Improving the Teaching and Learning of Mathematics with Numeracy Support Teachers: A Program Evaluation of Newfoundland and Labrador's Excellence in Mathematics Strategy

by

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Bachelor of Arts, University of Ottawa, 1994
Bachelor of Education, Memorial University, 1996
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Supervisory Committee

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This mixed methods study is a program evaluation of Newfoundland and Labrador's Excellence in Mathematics Strategy commencing in 2007 with a curriculum review leading to the implementation of the Western and Northern Canadian Protocol Common Curriculum Framework in K-12 mathematics along with the implementation of numeracy support teachers in classrooms across the province. The goals of the Strategy were to improve student achievement with the curriculum change; to support teachers, students, and parents; and to encourage an increased interest and enthusiasm for mathematics.

This study included a quantitative analysis of the provincial mathematics assessment results in Grades 3, 6, and 9 from 2007 to 2012 by comparing assessment items that were common to both the old and new curricula, and comparing results of items anchored in 2011 and 2012. Assessment results demonstrated inconsistent results on common curriculum items. Results of items anchored decreased in all grades in 2011 but items anchored in 2012 increased in all grades.

Another quantitative analysis was conducted on the effect of numeracy support teachers (known elsewhere as mathematics specialists, coaches, or mentors) on students' mathematics achievement in schools having Grade 3 and 6 classrooms receiving numeracy support from 2007 to 2011. Schools with numeracy support in Grades 3 and 6

for four years were mostly lower-achieving schools and had achievement results move closer over time to schools receiving one or no years of support which were mostly higher achieving schools. Schools receiving support in both Grades 3 and 6 had the highest proportion of students moving from below standard to at/above standard on rubric-scored open-constructed response questions.

A qualitative analysis was conducted of focus groups with numeracy support teachers and supported the quantitative analysis of the provincial assessment results. Numeracy support teachers shared their observations of teachers' unconventional assessment methods and students' increase in communicating, reasoning, problem solving, and strategizing about mathematics. Lower-achievers were more engaged in these classrooms and manipulative use in problem solving improved. Numeracy support teachers witnessed physical and attitudinal changes through planning, modelling, co-teaching, and reflecting with teachers thereby helping change the culture of students' classrooms. The goal of numeracy support teachers to build capacity in their teachers through collaboration was evident in some classrooms as beliefs and habits were changing, but some were resistant.

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Chapter 1
Introduction

This dissertation is an academic program evaluation of how Newfoundland and Labrador's *Excellence in Mathematics Strategy* effects the teaching and learning of mathematics through the work of numeracy support teachers in classrooms throughout the province. A background is provided regarding the educational and political history to the *Excellence in Mathematics Strategy*, the evaluation research questions considered, and the underlying assumptions of the research.

Background

The teaching and learning of mathematics often strikes up debate among parents, teachers, media, and the general public in Newfoundland and Labrador and in Canada and the United States; essentially, whether to teach mathematics with conceptual understanding or to go "back to the basics" with a foundation of developing basic skills to a point of automaticity (Atlantic Evaluation and Research Consultants (AERC), 2007; National Council of Teachers of Mathematics (NCTM), 2006; Schoenfeld, 2004). For decades mathematics curricula has focused on developing these basic skills without much focus on conceptual understanding, but since the early 1990s, mathematics curricula focused more on students developing conceptual understanding with less focus on skill development. Over the past decade, mathematics curricula have been attempting to find a balance between both conceptual understanding and skill development (AERC, 2007; NCTM, 2006; Western and Northern Canadian Protocol (WNCP), 2006).

Following many years of negative concerns from educators and parents regarding K-12 mathematics in the province of Newfoundland and Labrador, the Government of

Newfoundland and Labrador's Department of Education Minister Joan Burke announced the *Excellence in Mathematics Strategy* on April 4, 2007 (Newfoundland and Labrador Department of Education, 2007a). This *Strategy* would invest $11.3 million over a three-year initiative. The ultimate goal of the strategy was "to improve student achievement in mathematics in the K-12 system." She stated that, "the *Excellence in Mathematics Strategy* is designed to provide substantial support to students, teachers and parents. Our goal is to address areas of concern identified by parents and teachers, help students with their performance, and encourage an increased interest and enthusiasm for math."

Newfoundland and Labrador's curriculum at the time of the announcement of the *Excellence in Mathematics Strategy*, along with most Canadian and American mathematics curricula in recent decades, had been based on the National Council of Teachers of Mathematics (NCTM, 1989) *Curriculum and Evaluation Standards for School Mathematics* (the *Standards*). This publication was the beginning basis for many Canadian and American educational jurisdictions to change their mathematics curricula by guiding educators as which topics to give increased attention. The *Standards* was a fundamental change in moving mathematics education to a student-centred curriculum grounded in the philosophy of learning being an active process rather than the traditional development of mathematics skills by means of drill and practice.

An educational revolution followed in educational jurisdictions across Canada and the United States with the rewriting of their mathematics curricula in line with the *Standards* (AERC, 2007; Atlantic Provinces Education Foundation (APEF), 1993; WNCP, 1995). For the first time, many provinces in Canada took initiatives to create common curriculum frameworks based on these standards, such as the *Common*

Curriculum Framework for K – 12 Mathematics (WNCP, 1995) and the *Foundations for the Atlantic Canada Mathematics Curriculum* (APEF, 1993). Since the publication of the *Standards* and the *Foundations for the Atlantics Canada Mathematics Curriculum* the implementation of this first-generation standards-based curriculum, led to concerns about the mathematics teaching methods and student achievement results.

Newfoundland and Labrador's Department of Education eventually reacted to areas of concern identified by parents and teachers across the province. Like many other provinces and states, Newfoundland and Labrador began to look back at its standards-based curriculum. It was described as having too many outcomes, having inadequate resources, and not having enough time to teach the curriculum completely within a school year. Similarly, NCTM (2006) described that the current major problem of mathematics curricula is it being "a mile wide and an inch deep." The WNCP found that there was too much content for the allocated instructional time and that there should be an emphasis on teaching fewer topics and teaching those topics in more depth with a particular increased focus on early numeracy (2006).

Along with the introduction of new teaching positions to support the *Strategy*, referred to as numeracy support teachers, the government indicated three more major components of the *Strategy*:

1. Excellence in Teaching and Learning: with a focus on professional development and resources for teachers;
2. Curriculum Development and Review: with a focus on the nature and amount of curriculum covered and a review of textbooks;

3. Parent Support: with a focus on sessions and workshops for parents and the development of materials to assist parents at home.

(Newfoundland and Labrador Department of Education, 2007a)

Numeracy Support Teachers

By the beginning of the 2007 school year numeracy support teachers were hired across Newfoundland and Labrador. Other North American jurisdictions may call them mathematics specialists, coaches, or mentors. Some of the numeracy support teachers started Spring 2007 and others, myself included, started in Fall 2007. School districts were responsible for hiring these numeracy support teachers. There were no positions allocated to the Francophone school district, comprised of only five schools across the province. Twenty-one of the numeracy support positions were placed in the primary/elementary grades and three positions in the secondary grades. The primary/elementary numeracy support teachers were allocated based on student population with two in the Labrador School District, four in the Western School District, five in the Nova Central School District, and ten in the Eastern School District. I was the sole secondary numeracy support teacher based in the Eastern School District. Two other secondary positions were based in the Western School District and Labrador School District. In Newfoundland and Labrador, Primary refers to Kindergarten to Grade 3, Elementary refers to Grades 4 to 6, and Intermediate refers to Grades 7 to 9.

Numeracy support teachers mainly worked with the first component of the *Strategy*, the Excellence in Teaching and Learning, by working with teachers at the grassroots level of the classrooms. Numeracy support teachers travelled from community to community, school to school, classroom to classroom working with classroom teachers

and their students within their school districts. Each numeracy support teacher was provided 25 substitute days annually to release teachers from their classrooms. These days allowed numeracy support teachers the time to work with their cooperating teachers to plan, reflect, and prepare for various mathematics lessons and activities during the regular school day.

Mathematics Curriculum Review

Within two months of the *Excellence in Mathematics Strategy* announcement, the government undertook a review of the curriculum addressing the largest concern being that the curriculum is "too dense, with too much material to cover" (Burke, 2007a) and began to make immediate changes by reducing content in primary mathematics and Academic Mathematics 1204, a Grade 10 course, and reducing content in the elementary grades for that coming September 2007.

There was much public debate locally with numerous editorials and letters to the editor in the provincial newspaper, The Telegram, as well as discussions on provincial current affairs radio on CBC Radio Noon and VOCM Cross Talk. To display the various public opinions of the current state of the provincial mathematics curriculum, are some letters to the editor from The Telegram. First the Minister of Education supports the spending and defends the work being done on the current curriculum as well as the goal to improve student performance. She writes:

> The Excellence in Mathematics Strategy is in direct response to the needs identified, not only by teachers, but by other educators and parents, as well as students themselves, through their performance on criterion references testing. … Let me be very clear. This is not about "tweaking" the math curriculum. … I am

> not interested, nor is the Williams government interested in investing $11.3 million of taxpayers' money without the full intent and expectation of achieving real change and improvements. This applies not only to the changes to the math program itself, but more importantly, to our students' performance. … The goal of the strategy is not only to improve the program and student performance. We also want to create a culture that understands and embraces the importance of mathematics. A solid foundation in math is critical for a well-rounded education and future professional success. The critical thinking, analytical skills and problem-solving experiences gained through the study of math are powerful tools that support many career choices. (Burke, 2007a)

In the same issue of The Telegram, Dr. Bruce Shawyer, Professor Emeritus, with the Department of Mathematics and Statistics at Memorial University critiques the current curriculum as being focused more on problem-solving rather than having a solid foundation of the basics. He writes:

> When the province decided to join the Maritime provinces with a joint curriculum, post-secondary mathematicians were highly critical of it. We are now suffering the results of this ill-conceived and badly written curriculum. It is based on a now outmoded idea that mathematics can be learned using problem-solving without a solid foundation in the basics. Like anything, the tools to use are the basis of success. What are the tools for studying mathematics? To begin with, certain facts must be known. By that I mean that certain things must be automatic. … In my opinion, "tweaking" the present curriculum is a waste of time and money. The powers that introduced the outmoded idea that mathematics can be

> learned using problem-solving without a solid foundation in the basics – the National Council of Teachers of Mathematics, an American organization – have recanted and seen the error of their previous ways. It is time for the Department of Education to have the moral fortitude to do the same. (Shawyer, 2007)

One week later, Sarah Colborne Penney responds, "there must be greater emphasis on the acquisition of basic skills. … There needs to be a return to formal drill and practice as a means of acquiring basic skills to the point where those skills become automatic." (Penney, 2007)

Another response from Minister Burke came months later, as she defends the *Excellence in Mathematics Strategy*, and advocates "a balance between basics and problem-solving." She continues:

> In fact, there was never an intention to remove math basics from the program. It provides the foundation required to build success. Teachers are aware of this. They are being provided with professional development to ensure any uncertainties they have or assistance they need is addressed. (Burke, 2007b)

The extensive mathematics curriculum review was conducted for the Department of Education by AERC led by Dr. Robert Crocker, submitted in November 2007. AERC conducted a review of the curricula across Atlantic Canada, Western Canada, and Ontario, a review of the literature in the teaching and learning of mathematics, and a review of student achievement in Newfoundland and Labrador. They also gathered input through focus groups from parents, teachers, school administrators, guidance counsellors, and others on the current mathematics curriculum, as a public call for submission on this matter.

AERC (2007) made 15 recommendations under four key areas, all of which the Department of Education accepted (See Appendix A). In particular: (1) that the new WNCP curriculum be adopted as the basis for the K-12 mathematics curriculum in Newfoundland and Labrador; (2) that new textbooks and resources based on the new WNCP curriculum be adopted as an integral part of the program change; (3) that significant initial and sustained professional development for teachers be provided with numeracy support teachers and mathematics department heads having a primary role in the delivery of this professional development; and (4) that guidelines for the assignment of homework be developed.

Curriculum Implementation

After the release of the *Math Curriculum Review: Final Report* (AERC, 2007), major work started at the Department of Education to move forward with these 15 recommendations. Within less than six months, the Department of Education intended to have a major curriculum change enabled to start September 2008 for Grades K, 1, 4, and 7. Resources were to be chosen, curriculum implementation sessions developed, and those sessions offered to teachers prior to the end of June 2008.

