agree	0	0

Table K.25: Training is too time consuming

Scale	Freq	%
Strongly Disagree	3	23.1
Moderately Disagree	3	23.1
Slightly Disagree	1	7.7
Slightly Agree	5	38.5
Moderately Agree	1	7.7
Strongly Agree	0	0

Table K.26: Increases stress and anxiety of students

Scale	Freq	%
Strongly Disagree	2	15.4
Moderately Disagree	2	15.4
Slightly Disagree	5	38.5
Slightly Agree	3	23.1
Moderately Agree	1	7.7
Strongly Agree	0	0

Table K.27: Requires extra time to plan learning activities

Scale	Freq	%
Strongly Disagree	1	7.7
Moderately Disagree	0	0
Slightly Disagree	2	15.4
Slightly Agree	4	30.8
Moderately Agree	3	23.1
Strongly Agree	3	23.1