The numeracy support teachers played a key role in the curriculum development and implementation of this WNCP-based curriculum. As the *Final Report* recommended, all teachers received two professional development days of curriculum implementation in Spring 2008 and one full day in Fall 2008. Some numeracy support teachers were on provincial implementation teams traveling across all districts. Personally, as an intermediate numeracy support teacher, I assisted in the Grade 7 implementation working with almost every Grade 7 mathematics teacher across the province except approximately

20 teachers on the Great Northern Peninsula. For the following two years for Grades 2, 5, 8, and 3, 6, 9, the implementation teams were at a district level where teachers were provided two professional development days, one in the spring and one in the fall.

Special Education teachers for Grades K, 1, 4, and 7 were provided one professional development day in the fall, separately from the regular classroom teachers. In the following two years, Special Education teachers accompanied the regular classroom teachers receiving the same implementation session. This later model followed the Department of Education initiative of inclusion in the classroom.

Statement of the Problem

The "ultimate" goal of the *Excellence in Mathematics Strategy*, as described by the Minister of Education, was to improve student achievement in mathematics. To attempt to improve student achievement the Department of Education implemented a new curriculum and had numeracy support teachers work with classroom teachers across the province. This study centres on four specific questions:

1. Are students' achievement scores on Newfoundland and Labrador Primary, Elementary, and Intermediate Mathematics Assessments significantly different for students who have taken the newly implemented curriculum compared to those who have taken the previous provincial curriculum?
2. Are students' achievement scores on Newfoundland and Labrador Primary, Elementary, and Intermediate Mathematics Assessments significantly different for students who were in classrooms that received numeracy support compared to those who did not?

3. What qualitative evidence is there for a change in student achievement due to the newly implemented curriculum and numeracy support?
4. What qualitative evidence is there for an increased interest and enthusiasm for mathematics?

Provincial Mathematics Assessments

Since 2005, the Department of Education annually administered mathematics assessments to every Grade 3, 6, and 9 student in the month of June. These assessments are criterion reference tests, referred to by teachers and students as CRTs, based on the specific curriculum outcomes of that particular grade level. The Primary, Elementary, and Intermediate Mathematics Assessments consist of selected response items and closed-constructed response items. The Primary and Elementary Mathematics Assessments also include open-constructed response items.

After students write the assessments, all assessments are returned to the Department of Education. The selected response items are graded electronically, while the closed- and open-constructed response items are graded by a panel of teachers from across the province every July.

Prior to sending in the assessments, intermediate teachers grade the assessments as a final examination used in the determination of students' grades. Teachers do not mark on or copy the assessments, but do record the student grades. This is not a requirement of the Department of Education, but it is a requirement of the school districts. This is due to intermediate students writing final examinations in all core subject areas in June. The school districts determined it unnecessary for students to write both a school-based and a province-based assessment. Thus, as an example, the provincial

assessments in the Eastern School District were weighted 20% of each student's final grade.

The provincial assessment data is released to the districts, school administrators, teachers, and parents in the fall of the next school year. This data is influential in decision making at every level of education from the classroom to the Minister of Education. The data is analyzed at every level of education. School districts are compared to each other and schools are compared to each other. Strengths and weaknesses in specific curriculum outcomes are indicated to guide the learning and teaching of mathematics for the following school year.

Assumptions

While the *Excellence in Mathematics Strat*egy was announced as a response from the Minister of Education to the public within an economic and political forum, this research takes an academic perspective of numeracy support teachers' work with the learning and teaching of mathematics in Newfoundland and Labrador classrooms. Not only am I the principal investigator of this research, but also through all research stages I was a numeracy support teacher employed by the Eastern School District that worked under the Newfoundland and Labrador Department of Education. While researching and working under this dual role, I limited my focus group participants to those whom I did not work directly with or under, therefore could only consider primary/elementary numeracy support teachers and mathematics program specialists from other districts.

When working with achievement data from the Department of Education, and numeracy support school data, one assumption is that students are considered to have received numeracy support if their school received numeracy support in Grade 3 or 6,

even though some students may not have been in a classroom where a teacher did receive numeracy support. One example of this is where there are many classes in one grade, and some, but not all, of the teachers received numeracy support. Because these teachers often work together at a grade level, while only some teachers may have received support, their learning and experiences may have had an effect on the learning and experiences of those in the same grade that did not receive support. For example, some schools have English classrooms and French Immersion classrooms. Some numeracy support teachers could only support English classrooms since they did not have experience in French Immersion classrooms.

Although many teachers received numeracy support from Kindergarten to Grade 9, schools receiving numeracy support in only Grades 3 and 6 were considered. The Provincial mathematics assessments were administered only in Grades 3, 6, and 9, and the majority of numeracy support was offered to teachers from Kindergarten to Grade 6. Therefore, to determine the effectiveness of numeracy support on student achievement, the results for the Provincial Mathematics Assessments in Grades 3 and 6 and the data of only those schools receiving numeracy support in those same Grades 3 and 6 were considered. Also those teachers receiving numeracy support in Grades K, 1, 2, 4, and 5 may have a positive effect on Grades 3 and 6 classrooms due to the collegial nature of teachers working together at a school, and that teachers may move to a different grade in a subsequent year.

One final assumption is that the interviews of numeracy support teachers and mathematics program specialists represent the observations of many classroom teachers and their students. Their sharing of experiences gives a wider nature of the *Excellence in*

Mathematics Strategy effect on supporting students, teachers, and parents, as well as observations of students' achievement and interest and enthusiasm in mathematics for students and teachers. The numeracy support teachers share their perspective of the actual experiences both in and outside the classroom. Interviewing these numeracy support teachers instead of interviewing a selected group of students, teachers, and parents, gave a wider knowledge of what may be happening in mathematics classrooms across Newfoundland and Labrador.

Summary

The main focus of this research of the *Excellence in Mathematics Strategy* was to examine how numeracy support affected students' mathematics achievement, the learning and teaching of mathematics in the classroom, and teachers' and students' interest and enthusiasm in mathematics. Using a mixed methods approach, quantitative analysis was conducted on both the curriculum change and numeracy support and qualitative evidence was gathered from numeracy support teachers of their work with the curriculum change, their work with teachers in classrooms, their observations of student learning and achievement, and their observations of interest and enthusiasm of mathematics.

To effectively assess the main goal of the *Excellence in Mathematics Strategy*, to increase student achievement in K-12 mathematics, the data from the student provincial mathematics assessments were used as well as qualitative data collected and analyzed from numeracy support teachers and other mathematics specialists. The students who wrote the Primary, Elementary, and Intermediate Provincial Mathematics Assessments from June 2007 to June 2012 were considered in the study. Each assessment was divided into two categories, that being items that are common to both the old curriculum and the

new curriculum and items being either only in the old curriculum (prior to 2011) or in the new curriculum (2011 onward). The data was then used to determine if there were any significant differences in achievement results on items pertaining to the different curricula over time.

The second factor to consider with the student assessments is that of numeracy support. In particular it was to compare the student achievement on the provincial mathematics assessments for those who were in classrooms that received numeracy support to those that did not.

To strengthen the findings of changes in student achievement due to the curriculum change and numeracy support, qualitative evidence was gathered through focus groups and interviews from numeracy support teachers and one mathematics program specialist who worked with classroom teachers. These participants also accounted for observed increases of interest and enthusiasm for mathematics in students and teachers across the province.

To effectively evaluate the goals of the *Excellence in Mathematics Strategy* the following were conducted:

1. A comparison of student achievement of students from 2007 to 2012 based on items classified as being part of the new, common, or old curricula.
2. A comparison of student achievement in those classrooms that received numeracy support to those classrooms that did not receive numeracy support.
3. A collection and analysis of qualitative evidence to support any change in student achievement.

4. A collection and analysis of qualitative evidence to support any increase in interest and enthusiasm for mathematics.

This chapter began with a background to *Excellence in Mathematics Strategy*, describing the numeracy support teacher model, the mathematics curriculum review, and the subsequent curriculum implementation of the WNCP Common Curriculum Framework (2006), followed by the research questions and a description of the Provincial Mathematics Assessments used for analysis. In the remaining chapters, Chapter 2 is the literature review sharing about the background to the *Excellence in Mathematics Strategy*, mathematics achievement in Newfoundland and Labrador, the learning and teaching of mathematics, and the professional development of teachers. Chapter 3 is the method describing the program evaluation design using Wholey's (1979) logic model as the basis for answering the research questions. Chapter 4 is the results which shares the quantitative student mathematics achievement results with reference to the curriculum change and numeracy support, and the finding from the focus groups and interviews of numeracy support teachers regarding their experiences and observations of themselves, their teachers and students in classrooms across Newfoundland and Labrador. Chapter 5 supplies a summary sharing the conclusions, some limitations to the research, and some further recommendations for the learning and teaching of mathematics in Newfoundland and Labrador and elsewhere.

Chapter 2
Literature Review

"Any serious fundamental change in the intellectual outlook of human society must necessarily be followed by an educational revolution" (Whitehead, 1929, p. 77).

Introduction

Four areas of literature related to the *Excellence in Mathematics Strategy* are identified in this chapter. First, a background is provided demonstrating how the *Excellence in Mathematics Strategy* came to be through the analysis of a Standards-based curriculum in North America and particularly in Newfoundland and Labrador. Second, the research is provided on Newfoundland and Labrador students' achievement in mathematics at the provincial level through the provincial mathematics assessments and at the national and international levels through other assessment programs. An analysis of how students achieve on provincial criterion reference tests is provided. Third, an analysis of the recent research topics on the teaching and learning of mathematics is provided. Finally an analysis of how one improves the student achievement and teaching of mathematics through professional development of teachers is provided.

Standards-Based Curriculum

Sixty years after Whitehead published his essay *The Mathematics Curriculum*, the National Council of Teachers of Mathematics (NCTM, 1989) published *Curriculum and Evaluation Standards for School Mathematics* (the *Standards*). The *Standards* had two goals: to "create a coherent vision of what it means to be mathematically literate in a rapidly growing and changing world"; and to "create a set of standards to guide the revision of the school mathematics curriculum" (NCTM, 1989, p. 1). A standard is

defined as “a statement that can be used to judge the quality of mathematics curriculum or methods of evaluation. Thus, standards are statements about what is valued” (NCTM, 1989, p. 2). The *Standards* was the beginning basis for many Canadian and American jurisdictions to change their mathematics curriculum and to incorporate the 54 standards, including what topics to give increased attention in the school curriculum. The document was used as a blueprint for curriculum development and as an assessment basis to determine whether students “met the standard,” although these were not the intent of the *Standards* (Schoenfeld, 2004).

The *Standards* was a fundamental change in moving mathematics education to a student-centred curriculum grounded in the philosophy of learning being an active process rather than traditional development of mathematics skills with drill and practice. The *Standards* was organized around the following goals for all students: “(1) learn to value mathematics, (2) become confident in the ability to do mathematics, (3) become mathematical problem solvers, (4) learn to communicate mathematically, and (5) learn to reason mathematically” (NCTM, 1989, p. 5).

Schoenfeld (2004) described the *Standards* as both conservative and radical, by being vaguely written from a consensus of the authors for a broad audience of mathematics teachers and to challenge the traditional elitist curriculum where high school mathematics was meant for only those students who were university bound. An educational revolution followed in educational jurisdictions across Canada and the United States with the rewriting of their mathematics curricula in line with the *Standards*. For the first time many provinces in Canada took initiatives to create common curriculum frameworks, for example the Atlantic Canadian publication of the *Foundation for the*

Atlantic Canada Mathematics Curriculum (1993) and in Western Canada the publication of the *Common Curriculum Framework for K – 12 Mathematics* (1995).

Since the publication of the *Standards* in 1989 and the resulting multitude of mathematics curricula, concerns arose across North America about the mathematics teaching methods and student results. There was much published acrimony, leading to the term "math wars." Those who laid the blame on NCTM and the resulting curriculum advocated for the mathematics curriculum to return to the "basics" and not follow the *Standards* of the NCTM. Schoenfeld (2004) detailed the political background and evolution of the math wars in the United States following the Reagan administration report *A Nation at Risk* (National Commission on Excellence in Education, 1983). This report brought political pressure on mathematics achievement in American schools. The NCTM *Standards* were developed in response. Schoenfeld (2004) also described the political leaders who influenced mathematics education and the leadership position NCTM took in mathematics education through to today. The debate continues today locally here in Newfoundland and Labrador as some of the public and teachers do not support the idea of teaching mathematics with conceptual understanding, believing it interferes with basic skill development, which is in contrast to the literature (AERC, 2007).

Mantyka (2007) described the *Standards* as recommending "an increased emphasis in problem solving and a decreased emphasis in numeric and symbolic manipulation" (p. 67). She continues that, "while this is not necessarily a bad thing, taking it in the extreme, as has been the case in the new curricula, is disastrous." She writes about students who get accepted into Memorial University with good grades in

high school mathematics only to fail Memorial University's mathematics placement tests. Since they were not "proficient to a point of automaticity" in fundamental mathematics elements of multiplication facts, how to factor polynomials, or the laws of exponents, they could not pass first year calculus unless there is a remediation done at university (Mantyka, 2007). The *Math Curriculum Review: Final Report* (AERC, 2007) found strong evidence that teachers felt that the balance between the conceptual and investigative approach to mathematics and the mastery of basic skills has shifted too far to the former. Students were progressing through the grades without having mastered basic skills needed as more advanced mathematics content is introduced.

A decade later, *Principles and Standards for School Mathematics* (*Principles and Standards*) was released by NCTM to clearly articulate the goals for students and the best vision for teaching and assessing mathematics (NCTM, 2000). The principles of equity, curriculum, teaching, learning, assessment, and technology reflect the "basic precepts that are fundamental to a high-quality mathematics education" (NCTM, 2000, p. 6). The number of standards originally proposed by the NCTM decreased from 54 to 10. There were now only five content standards (number and operations, algebra, geometry, measurement, and data analysis and probability) and only five process standards (problem solving, reasoning and proof, connections, communication, and representation). The intention of this reduction was to have the content standards entwined within the process standards. An example is that you cannot consider learning algebra without being able to have multiple representations using the concrete, pictorial, and abstract along with making connections between these representations and to the real world around us.

In September 2007, schools across Western Canada and the Territories began implementing an updated mathematics curriculum as part of the WNCP in Grades Kindergarten, 1, 4, and 7. The full implementation through to Grade 12 was completed by the 2012 – 2013 school year. This is the second time in this generation that the mathematics curriculum has been overhauled, and the result is now a curriculum guide vastly different from the first *Common Curriculum Framework* of 1995.

The new WNCP *Common Curriculum Framework for Mathematics K – 9* (2006) was released only months prior to the NCTM report *Curriculum Focal Points for Prekindergarden through to Grade 8: A Quest for Coherence* (2006). Both agree that the current major problem of mathematics curricula was that it is "a mile wide and an inch deep" (NCTM, 2006). Locally, in Newfoundland and Labrador, teachers viewed their mathematics curriculum being too crowded and that it is impossible in most grades to cover all of the expected outcomes in the depth required for adequate student learning (AERC, 2007).

In particular WNCP (2006) found that there was too much content for the allocated instructional time and that there should be an emphasis on teaching fewer topics and teaching those topics in more depth with a particular increased focus on early numeracy. Focusing on numeracy in the early grades, and moving topics traditionally taught in earlier grades would allow more time for teachers and students to develop numerical literacy (WNCP, 2006). Some examples are moving transformations from Kindergarten to Grade 4, moving tessellations from Grade 5 to Grade 8, starting data analysis in Grade 2, and starting chance and uncertainty in Grade 5 instead of Grade 1 (WNCP, 2006). Allowing for this early start of numeracy did not mean teachers should

not use other means to enrich a students' learning. Teachers could still use topics that traditionally were a separate outcome as a way to teach the outcomes of early numeracy. An example would be to use data analysis to allow children to make connections and allow multiple representations of adding and subtracting numbers.

The release of the second WNCP *Common Curriculum Framework* (2006) could allow an education revolution by having the NCTM *Principles and Standards* (2000) staying the course and maintaining its place in classrooms across Canada and the United States. This is a move from using formal algorithms to using personal strategies to develop understanding. Many disagree with the goals of the *Principles and Standards*, advocating a return to the basics by completing drill and practice of traditional algorithms until they become second nature to the point of automaticity.

After much debate within and between the communities of mathematics education and mathematics, common ground has been reached about the learning of mathematics. It should go beyond mathematical facts and procedures and include being able to reason mathematically and to interpret and solve mathematical problems (Artelt, Baumert, Julius-McElvany, & Peschar, 2003; Boaler, 2002; NCTM, 1989; National Mathematics Advisory Panel (NMAP), 2008). In particular, NMAP (2008) reported three critical foundations of proficiency for elementary mathematics. First, students are to develop fluency with whole numbers, in particular to have an automatic recall of basic facts for addition and multiplication from 0 to 10. Second, students are to develop fluency with fractions, including the relationships between ratios, proportions, and percentages as they set the foundation for algebra. Finally, students are to develop particular aspects of geometry and measurement, including lengths and angles, similar triangles, and

properties of two- and three-dimensional shapes. These crucial foundations are similar in nature with the WNCP *Common Curriculum Framework* (2006).

NCTM (2006) and WNCP (2006) attempted to confront the problem of North American mathematics curriculum outcomes spiralling through the grades. Topics became more focused within particular grade levels allowing students to have an opportunity to develop a greater proficiency in mathematics concepts and accompanying procedures. Proficiency is both computational fluency while at the same time having an understanding of the underlying ideas and principles (Ball et al., 2005).

In the Spring of 2014, Nhung Tran-Davies, a parent and physician in Alberta collected over 12 000 signatures to petition to the Government of Alberta to go "back to the basics" in regards to teaching Kindergarten to Grade 6 mathematics in schools and has led rallies outside the Alberta Legislature (Edmonton Journal, 2014). The Globe and Mail reported the Education Minister of Alberta has "bent to pressure" regarding the curriculum changes being pushed by parents and will "require students to memorize their multiplication tables" starting September 2014, "dealing a set-back to the creative-math movement" (Alphonso, 2014). This recent public debate in Alberta is a reaction to the current curriculum being taught in both Western and Eastern Canada, and is still not settled between the Alberta public and their Ministry of Education.

Curriculum Change in Newfoundland and Labrador

The Department of Education's *Excellence in Mathematics Strategy* arose out of concerns about the adequacy of the mathematics curriculum and particularly with performance on provincial, national, and international assessments being a preparation for higher education (AERC, 2007). Similar to other jurisdictions across Canada and the

United States, Newfoundland and Labrador was not immune to the "math wars." Prior to the release of the *Excellence in Mathematics Strategy* and the *Math Curriculum Review*, the mathematics curriculum received attention in the media through numerous letters to the editor, editorials, articles, and attention on local radio current affairs and call-in shows (AERC, 2007) and previously referenced in Chapter 1.

To answer the call by the public about the mathematics curriculum and student results, the Department of Education funded the *K – 12 Mathematics Curriculum Review: Final Report* completed by AERC with Dr. Robert Crocker as the lead researcher. Submitted in November 2007 and released by the Department of Education in March 2008, one of the main recommendations was to adopt the WNCP Common Curriculum Framework as the basis for the Newfoundland and Labrador mathematics curriculum. For the first time since the establishment of APEF in 2003 and the release of the Atlantic Canadian initiative of a common mathematics curriculum, Newfoundland and Labrador was breaking away from the three Maritime provinces and deciding to follow another established curriculum.

The differences between the AERC (2007) proposed implementation schedule (see Table 1) and the actual implementation schedule (see Table 2) differs only with the postponement of one year for the high school curriculum.

Table 1.

Proposed Implementation Schedule

Year	2008	2009	2010	2011	2012
Grade	K, 1, 4, 7	2, 5, 8	3, 6, 9, 10	11	12

Table 2.

Actual Implementation Schedule

Year	2008	2009	2010	2011	2012	2013
Grade	K, 1, 4, 7	2, 5, 8	3, 6, 9	10	11	12

The mathematics curriculum being phased out was implemented between 1999 and 2005. As a provincial curriculum, its origins stem from work of the APEF. It has since been superseded by the Council of Atlantic Ministers of Education and Training (CAMET). The guiding structures for the mathematics curriculum are based on the *Curriculum and Evaluation Standards* of the National Council of Teachers of Mathematics (NCTM, 1989).

AERC (2007) found the local mathematics curriculum to be unsustainable in its current form. It had too many outcomes with equal emphasis on all strands required at many levels. This "spiral approach" resulted in the repetition of outcomes, at greater levels of depth, in successive grades. Public and teacher support of the mathematics curriculum must be achieved to be successful. NCTM and WNCP have both addressed similar concerns to Newfoundland and Labrador.

AERC (2007) also found a major issue with the local curriculum to be the frustration for students, teachers, and parents with the perceived low quality of textbooks, the lack of match of outcomes in the textbooks, the lack of appropriate practice in the textbooks. Due to the problem of market size, cost, and time to produce textbooks for a local curriculum, adoption of the WCNP-based texts resolved many of these issues (AERC, 2007).

Mathematics Student Achievement

Mathematics achievement of students in Newfoundland and Labrador is reported at the provincial level with the provincial mathematics assessments administered by the Department of Education. It is reported at the national level with the Pan-Canadian Assessment Program (PCAP), formerly known as the School Achievement Indicators Program (SAIP). It is also reported at an international level with the Programme for International Student Assessment (PISA) in which Canada is compared to other countries and the provinces are compared to these countries as well.

Newfoundland and Labrador Provincial Mathematics Assessments

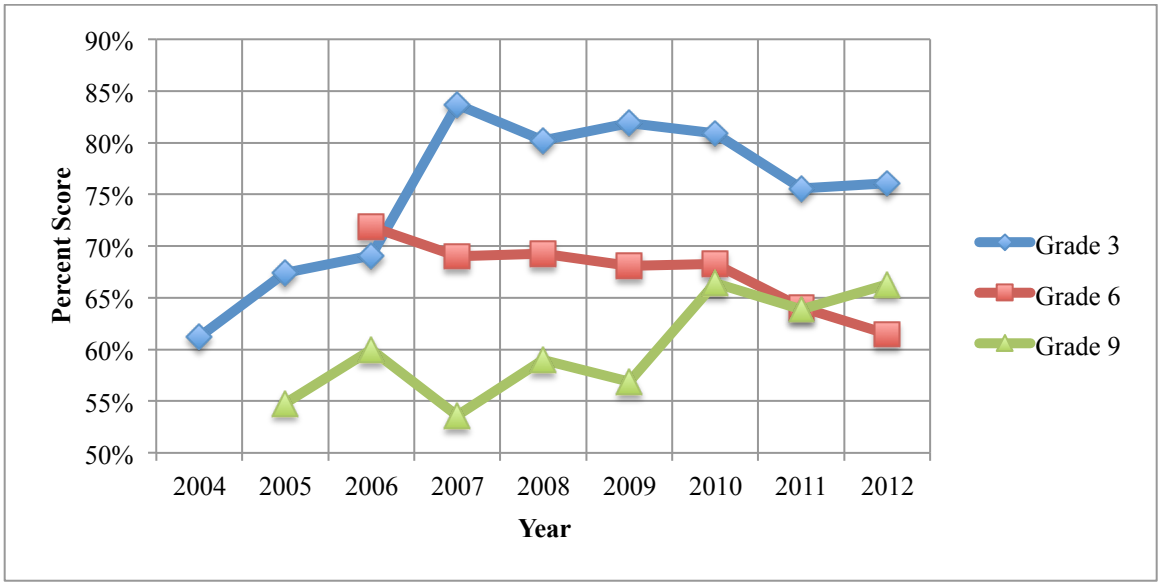
Provincial mathematics assessments are administered annually to all Grade 3, 6, and 9 students in Newfoundland and Labrador by the Department of Education. These assessments are criterion reference tests and consist of both selected response and constructed response items. Prior to 2010, all yearly assessments were released to the public. From 2010 onward, assessments were made secure by not making them available to the public, thus allowing the Department to anchor, or reuse items, from one year to the next. Although the general format of the assessments remained the same, the number of items varied each year. Due to financial restraints across all Departments of the Government of Newfoundland and Labrador in the 2013 budget, mathematics was not assessed for Grades 3, 6, and 9 in June 2013 (Newfoundland and Labrador Department of Finance, 2013).

Figure 1 displays the provincial assessments results with the students starting to be assessed annually for Grade 3 in 2004, Grade 6 in 2006, and Grade 9 in 2005. As final scores were not published consistently on the Department of Education website, results

could be calculated from the provincial results through access to the School Demographics and Achievement Data (Newfoundland and Labrador Department of Education, 2002, 2003, 2004, 2005a, 2005b, 2006a, 2006b, 2006c, 2007b, 2007c, 2007d, 2008a, 2008b, 2008c, 2009a, 2009b, 2009c, 2010a, 2010b, 2010c, 2011a, 2011b, 2011c, 2012a, 2012b, 2012c). The results for the selected response items and closed-constructed response items show a pattern of annual improvement for Grade 3 from 2004 to 2007, and then a slight trend of decline thereafter. The results for Grade 6 show a steady but slight decline from 2006 to 2012. The results for Grade 9 show about a 10% improvement over time from 2005 to 2012. When considering these results in analyses, one must remember the variability in the assessments from year to year, as the number of items and the difficulty of the items changed annually, and the assessments started to be secure from the public from 2010 onward.

Figure 1.

Newfoundland and Labrador Provincial Mathematics Assessment Results



School Achievement Indicators Program (SAIP)

The School Achievement Indicators Program (SAIP) was a pan-Canadian assessment of 13-year-old and 16-year-old students that was in place from 1993 to 2004. During that time, three mathematics assessments were conducted in 1994, 1997, and 2001. SAIP was replaced by a new assessment called the pan-Canadian Assessment Program (PCAP) starting in 2007.

The SAIP performance of 13-year-old students in Newfoundland and Labrador was similar to most other provinces with the exception of Quebec, Alberta and British Colombia (AERC, 2007). Performance did not change much over the three assessments. For 16-year-olds, performance in Newfoundland and Labrador was lower than that for most other jurisdictions, especially in 2001. Performance also declined over this period as it did for several other jurisdictions. Again the highest performing jurisdictions were Quebec, Alberta, and British Columbia. Nova Scotia was also fairly high in the first two assessments but declined significantly in 2001.

Pan Canadian Assessment Program (PCAP)

PCAP assesses the performance of 13-year-old students in three core subjects of reading, mathematics, and science. Administered once every three years, PCAP had science as the major domain for 2013, mathematics for 2010, and reading for 2007.

Table 3 displays the mean scores of the ten Canadian provinces and the Yukon Territory. With a Canadian mean score of 500, students in Newfoundland and Labrador performed lower than most jurisdictions, with an average score of 472, ranking 8th out of 11 jurisdictions (Council of Ministers of Education (CMEC), 2011). Three years previous, in 2007, Newfoundland and Labrador performed significantly higher in the

mathematics assessment than those in other Atlantic provinces, with an average score of 478. Each year Quebec, Ontario, and Alberta were either at or above the Canadian mean (CMEC, 2008, 2011). Newfoundland and Labrador students wrote the 2007 PCAP under the APEF curriculum, whereas they wrote the 2010 assessment under the newly implemented WNCP curriculum, although it was the first year of the program for Grade 8 students.

Table 3.

PCAP 2007 - 2010 Results in Mathematics - Canada and Jurisdictions

(CMEC, 2008, 2011)

	2007		2010	
	Mean	Rank	Mean	Rank
Newfoundland and Labrador	478	6	472	8
Prince Edward Island	450	11	460	11
Nova Scotia	457	9	474	7
New Brunswick	461	8	478	5
Quebec	517	1	515	1
Ontario	506	2	507	2
Manitoba	479	5	468	10
Saskatchewan	461	7	474	6
Alberta	499	3	495	3
British Columbia	484	4	481	4
Yukon	451	10	469	9

Programme for International Student Assessment (PISA)

The Programme for International Student Assessment (PISA) project began in 2000 to focus on the capabilities of 15-year-olds to assess students on mathematical, reading, and scientific literacy (Brochu, Duessing, Houme, & Chuy, 2013). The assessments target students in the entire Organisation for Economic Co-operation and Development (OECD) countries as well as a number of partner countries. Mathematical literacy was the major focus for the 2003 and 2012 assessments. Therefore the mathematics results for those years are more detailed and reliable than those for other years.

Table 4 displays the averages for the OCED, Canada, and the provinces. The Canadian averages for each PISA were significantly higher than the OECD averages. These were close to the highest among the participating countries. On international comparisons in 2012, when mathematics was the major domain assessed, Quebec ranked 8th below seven Asian countries. To compare, Alberta was second only to Hong Kong-China in 2003. Newfoundland and Labrador clustered among the other Atlantic provinces with average scores higher than the OECD average, but lower than those for other Canadian jurisdictions. Newfoundland and Labrador's ranking over time has dropped when compared to all countries and all Canadian provinces (treated as countries for the comparison) with the ranking of 16th in 2003, 21st in 2006, 27th in 2009, and 37th in 2012, only surpassing Prince Edward Island consistently. Newfoundland and Labrador's scores had declined by 26 points over the nine-year span, compared to Canada's national scores dropping by 24 points. Newfoundland and Labrador's results are low when compared within Canada, but higher when compared by international standards. Newfoundland and

Labrador students writing the 2012 PISA were the first students to be following the newly implemented WNCP curriculum from when they were in Grade 7 up to that point in time, being Grade 10.

Table 4.

PISA 2000 - 2012 Results in Paper-Based Mathematics - OECD, Canada, Provinces

(Brochu et al. (2013); Knighton, Brochu, & Glusynski (2010); Bussière, Knighton & Pennock (2007); Bussière, Cartwright, & Knighton (2004); Bussière, Cartwright, Crocker, Ma, Oderkirk, & Zhang (2001)).

	2000	2003	2006	2009	2012
OECD	500	500	498	497	494
Canada	533	532	527	527	518
Newfoundland and Labrador	509	517	507	503	490
Prince Edward Island	512	500	501	487	479
Nova Scotia	513	515	506	512	497
New Brunswick	506	512	506	504	502
Quebec	550	537	540	543	536
Ontario	524	530	526	526	514
Manitoba	533	528	521	501	492
Saskatchewan	525	516	507	506	506
Alberta	547	549	530	529	517
British Columbia	534	538	523	523	522

The 2012 PISA included a new computer-based assessment of creative problem-solving. The time-restricted assessment focused on general reasoning skills, the ability to

regulate problem-solving processes, and the willingness to do so by assessing students with problems that do not require expert knowledge to solve. The PISA 2012 results show that "Canadian youth are well equipped to apply their skills and competencies to solve challenging problems" (CMEC, 2014, p. 13). "Canada is one the top performing countries, being surpassed by only seven of the 44 participating countries and economies" (p. 13). Newfoundland and Labrador scored 504, above the OECD average of 500, yet below the Canadian average of 526.

Overall, these results do not point to any drastic deficits in mathematics achievement in this province relative to the highest performing jurisdictions but rather to a persistent low level difference that seems immune to change over time. Since most of the results predated the full implementation of the APEF curriculum, and because so many other factors influence achievement, it is not possible to determine that these results are in any way related to curriculum change (AERC, 2007).

The 1989 *Mathematics/Science Task Force Report* took the need to improve achievement levels in mathematics and science as its core argument, stating that the time had come to create a culture of high expectations. In 1994, following the *Royal Commission* (Government of Newfoundland and Labrador, 1992), the government produced a blueprint for improving learning (Government of Newfoundland and Labrador, 1994). The declared goal was to bring about a substantial improvement in the quality of education, to the point where the achievement of our students would rank with the best in Canada. This goal is based on the belief that high levels of education are essential to the economic and social well-being of the province. AERC (2007) stated that this goal had not yet been achieved. However there is evidence that the government and

the public are ready to set higher targets for achievement and to implement measures to accomplish these targets. AERC found that the *Excellence in Mathematics Strategy* and other components of the government's educational policy are evidence that this is the case. They stated there is "the need to create a culture of high achievement" and to bring "the achievement of students in [Newfoundland and Labrador] to a level comparable to the best in Canada" (AERC, 2007, p. 87). The achievement results of Newfoundland and Labrador students has yet to be at a level equal to the best in Canada, and is showing a decline over time, both nationally and internationally.

The Teaching and Learning of Mathematics

The debate about mathematics education is not necessarily about what we teach children but how to teach children (Marshall, 2006). While an agreement is now reached on what should be taught in mathematics, there is a larger concern about how to improve students' mathematics achievement (AERC, 2007; Hiebert & Stigler, 2004; Jacobs et al., 2006; Stigler & Hiebert, 1999). The Conference Board of Mathematical Sciences (CBMS) states that "perhaps the most publicized challenges involve the education of elementary teachers" (CBMS, 2012, p. 3-4) and that these teachers have well-established unproductive traditional beliefs about mathematics (CBMS, 2012). "For many prospective teachers, learning mathematics has meant only learning its procedure and, that many, in fact, have been rewarded with high grades in mathematics for their fluency in using procedures" (CBMS, 2012, p. 11). They describe the situation as grim, but not intractable, with "collaborations between mathematicians, and mathematics educators in teacher education making remarkable progress in developing ways to address teachers'

unmathematical beliefs and practices as well as gaps in their mathematics knowledge" (p. 11).

As indicated by the CBMS (2012), one of the main factors influencing student achievement in mathematics is teachers' mathematical knowledge, also known as mathematical knowledge for teaching (Hill, Ball, & Schilling, 2008) or mathematics-for-teaching (Davis & Simmt, 2006). "It is not enough for teachers to rely on their past experiences as learners of mathematics" (CBMS, 2012, p. 23). Student learning and student achievement are closely related to teachers' experiences presented to them in classrooms, as what teachers know and do make a difference in student achievement (Darling-Hammond, 2000; Hattie, 2003, NCTM, 2000). Teachers' learning and continuous growth are identified to improve the quality of education offered to students (Darling-Hammond, 2005, 2000; Darling-Hammond, Wei, Andree, Richardson, & Orphanos, 2009; Desimone, 2011; Hattie, 2003).

Mathematical Knowledge for Teaching

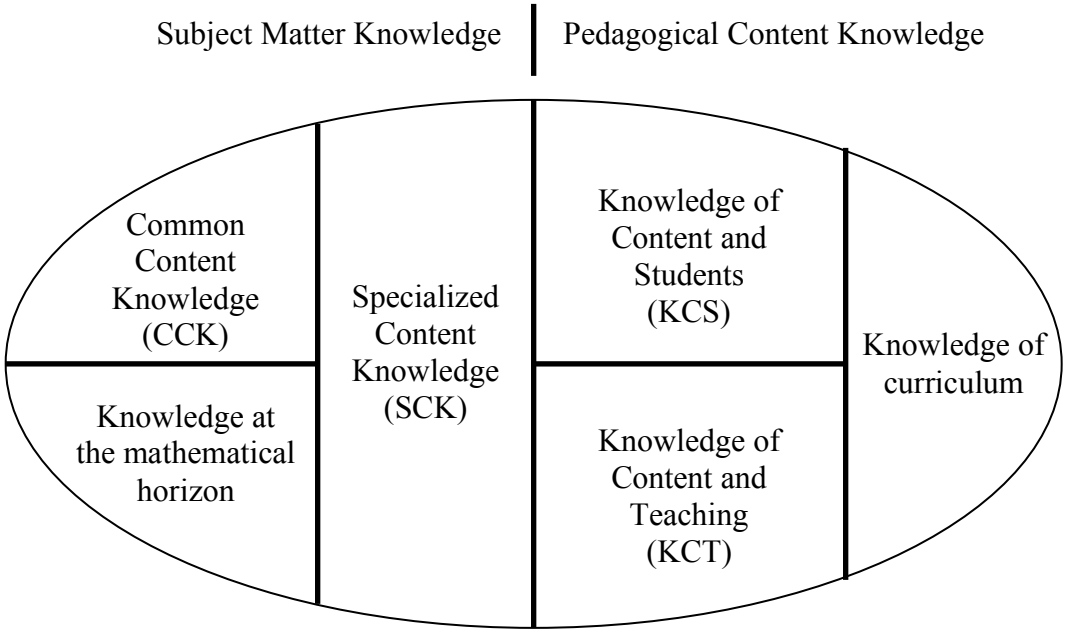
Mathematical knowledge for teaching (MKT) is defined as "the mathematical knowledge that teachers use in the classrooms to produce instruction and student growth" (Hill et al., 2008, p. 374) and it stems from the seminal work of Shulman's (1986) concept of pedagogical content knowledge (PCK). PCK is known as specialized content-related knowledge for teaching. Teachers who develop PCK are able to anticipate students' understanding, and more importantly, misunderstandings within a specific topic, and develop certain strategies to use when students demonstrate misunderstandings. PCK differs from the subject matter knowledge of mathematics. If one has only subject matter knowledge, then one is able to correctly calculate, simplify,

or solve a posed mathematics question, but does not necessarily know what possible errors may arise from students' solutions.

Hill et al. (2008) developed a model describing MKT using Schulman's ideas of PCK and subject matter knowledge (See Figure 2).

Figure 2.

Domain Map for Mathematical Knowledge for Teaching (Hill et al., 2008)



Subject matter knowledge includes common content knowledge (CCK) and specialized content knowledge (SCK). CCK, equivalent to Shulman's (1986) notion of subject matter knowledge, is the mathematical knowledge used in teaching that is also used by other professionals when they use mathematics. SCK is the mathematical knowledge that allows teachers to engage in specific teaching tasks, such as how to represent mathematical ideas, to give mathematical explanations for common rules and procedures, and to understand different solutions provided by students to mathematical problems posed. The learning and teaching of mathematics is not part of the subject matter knowledge, but of PCK that includes knowledge of the curriculum, knowledge of

content and students (KCS), and knowledge of content and teaching (KCT). KCS is defined as "content knowledge intertwined with knowledge of how students think about, know, or learn this particular content" (Hill et al., 2008, p. 375). KCS is separate from knowledge of teaching, but builds on students' mathematical thinking or helps correct students from making more errors. KCS is also separate from a teacher's knowledge of curriculum materials.

Profound Understanding of Fundamental Mathematics

Ma (1999) researched how teachers develop mathematical knowledge for teaching through the notion of one having a profound understanding of fundamental mathematics (PUFM). Her ground-breaking study about the knowing and teaching of elementary mathematics compared 23 "above average" American elementary teachers with 72 Chinese elementary teachers from a range of schools.

One of the most fascinating examples in her study was about teachers generating representations by dividing fractions. Only 43% of American teachers correctly calculated $1\frac{3}{4} \div \frac{1}{2}$ but all of the Chinese teachers calculated it correctly. Only one American teacher created an accurate story to represent the division of fractions, as compared to 90% of the Chinese teachers. Ma (1999) believes this reflects that American teachers lack understanding about the division of fractions because they lack the ability to make connections and links. She believes that this ability, to make connections and links, is vital to effective teaching of mathematics.

Goya (2006) also reports that her preservice elementary teachers do not understand fractions as they cannot demonstrate beyond the division algorithm and most are unable to give real-world examples of dividing by a fraction. A short video by Appel

and Garneau, *Rote Procedures and Personal Strategies* (Zapple Educational Consulting, 2007) parodies the traditional procedural yet concept-empty idea that students are "not to question why, just invert and multiply" when dividing fractions. This humourously reinforces the notion of procedural learning while lacking conceptual understanding.

The lack of connection and inability to represent various concepts by teachers in Ma's (1999) study is one example of how teachers have a traditional procedural knowledge of mathematics, even though they espouse the philosophy of the NCTM process standards of connections, communication, reasoning, representation, and problem solving. Research supports a disparity between teachers' views of the standards and actual practice of the standards in their classrooms (Stigler & Hiebert, 1999; Hiebert & Stigler, 2004; Jacobs et al. 2006). The Third International Mathematics and Science Study (TIMSS) (1995) included classroom video studies of mathematics classes in terms of how daily lessons were organized, if teachers knew about the NCTM standards, and if those same teachers demonstrated practices of the standards in their classrooms. 95% of American teachers were aware of the reforms from NCTM and claimed that they were implementing the reforms into their classrooms, while 70% of American teachers said they had implemented them and that evidence would be found in their classrooms (Stigler & Hiebert, 1999). Contrary to the teachers' claims, the video study found little evidence of teachers using these notions in the classroom (Stigler & Hiebert, 1999). This research continued during the 1999 TIMSS, which found there was little to no growth of teachers' lessons in line with the *Principles and Standards* (NCTM, 2000) over this four-year span (Jacobs et al., 2006).

In order to have a solid pedagogical representation of a mathematical concept, teachers should first have a comprehensive understanding of the concept. They have to develop "mathematics eloquence", meaning to think rigorously, use mathematics terms consistently and correctly, and to justify mathematical arguments. It is not necessary to know mathematical concepts beyond the elementary mathematics level to teach children, but it is necessary to know the concepts being taught with a PUFM (Ma, 1999). Her notion of PUFM can be simply stated as "to know how and to know why." More precisely, PUFM is to be able to carry out an algorithm and to know why it makes sense mathematically, in a deep, broad, and thorough sense. Teachers with this understanding establish "knowledge packages" which include meanings of concepts, relate them to other mathematical concepts, while being able to make representations of these concepts, and make connections between these various concepts.

A teacher with PUFM is able to make connections within both simple and complex concepts and procedures of mathematics. Teachers must be flexible as they work with students and must be able to work with multiple student perspectives as they guide their students to understand mathematical concepts and procedures. They must recognize basic ideas of simple yet powerful concepts, like equality, and have positive attitudes which influence their students to focus on effort. Finally, teachers must have a longitudinal coherence of the whole curriculum, knowing what concepts were taught to students previously and future concepts that students will encounter so that teachers can lay a solid foundation of key concepts and procedures.

Mathematics-for-teaching

Similarly, Davis and Simmt (2006) distinguish a difference between mathematics and mathematics-for-teaching arguing that for teachers "knowledge of established mathematics is inseparable from knowledge of how mathematics is established" (p. 297). Teachers need to know the mathematics as a stable concept being taught but at the same time move within the dynamic classroom considering how students understand the mathematics around them. One concept shown as an abstract algorithm may be effective with one child's understanding, but another may need to play with manipulatives, create drawings, or write what they experience as a descriptive metaphor. Mathematics-for-teaching moves us as educators from the forefront and puts the collective classroom of interactive students at the centre.

Some believe to be a competent mathematics teacher, all one needs is to have a teacher with a strong mathematics background, some common sense, and a small amount of general pedagogical training (Schoenfeld, 2006). To the contrary, teachers must have a strong base of pedagogical competency. PUFM has a mathematical and pedagogical base. This differs from other professionals who use mathematics in their careers. Teachers establish meaning of concepts while also developing numerous ways that concepts can be understood and represented, while being able to make connections to other mathematical concepts and procedure.

One does not develop a PUFM while being a student, during a pre-service teacher program, or during the first years of teaching. Rather it is developed over time by learning, working with colleagues, teaching students, doing problems oneself, and studying materials intensely (Ma, 1999). These teachers who develop their PUFM are

provided time during the school day to study their teaching material, consult with other teachers in the form of lesson studies, and reflect on their own teaching practices. PUFM is developed as a teacher empowers ones' students with mathematical competence. Teachers need to be in a teaching and learning environment so that they can improve their knowledge of school mathematics while they simultaneously improve their teaching of mathematics.

Davis and Simmt (2006) claim the key to mathematics teachers' competence is the ability to translate notions from one symbolic system to another by moving among underlying images and metaphors of procedural knowledge. Davis and Simmt state that the issue of teachers' knowledge of mathematics has been prominent for several decades with little progress made towards a consensus on the question of what teachers need to know. They state that in most Canadian universities prospective secondary education programs require a core number of mathematic courses usually drawn from mathematics department courses with the bulk including calculus, linear algebra, discrete mathematics and introductory statistics. Most elementary education programs require at least one mathematics department course. This practice is based on the assumption that courses in formal mathematics are vital to effective teaching even though this belief is not easily substantiated. Davis and Simmt state there are a growing number of researchers who claim that there is a distinct knowledge associated with mathematics teaching. Teachers must be adept at interpreting concepts for learners. This competence requires knowledge of how mathematical topics are connected, how ideas anticipate others, what is a valid argument, etc. This is not a watering down of formal mathematics but a demanding area of mathematical work.

Teaching for understanding is not easy for teachers, especially when they have been educated primarily using rote memorization. We cannot expect students to understand if their teachers do not. Mathematical concepts that our brain does not understand are more likely to be forgotten (Marshall, 2006). Maybe when students do not perform well on standard assessments in secondary and post-secondary mathematics, it could be due to students' limited exposure to understanding mathematics when learning by rote memorization in elementary school. We expect our students to know elementary mathematics, but for post-secondary we expect them to know it well, and that takes understanding and not just computing and memorizing. For effective learning to take place classroom teachers need to include problem solving as well as skills practice, teamwork as well as individual learning and teacher exposition, real-life problems as well as abstract problems, learning by talking as well as silent learning in their teaching (Sfard, 2003).

Two factors directly relate to student achievement. First, if our teachers do not develop a profound understanding of this foundational mathematics, then student achievement will not improve (Ball et al., 2005; Hill et al., 2008; Ma, 1999; NMAP, 2008). Second, children's beliefs about the importance of effort in learning mathematics relate to greater engagement in mathematics learning and through this engagement mathematics achievement is improved. However many teachers, parents, and the public view children's learning of mathematics to be an inert talent and ability, instead of learning and practicing for hours of practice to improve their abilities in mathematics (Gladwell, 2008; Ma, 1999; NMAP, 2008).

Educational Change

To bring about change in the teaching and learning of mathematics in Newfoundland and Labrador, one must first consider the broader area of educational change first. Fullan (2001) describes change as a process and that one of the keys to successful change is the improvement of relationships. Fullan indicates that educational change "requires intensive action sustained over several years to make it possible both physically and attitudinally for teachers to work naturally together in join planning; observation of one another's practice; and seeking, testing, and revising teaching strategies on a continuous basis. It means changing the cultures of classrooms" (Fullan, 2007, p. 7). Education change requires capacity building with a focus on results where reculturing of how teachers come to question and change their beliefs and habits is what is needed.

Most pre-service teachers enter teaching with the aim to make a difference in students' lives and society (Stiegelbauer, 1992). Once teachers start in the classroom, most fall into a routine of feeling isolated from other teachers and from opportunities to grow professionally (Breyfogle & Spotts, 2001; Neufeld & Roper, 2003). Coaches or specialists are put in classrooms to produce change (Anstey & Clake, 2010). To bring change, coaches assist teachers in creating a personal vision, develop the desire of continuous personal growth, increase personal mastery and know-how, and create a culture of collaboration with other teachers (Fullan, 1993). According to Fullan, these must be present for effective change.

Fullan (2007) indicated three components for implementing a new program:

(1) the possible use of new or revised materials, (2) the possible use of new teaching approaches, and (3) the possible alteration of beliefs. “Change has to occur in practice along the three dimensions in order for it have a chance of affecting the outcome.” (p. 31). It is possible to change “on the surface” by agreeing to goals, using particular materials, and imitating behaviours without understanding the principles and rationale of the change. It is possible to value and be articulate about the goals of the change without understanding their implications for practice.

Fullan (2007) indicates roles of teachers in bringing change into practice:

- Teachers must draw out and work with the preexisting understandings that their students bring with them.
- They must teach some subject matter in depth, providing many examples in which the same concept is at work and providing a firm foundation of factual knowledge.
- The teaching of metacognitive skills should be integrated into the curriculum in a variety of subject areas.

Datnow and Park (2010) indicate a focus in Western countries to create a systematic infrastructure to support change across many schools at once, with federal and provincial or state systems of standards and accountability and system-wide implementations of both literacy and numeracy programs. Large-scale educational change is marked by standards, assessments, and accountability as they directly influence instruction and student outcomes. But the instruments are weak because the how and why of teaching and learning remain unaddressed. “Standards provide guidance on classroom content but do not assist teachers in translating standards into effective instructional

practices" (p. 210). One must consider Fullan's (2007) work with continuous and sustainable education change to bring these standards into effective instructional practices.

Districts are key players in educational change by helping schools to focus on student achievement and quality of instruction (McIver & Farley, 2003; Togneri & Anderson, 2003). According to Petrides and Nodine (as cited in Datnow & Park, 2010), districts are changing their professional development practices from a focus on compliance to support in order to build the capacity of teachers to participate in decision-making processes and create an organizational culture of inquiry, where professional development is moving to being teacher-focused and teacher-led.

Professional Development

To implement new curricula like WNCP Common Curriculum Framework (2006), mathematics teachers can be supported through on-going professional development by voluntarily participating in professional learning communities lead by lead teachers, mathematics coaches, or numeracy support teachers. Many school districts have established numeracy book clubs like in the Greater Victoria School District where teachers meet regularly to discuss current literature provided and how that is impacting their teaching and student learning. Newfoundland and Labrador added numeracy support teachers in 2007 to assist teachers in improving their mathematics teaching.

AERC (2007) found teachers thought that they did not receive adequate professional development to deal with the APEF curriculum. Some thought that primary and elementary teachers are often not comfortable with mathematics, but it was not clear if the issue could be solved by professional development. It was clear that more intensive

professional development efforts are required if the principles underlying the new mathematics program are to be maintained. The *Math Curriculum Review* recommended the WNCP-based mathematics curriculum implementation be accompanied by an introductory professional development program prior to the first year of implementation, and that numeracy support teachers have a primary role in the delivery of that professional development (AERC, 2007).

Desimone (2009) states that traditional professional development such as workshops and conferences do not address the needs of most teachers. Sowder (2007) states that professional development of teachers must move away from the traditional model of short workshops on single topics which have no continuity or direction and these workshops have little effect on teachers. Sowder summarizes the need for a continual, coherent professional development for teachers. First, teachers need assistance directly related to the day-to-day work of teaching through supporting individual teacher's practice or by guided group discussions about student work, instructional tasks, or cases of instructional practice written by and for teachers. Second, teachers need assistance grounded in the content of teaching and learning as accountability increases with standards reform while teachers need to encounter the discipline as learners themselves before struggling with how to teach it. Third, development is needed to establish and maintain teacher communities of professional practice. Collegiality among teachers is encouraged as they develop capacities to explain, challenge, and critique the work of peers, and teacher leaders develop out of this practice. Fourth, collaboration is needed with experts outside of the teaching community to bring fresh perspectives and ideas about what has proven successful or unsuccessful elsewhere while providing an

analytic stance toward the school improvement process. Finally, there is a need for consideration of the organizational context ranging from unwritten cultural norms to explicit regulations and policies.

Stigler and Hiebert (1999) state professional development within the job requires significant commitment and understanding. Improving teaching is not something that can be left to evening courses or during summer institutes. Improving teaching must be done at school, in classrooms, and it must be seen by teachers, parents, and administrators as a substantial and important part of the teacher's work. Mathematics for teachers is learned through preservice teacher education, by supporting teachers within the first years of teaching, and continually through professional development of teachers (NMAP, 2008).

The Conference Board of Mathematical Sciences (2012) indicates elementary teachers to rarely have sustained professional development centred on mathematics and recommends comprehensive professional development in mathematics. Professional development should "not only aim to remedy weaknesses in mathematical knowledge, but also help teachers develop a deeper and more comprehensive view and understanding of the mathematics they will or already do teach" (p. 23). Once elementary teachers begin teaching they need to "continue opportunities to deepen and strengthen their mathematical knowledge for teaching, particularly as they engage with students and develop better understanding of their thinking" (p. 32).

Professional development may take on a variety of forms. The Conference Board of Mathematical Sciences (2012) continue:

> A group of teachers might work together in a professional learning community, and they might choose to focus deeply on one topic for a period of time. … A

> group of teachers might watch demonstration lessons taught by a mathematics specialist (numeracy support teacher) and then meet to discuss the lessons, plan additional lessons, and study the mathematics of the lessons. … The best professional development is ongoing, directly relevant to the work of teaching mathematics, and focused on the mathematical ideas (p. 32).

Mathematics Specialists

These numeracy support teachers are also known elsewhere as mathematics specialists and may hold the title of elementary mathematics coach, elementary instructional leader, mathematics support teacher, mathematics resource teacher, mentor teacher, or lead teacher (CBMS, 2012). Specialists serve a variety of functions: mentoring their teacher colleagues, conducting professional development, teaching demonstration lessons, leading co-planning or data teams sessions, observing teachers, or serving as the lead teacher for all the mathematics classes for a particular group of students. In addition to an understanding of the content, these specialists are to be "prepared in the areas of the learners and learning (including teachers as adult learners), teaching, and curriculum and assessment. They are asked to develop knowledge and skills in the area of leadership as they are often called upon to function in a leadership capacity at the [school] or district level" (CBMS, 2012, p. 36).

Preparation for programs in mathematics coaching are described as preparing the foundation of the program by defining the coaching, bridging the past to the present and building rapport with teachers (Hull, Balka, & Miles, 2010; Balka, Hull, & Mills, 2010). Further they focus on the coaching model, in particular by focusing on the curriculum as

intended along with planning, coteaching, analyzing, and reflecting on lessons and how to sustain the learning of teaching.

Placing coaches or specialists in K-12 schools have become common practice in literacy, mathematics, and science (Sailors & Shanklin, 2010). Coaches or specialists are placed in schools with the intent of improving teachers' instructional practices and improving the chances of student learning, therefore improving achievement (Campbell & Malkus, 2013; Keller, 2007; Neufeld & Roper, 2003; Obara, 2010). There are many functions for mathematics specialists in particular. Three of these functions have a direct effect on teacher knowledge and have the potential to influence student achievement. First, mathematics specialists can affect change in teachers' instructional practices, strategies, perception, and beliefs about mathematics teaching (Bruce & Ross, 2008; Keller, 2007; Murray, Ma, & Mazur, 2009; Nickerson, 2009; Obara, 2010). Second, mathematics specialists assist in improving students' learning and achievement (Campbell & Malkus, 2011; Dobbins, 2010; Valente, 2013; Foster & Noyce, 2004; Vale et at., 2010). Third, mathematics specialists help teachers have a better understanding of curriculum (Harrison & Killion, 2007; Von Rotz, 2006).

Some teachers are willing to try different practices and strategies if they are supported by and collaborate with a colleague in the process (Kohler, Crilley, & Sherarer, 1997). Despite considerable investment of time, effort, and resources, when schools embark in peer coaching activities there are clear benefits from this professional development (Kohler, Ezell, & Paluselli, 1999).

Professional development using a peer coaching model allows for learning that is (1) content specific; (2) requires active participation of the coach and teacher; (3)

addresses specific standards-based learning outcomes; (4) can be sustained over a period of time; and (5) requires much collaboration from the coaches and teachers. These characteristics have been identified as necessary for effective professional development that promotes teacher growth and has the potential to positively affect student achievement (Desimone, 2009, 2011; Jeanpierre, Oberhauser, & Freeman, 2005; Johnson, Kahle, & Fargo, 2007; Penuel, Fishman, Yamaguchi, & Gallagher, 2007).

Campbell & Malkus (2013) found mathematics specialists to have a positive effect on student achievement in Grades 3, 4, and 5, on standardized assessments. In particular, using the treatment-versus-control analysis of schools having a mathematics specialist, the achievement results were significantly higher on schools where the mathematics specialist was placed for three years, but no significant difference if the mathematics specialist was at the school for only one year. Valente (2013) also found mathematics coaches to have a positive effect on student achievement, where Grades 3 to 6 students' Tennessee Comprehensive Assessment Program scores were significantly higher two years after the placement of the mathematics specialist than scores before specialists.

Summary

Newfoundland and Labrador's *Excellence in Mathematics Strategy* is grounded in implementing and maintaining a standards-based curriculum which is based on both conceptual understanding and development of basic skills, similar to other jurisdictions across Canada. While finding a balance between the development of the concepts and mastery of skill is challenging for teachers and parents, much debate continues on where the balance should rest.

While improving student achievement was a main goal of the *Excellence in Mathematics Strategy*, overtime students assessed in Newfoundland and Labrador classrooms demonstrated improvement only in Grade 9 provincial assessment, and not in Grade 3 or Grade 6. Nationally, overtime students from Newfoundland and Labrador do not perform as well as most other provinces on national assessments or international assessments, but do perform well in comparison to most other countries in the international assessments.

The research demonstrates that teachers must develop their mathematical knowledge of teaching to have an effective change on student learning and achievement (Ball et al., 2005; Hill et al., 2008; Ma, 1999; NMAP, 2008). This can be achieved through ongoing professional development with mathematics specialists as teachers develop their mathematical knowledge of teaching. Working with mathematics specialists allows them to build capacity within their teachers, to work collaboratively to develop their new teaching methods and see how they work. Although there is much literature on the how to implement and maintain a mathematics coaching program, little is available as how the mathematics specialists affect student achievement.

Chapter 3

Method

This program evaluation was an attempt to determine whether Newfoundland and Labrador's *Excellence in Mathematics Strategy* achieved its goals after four years from its 2007 implementation. The primary goal of the *Strategy* was to improve student achievement in mathematics. Secondly, the *Strategy* was designed to provide substantial support to students, teachers, and parents. Finally, the *Strategy* was designed to encourage an increased interest and enthusiasm for mathematics. This program evaluation is divided into three parts aligned with the *Strategy's* three goals.

From the *Strategy* came a major curriculum change in mathematics as Newfoundland and Labrador adopted the newly developed WNCP Common Curriculum Frameworks as the basis for its mathematics curriculum. Within three years, the new curriculum was fully implemented from Kindergarten through Grade 9. The 2010-2011 school year was the last of implementation for Grades 3, 6, and 9. The high school mathematics curriculum implementation was fully implemented by June 2014.

To evaluate the first goal of improvement in student achievement, this study compared the students' achievement on the Department of Education's criterion reference tests administered from June 2007 through to June 2012. The experimental group, students writing assessments based on the new curriculum, had their achievement results divided into two groups: new and common curriculum. The control group, students writing older assessments prior to 2011, had their results also divided into two groups: old and common curriculum. Finally, scores of anchor items, that being items reused exactly, from 2010 onward were considered.

To evaluate the second goal of the *Strategy*, this study compared mathematics achievement results of those students who were in classrooms that received numeracy support to those students who were in classrooms that did not receive numeracy support. Achievement results on the provincial criterion reference tests of June 2007 through to June 2011 were compared considering the amount of support classrooms received each year of the numeracy support initiative. Students who wrote assessments in June 2007 received no numeracy support as the *Strategy* commenced after the Government budget of that same year. Throughout the following four years, student results were compared to identify any change in achievement after the implementation of numeracy support across the province. The experimental group is the group of students writing the June 2008 to 2011 assessments in which a classroom received up to four years of numeracy support. The control group is the group of students writing the June 2007 assessment who received no numeracy support. Each district determined which classes were to receive numeracy support.

To evaluate the third goal of the *Strategy*, this study gathered qualitative evidence from numeracy support teachers and one mathematics program specialist on their observations of student achievement from the newly implemented curriculum, their classroom support, and possible increases in interest and enthusiasm for mathematics. These numeracy support teachers worked with many classroom teachers and students, as their primary purpose was to support teachers in the teaching and learning of mathematics. They were witnesses to students' and teachers' interest and enthusiasm over time as they worked through lessons, activities, professional development, and school-wide events.

It is important to note that this study does not attempt to evaluate any increase in student achievement for high school mathematics, as that curriculum was not fully implemented until 2014. This study does not attempt to evaluate the new curriculum with respect to implementation issues, resources, or teacher practices. Accordingly, the study focuses solely on the three *Strategy* goals of student achievement, numeracy support, and interest and enthusiasm for mathematics.

Program Evaluation Design

The accepted definition of evaluation is the determination of the merit or worth of some entity (Lapan, 2004). Evaluators, compared to other researchers, make conclusions such as "X is a good program or has merit" instead of "X causes Y," although there is much overlap between the two. In particular Lapan (2004) states that program evaluation emphasizes how education programs are implemented, how they operate, and what effect they have, and that the important task of program evaluation is to establish a clear connection between the program and its effects on students. Evaluations should be based on the content, purpose, and outcomes of the program, rather than being driven by data collection methodologies (Lapan, 2004). There are many approaches to program evaluation. Some common approaches are to determine if a program is achieving the goals set out for it, along with the use of testing, indicators, or experiments. Evaluations may be used for many types of decisions like course-improvement decisions, decisions about individual students, and administrative regulation.

A Logic Model as described by Wholey (1979) is the basis of this program evaluation. The Logic Model is a multi-method evaluation focusing on data collection activities on relevant activities and outcomes, organize the data, and interpret the data

from multiple methods and courses within an integrative framework (Wholey, 1979).

The logic model has six phases for the program evaluation of the *Excellence in Mathematics Strategy*. The first three phases were completed in preparation for the evaluation: (1) developing the conceptual model; (2) developing evaluation questions and defining measureable outcomes; and (3) developing the evaluation design. They are discussed in this chapter. The last three were completed after receiving Human Research Ethics Board Approval and school district approvals (see Appendix B): (4) collection of the data; (5) analysis of the data; and (6) reporting of the findings. The methods for data collection and analyses of the data are discussed in this chapter. The analyses of the data and reporting of the findings are discussed in Chapters 4 and 5 respectively.

The logic model of evaluation is not rigid in specifics. Resources, activities, outputs, and outcomes are included in flow charts that display a sequence of logical steps in program implementation and the achievement of desired outcomes. It is unique in communicating the relationship of program resources and operations to outcomes in a simple picture. The logic model can be easily adapted from both Stake's (1977) culturally responsive model of antecedents, transactions, and outcomes, and Stufflebeam's (2003) accountability model of context, inputs, processes, and products. The logic model components can vary and are flexible, as they can involve the assumptions held by different stakeholders about how a program works (Green, 1993).

Wholey (1994) discusses four general problems with all program evaluations: (1) lack of agreement on goals, objectives, side effects, and performance criteria; (2) program goals and objectives are unrealistic given the resources and activities under way; (3) unavailable relevant information; and (4) policymakers unable to act on the

evaluation. Due to some of these constraints and the fact that I am the principal investigator not hired by the Department of Education, but as an academic researcher conducting an evaluation on the Newfoundland and Labrador mathematics reform choices, I believe the best model for me to adopt would be the logic model as it allows me to evaluate the inputs, activities, and outcomes within the social-political climate of mathematics education in the province.

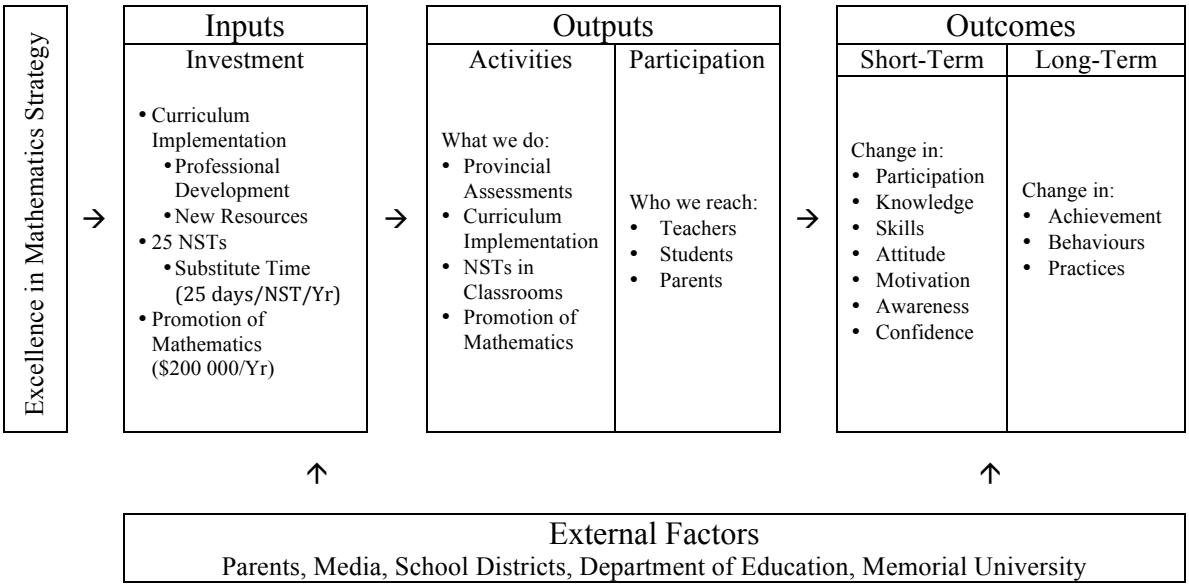
Phase 1: Develop a conceptual model of the *Excellence in Mathematics Strategy* and identify key evaluation points.

The conceptual model adapted from Taylor-Powell and Henert (2008) developed in Figure 3 provides the framework of the Department of Education financial inputs, the output activities of the Department of Education affecting the participants whom they reach, and finally evaluating the outcome goals for both the short-term and long-term by financing and implementing the *Strategy* to mathematics classrooms across the province. The financial investment inputs of the Department include implementing the new mathematics curriculum from Kindergarten to Grade 12 over 6 years with new resources provided along with at least two days of professional development for each mathematics teacher during the first year of each course. The Department funded numeracy support teachers starting in 2007 and provided each numeracy support teacher with 25 substitute days each year to release their classrooms teachers from the classroom allowing them to work together. The Department also funded various events each year for the promotion of mathematics. In addition to these initiatives the Department annually assessed students at Grades 3, 6, 9, and 12 using provincial mathematics assessments. These assessments are criterion reference tests aligned to the curriculum outcomes at each grade level. All of

these initiatives directly impacted students and teachers in their mathematics classrooms, and indirectly impacted parents. The short-term goals of the *Strategy* were to increase students' and teachers' participation, knowledge, skills, attitude, motivation, awareness, and confidence in the teaching and learning of mathematics. The long-term goals of the *Strategy* were to increase student achievement, along with behaviours and practices in the mathematics classrooms of students and teachers. Key stakeholders of this study include all participants along with external stakeholders of parents, school districts, the Department of Education, and Memorial University's Faculty of Education and Department of Mathematics and Statistics.

Figure 3.

Excellence in Mathematics Strategy Logic Model



Phase 2: Develop evaluation questions and define measureable outcomes.

The evaluation uses the mixed-methods approach that incorporates both quantitative analyses of student provincial mathematics assessments and qualitative

analyses of discussions from focus groups and interviews of numeracy support teachers and one mathematics program specialist. The program evaluation of the *Excellence in Mathematics Strategy's* level of attainment of its short- and long-term goals was conducted. This mixed-methods approach allows for triangulation of any findings.

As outlined in Chapter One, this program evaluation includes four questions:

1. Are students' achievement scores on Newfoundland and Labrador Primary, Elementary, and Intermediate Mathematics Assessments significantly different for students who have taken the newly implemented curriculum compared to those who have taken the previous provincial curriculum?
2. Are students' achievement scores on Newfoundland and Labrador Primary and Elementary Mathematics Assessments significantly different for students who were in classrooms that received numeracy support compared to those who did not?
3. What qualitative evidence is there for a change in student achievement due to the newly implemented curriculum and numeracy support?
4. What qualitative evidence is there for an increased interest and enthusiasm for mathematics?

Phase 3: Develop an evaluation design.

Methodological approaches include quantitative analysis of quasi-experimental designs along with qualitative analyses of discussions in focus groups, and one-on-one interviews. The data collection instruments include the student results on provincial mathematics assessments and questions developed for the focus groups and interviews. National Science Foundation (2002) supports the inclusion of qualitative elements in

evaluations since participants are in a complex social environment that has a bearing on the success of the program. Also by using different data sources and methods at various points, one can build on the strength of each type and minimize the weaknesses of any single approach. Using a mixed-methods approach can increase both the reliability and validity of the evaluation data further explained in Phase 4.

Phase 4: Conducting Data Collection

The program evaluation data collection was divided into three different parts: (1) collection of Primary, Elementary, and Intermediate Provincial Mathematics Assessment data for June 2007 through to June 2012 from the Department of Education; (2) indication of the schools that received numeracy support in Grades 3 and 6 from September 2007 to June 2011; and (3) conduct focus groups and interviews of numeracy support teachers and one mathematics program specialist.

Provincial Mathematics Assessments

The provincial mathematics assessments are criterion reference tests of the mathematics curriculum outcomes of the year they are written. The Department of Education K-9 Mathematics Test Development Specialist discussed with the principal investigator how the assessments were created, validated, checked for reliability, and graded (N. Barron, personal communication, August 28, 2013). In Newfoundland and Labrador, the Department of Education appoints committees of experienced teachers at each grade level to write assessment items which match the curriculum outcomes and achievement indicators according to a table of specifications, including the number of selected and constructed response items from each strand and the number of items as well as the division of items according to the cognitive levels of learning. The committee uses

the curriculum guides as the foundation for the items being written, as these curriculum guides are the foundation of the curriculum being taught and learned in mathematics classrooms. The item creation committee creates parallel items that are validated by separate committee of experienced teachers. The validation committee ensures each item represents the curriculum outcome intended and the cognitive levels of learning intended. The Department then creates two forms of the assessment from the parallel items and field tests the Grade 3, 6, and 9 items in Grade 4, 7, and 10 classrooms respectively in a sample of both rural and urban schools across the province. The selected response field test items are computer scored and the constructed response items are panel marked by another committee of experienced teachers to establish the internal reliability of the items, to ensure each item assessed the outcome intended. The final provincial mathematics assessments, one single version, written on a common time and date with provincial guidelines, are then panel marked by a provincially appointed committee of teachers occurring after the end of the school year during the summer.

The use of this standardized achievement test format (criterion reference test) has the following advantages as identified by Gall, Borg, & Gall (1996):

- the items are well written;
- internal reliability is usually high
- standard conditions of administration and scoring have been established.

In Newfoundland and Labrador, the Department of Education satisfies these points through the detailed creation, validation, and assessment processes described previously. However Gall, et al. also identify the drawbacks of using standardized achievement tests, including:

- that guessing, response set, or random or careless answers can distort the scores;
- the use of a restricted time limit may not accurately reflect the characteristics of individuals who are much slower, more deliberate or more thoughtful in responding than their peers;
- the scores do not reflect the unique experience of different types of individuals.

In Newfoundland and Labrador, the provincial mathematics assessments allow students to guess on selected response items. The assessments are timed, however students are allowed as much time as needed to complete them. It is true that the assessment may not reflect what a student demonstrates during a mathematics class. This will be further discussed in Chapter 4.

The general format of the assessments remained fairly consistent with reference to the number of selected response items and constructed response items up to 2010 (see Appendix G). From 2010 onward, the number of items increased in Grades 3 and 6 and the mental mathematics sections were assessed for the whole student population rather than a sample of the population.

Student results based on each mathematics strand are reported to school. Final student scores are not calculated by the Department of Education for Grades 3 and 6. Final student scores for Grade 9 are consistently marked out of 50 points. Standardized scores are not calculated by the Department of Education creating a challenge to compare student and school results from one year to the next.

Firstly, a quasi-experimental nonequivalent control-group posttest-only design formed the basis of evaluating any improvement in student achievement in mathematics due to the curriculum change implemented in Grades 3, 6, and 9 in the 2010-2011 school

year. The experimental groups were made up of all Grades 3, 6, and 9 students who wrote the Primary, Elementary, and Intermediate Provincial Mathematics Assessments respectively in 2011 and 2012 under the new curriculum. The control groups were made up of all Grades 3, 6, and 9 students who wrote the Primary, Elementary, and Intermediate Provincial Mathematics Assessments respectively from 2007 to 2010 under the old curriculum. A quasi-experimental design was necessitated because the research subjects could not be randomly assigned to either the control (old curriculum) or experimental (new curriculum) groups. The total population considered were all Grade 3, 6, and 9 students who wrote the provincial mathematics assessments from 2007 to 2012.

Both the experimental and control groups wrote parallel mathematics achievement assessments, as the provincial mathematics assessments were similar in the nature, number, and difficulty of items each year. These mathematics achievement assessments are the provincial criterion reference tests based on the specific curriculum mathematics outcomes. The assessments up to June 2009 are public documents and are available on the Department of Education website. Since June 2010, assessments are secure documents, so permission from the Department of Education was obtained to receive a print copy of the Primary, Elementary, and Intermediate Mathematics Assessments for 2010 onward agreeing not to publish any items from these assessments. Appendix E provides a list of the student files received from the Department that provided student achievement results from June 2007 to June 2012 omitting the identity of each student for confidentiality. In addition, longitudinal student achievement files linking the same Grade 3 student in 2007 to Grade 6 in 2010, and the same Grade 3 student in 2008 to Grade 6 in 2011 were received.

Although there was a curriculum change in the mathematics specific curriculum outcomes of the provincial mathematics assessments between the old and new curriculum, the general format of the assessments did not change. Individual item analysis was completed by classifying each item under one of three categories: if an item was part of the old curriculum only, part of the new curriculum only, or common to both the new and old curriculum. Items from the 2007 to 2010 assessments were classified as being from the old curriculum only or common to both the old and new curriculum. Items from the 2011 and 2012 assessments were classified as being from the new curriculum only or common to both the old and new curriculum by the principal investigator. Item classifications of old or common and new or common were then validated by the Department of Education K-9 Mathematics Test Development Specialist for Grade 3, and the provincial mathematics assessment chief markers for Grades 6 and 9. The validators were asked by the principal investigator to consider each item in the provincial mathematics assessments and ask if a student who learned in the old curriculum could complete the item and if a student who learned in the new curriculum could also complete the item based on the curriculum content of each curriculum. If the item satisfied both the old and the new curriculum outcomes, then the item would be considered common to both. Otherwise, the item remained either old in the previous curriculum, or new in the newly implemented curriculum. Appendix D displays the percent of each assessment being classified as common, old, and new.

Schools Receiving Numeracy Support

Secondly, another quasi-experimental nonequivalent control-group posttest-only design forms the basis of evaluating student achievement in mathematics of those

students who are in classrooms that received numeracy support. The experimental groups are made up of all Grades 3 and 6 students who wrote the Primary and Elementary Provincial Mathematics Assessments respectively up to June 2011 that were in classrooms receiving numeracy support for up to four years. They were compared to all Grades 3 and 6 students who wrote the Primary and Elementary Provincial Mathematics Assessments respectively in June 2007 who were in classrooms prior to the implementation of numeracy support teachers. The June 2012 results were not considered in this analysis as the numeracy support model changed that school year.

Focus Groups and Interviews

To further triangulate any findings in the program evaluation of the *Excellence in Mathematics Strategy* focus groups and interviews were conducted. The focus groups consisted of a sample of ten numeracy support teachers, five in one focus group, four in another focus group, and one interviewed one-on-one. These numeracy support teachers have been working with numerous teachers and their students. The numeracy support teachers were witness to many changes over time of the teaching and learning of mathematics in the classroom. These focus groups were interviewed not only on their observations of improvement of student achievement, but also to provide anecdotal evidence of any possible increase in teachers' and students' interest and enthusiasm for mathematics. The use of focus groups allows for the explicit access to group interactions, power dynamics and peer pressures of the participants (Morgan, 1988).

Finally, a qualitative interview was conducted with a mathematics program specialist. The mathematics program specialist worked with all mathematics teachers in her district, whether a teacher receives numeracy support or not. The program specialist

also worked with the numeracy support teachers, the school district personnel and the Department of Education personnel. This program specialist is a key player in most aspects of the *Excellence in Mathematics Strategy* success.

The principal investigator used the evidence shared by the numeracy support teachers and mathematics program specialist to provide findings of support provided to students, teachers, and parents instead of directly working with students, teachers, and parents. The numeracy support teachers worked with numerous students, teachers, and parents across Newfoundland and Labrador, therefore could share a wider knowledge base of how the Excellence in Mathematics Strategy was impacting these groups of individuals.

This mixed-methods design attempted to provide effective control of threats to internal validity such as: history, maturation, testing, instrumentation, statistical regression, differential selection, experimental mortality, and section-maturation interaction (Gall et al., 1996). Six years of student achievement data is considered in the evaluation to observe long-term changes of student achievement, including four years of data before the curriculum change and two years after the curriculum change, and to include four years of numeracy support with one year prior to numeracy support starting. The full student population of Grade 3, 6, and 9 students writing the provincial mathematics assessments each year were considered, therefore all results are considered to be statistically significant. The finding of the interviews and focus groups were member-checked by the participants. Triangulation was ensured by interviewing numeracy support teachers from different regions as well as a program specialist who shared her perspective of the numeracy support teachers and the *Excellence in*

Mathematics Strategy with their teachers allowing for overlapping evidence. Using both the quantitative and qualitative analyses of curriculum change, numeracy support, and student achievement, allows for triangulation of the validity of the results.

Phase 5: Analyzing the Data

The method for data analysis is described in three parts: (1) curriculum change and achievement; (2) numeracy support and achievement; and (3) the qualitative findings of the curriculum change, numeracy support, achievement, and interest and enthusiasm in mathematics.

Part 1: Curriculum Change and Achievement

To evaluate the first goal of the Strategy: to improve students' achievement in mathematics, this study compared the mathematics achievement results of students' assessments based on the old curriculum from 2007 to 2010, to students' assessments based on the new curriculum for 2011 and 2012. To analyze this goal, each assessment was divided into either old and common curriculum items or new and common curriculum items, according to the year.

Participants

All students who completed the Primary, Elementary, and Intermediate Provincial Mathematics Assessments were included in the analysis. The only students who did not complete the assessments were either absent or exempt. Approximately 15 000 students completed the annual assessments with about 5000 students in each Grade level. Since the percentage of Grade 3, 6, and 9 students who wrote the assessments range from 88%

to 99% of the student population (see Table 5), all the statistical tests are considered to be reflective of the population.

Table 5.

Comparison of Student Enrolment and Students Assessed

(Newfoundland and Labrador Department of Education, 2012d)

Year	Grade 3		Grade 6		Grade 9	
	Enrolled	Assessed	Enrolled	Assessed	Enrolled	Assessed
2007	5063	5003	5403	5349	6263	5711
2008	5106	5005	5393	5215	5726	5063
2009	5028	4936	5274	5167	5732	5120
2010	4935	4810	5212	5084	5556	5150
2011	4916	4879	5270	5068	5532	5147
2012	4906	4838	5155	5039	5392	5054

Provincial Mathematics Assessments

The student achievement data for the Primary, Elementary, and Intermediate Mathematics Assessments for 2007 through to 2012 was received from the Department of Education. This data was in the format of statistical data files with the student personal information removed for confidentiality. The data provided the following information for each student:

- School District
- School and School Identification Number
- Community of the School
- Teacher Name

- Individual Selected Response Item Responses
- Individual Item Scores

Although the Department did not calculate total scores for each student, they did provide detailed information about each assessment by indicating particulars about the item numbers for selected response, constructed response, and rubric marked items, which allowed total scores to be calculated for analysis.

The provincial assessments are criterion reference tests that reflect the curriculum outcomes for Grades 3, 6, and 9. Prior to 2010, all yearly assessments were released to the public. From 2010 onward, assessments were made secure by not making them available to the public, thus allowing the Department to anchor, or reuse items, from one year to the next. Although the general format of the assessments remained the same, the number of items varied each year. Due to financial restraints across all Newfoundland and Labrador Departments in the 2013 Budget, mathematics was not assessed for Grades 3, 6, and 9 in June 2013 (Newfoundland and Labrador Department of Finance, 2013).

Curriculum Item Analysis

All selected response and closed-constructed response items were considered in the curriculum analysis. The open-constructed response items, being rubric-scored, were not considered part of this analysis, as they could not be given a score on a similar scale to the other items in the assessments. The selected response items were allocated one point each, and the constructed response items were allocated one to three points each depending on the item. Each of the selected and closed-constructed items on all assessments was classified into one of two groups. For the 2007 to 2010 assessments, items were classified as either only in the old curriculum or common to both the old and

new curriculum. Similarly, the 2011 and 2012 assessments upon curriculum implementation, items were classified to be only in new curriculum or common to both the old and new curricula. Therefore each student had two scores: one for the common curriculum and one for either the old curriculum for 2007 to 2010 or the new curriculum for 2011 to 2012.

For an item to be considered common in both the old and new curricula, all elements of the item had to satisfy the other curriculum outcomes. If an element of an item is beyond the scope of the other curriculum, the item is classified as old for 2007-2010 or new for 2011-2012. For example, for Grade 3, 2008, Item 5 (see Figure 4), the curriculum content reflects the understanding of multiplication and division, which is common to both the old and new curricula. But it is not considered common because the multiplication fact is beyond 5 × 5. Therefore the item is classified as an old curriculum item.

Figure 4.

Grade 3 Provincial Mathematics Assessment, 2008, Item 5

What is the related division for 5 × 8 = 40?

(A) 8 ÷ 5

(B) 32 ÷ 8

(C) 40 ÷ 8

(D) 32 ÷ 5

Classifications for each item were made using the curriculum outcomes from the old and new curriculum guides. Checking of the classifications was completed with the Department's mathematics evaluation consultant and provincial assessment chief markers

for Grades 6 and 9, as these individuals had extensive knowledge of both old and new curricula in each Grade level.

Using the item classifications and student scores, three separate analysis were completed with each of the Primary, Elementary, and Intermediate Assessments. Since the number of items varied from year to year, item counts were completed displaying the percentage of common curriculum items from 2007 to 2012, old curriculum items from 2007 to 2010, and new curriculum items from 2011 to 2012. Next, the mean percentage scores were analyzed for the old curriculum, common curriculum, and new curriculum items in the respective years. Lastly, the mean percentage scores for anchor items were analyzed from 2010 onward. No items were anchored, or reused for three years in a row. Consideration was then given to the nature of the outcomes removed, remaining, or added to each Grade level from 2007 to 2012.

Part 2: Numeracy Support and Achievement

To evaluate the second goal of the *Strategy*, this study compared mathematics achievement results of those students who were in classrooms that received numeracy support compared to those students who were in classrooms that did not receive numeracy support. What evidence is there of any change in student achievement for those students who were in classes that received numeracy support when compared to those who did not? To answer this, achievement results on the provincial criterion reference tests of June 2007 through to June 2011 were compared considering the amount of support classrooms received each year of the numeracy support initiative.

Throughout the four-year initiative student results were compared for any change in achievement following the implementation of numeracy support across the province.

The experimental groups are students writing the June 2008 to 2011 assessments in which the classroom received up to four years of numeracy support. The control group is the group of students writing the June 2007 assessment who received no numeracy support.

Participants

Numeracy Support Teachers

The Government of Newfoundland and Labrador allocated 25 numeracy support positions to start in September 2007. Upon investigation, there were only 24 numeracy support positions allocated to the four provincial English school districts; 21 in Kindergarten to Grade 6, and 3 in Grades 7 to 12 (see Table 6).

Table 6.

Numeracy Support Teachers by District and Grade Level

District	Kindergarten – Grade 6	Grades 7 – 12
1 – Labrador	2	1 (first year only)
2 – Western	4	1
3 – Nova Central	5	0
4 – Eastern	10	1
Total	21	3

To look at the effect of numeracy support on student achievement, only the 21 positions from Kindergarten to Grade 6 were considered in the analysis. The secondary positions were not considered in the analysis because the position in Labrador was not filled after the first year due to teacher shortage, and the other two positions in Eastern

and Western were involved with curriculum implementation and only worked with few schools in their districts.

There were 34 individuals in the 21 numeracy support positions over the four school years from September 2007 to June 2011. The information about these 34 teachers was collected based upon personal experience, district websites, and from district mathematics program specialists. Data, via in-person, telephone, and email interviews, was gathered about all but one teacher. The one non-respondent worked in one region for 3 years accounting for missing numeracy support data from 12 schools.

Each numeracy support teacher provided a list of schools and classes to which they provided support in each of Grade 3 and 6. Numeracy support variables were created for each year representing if a school received support in Grade 3 or Grade 6. If there were no students in the grade level of that school year, the school was considered missing from the data for that year.

Once the individual years of support were created for each school, then the total years of numeracy support were considered, with four being the highest number of years of support for a school. Following an analysis of the total years of support, all schools with either one year or zero years of support were combined into one group. There are two reasons for this amalgamation. First, although there were approximately 20% of the schools receiving no support, these schools only accounted for approximately 5% of the student population and these schools were mostly rural and isolated (see Figures 23 – 32 in Appendix I). Furthermore, during the first year of support, the Eastern School District provided support to almost all schools in the district, with each individual supporting 12 schools (see Figures 33 – 40 in Appendix I). Feedback from the numeracy support

teachers was that they were spread across too many schools. Consequently in subsequent years, support was provided to a fewer number of schools, with each individual supporting 8 schools.

The numeracy support data considers a school to receive support if at least one class, not necessarily all classes, in that grade received support. This occurred mainly in larger urban schools where there were many classes at the same grade level.

Student Population

As discussed previously, approximately 10 000 students completed the Primary and Elementary Assessments each year (see Table 5), with about 5000 students in each Grade level. The only students who did not complete the assessments were either absent or exempt. Since the percentage of Grade 3 and 6 students who wrote the assessments range from 96 to 99% of the student population, all the statistical tests are be considered to be reflective of the population.

Students from Conseil scolaire francophone (District 5), private schools, and native federal schools were not considered in the numeracy support analysis. These schools were not allocated numeracy support teachers and accounted for less than 3% of the student population.

Provincial Mathematics Assessments

As discussed previously, the primary data of the student achievement for the Primary, Elementary, and Intermediate Mathematics Assessments for June 2007 through to June 2012 was received from the Department of Education. Longitudinal files that matched a student's Grade 3 open-constructed response item rubric scores in 2007 and

2008 with their Grade 6 open-constructed response item rubric scores in 2010 and 2011 was provided. Also, longitudinal school achievement results were created from the annual student achievement results. To complete the analysis, all of the numeracy support information was merged with each of the student achievement files. Every student had data regarding if support was provided to that school in that grade, and also the total number of years support was provided to that school in that grade.

To analyze the effect of numeracy support on mathematics achievement only the Grades 3 and 6 achievement data from June 2007 to June 2011 were considered. The full implementation of numeracy support teachers started after the 2007 assessments. After June 2011, some positions were combined into literacy and numeracy support positions.

Longitudinal Student Rubric Scores

The content area of Number Operations strand in both Grades 3 and 6 had four open-constructed long answered questions. A provincially appointed marking committee of teachers graded these four questions as a set and gave each student a rubric score ranging from 1 (very limited) to 5 (outstanding) on the process standards of reasoning, communication, connections, and problem solving. The longitudinal files contained students' four scores in Grade 3 and their scores in Grade 6.

For simplicity, a total mean rubric score was calculated at each grade level, and was then rounded, so that each student had an overall rubric score ranging from 1 to 5. Then the students were assigned into two groups, in a similar fashion to how the Department of Education reports the results. The first group was those students who scored below standard, that being very limited or limited, with a mean score of 1 or 2.

The second group was those who scored at or above standard, that being adequate, strong, or outstanding, with a mean score of 3, 4, or 5.

Students' results were then analyzed as to who had changed over time from Grade 3 to Grade 6, by comparing how students moved from one group to another. Thus a student could be below standard and moved to an at/above standard, or in the opposite direction. Students who remained within the same group were not considered as change in student achievement was the focus.

The students' results over time were the dependent variable with numeracy support as the independent variable. In particular, Grade 6 students who received support in 2010 were considered, and if there was a relation of numeracy support with student results. None of these students received support in Grade 3 in 2007. For the students who were in Grade 3 in 2008 and then in Grade 6 in 2011, four different comparisons of students' results were made: no support in either Grade 3 or 6, support in Grade 3 only, support in Grade 6 only, and support in both Grades 3 and 6. Cross tabulations were conducted to analyze the relation between numeracy support and rubric scores over time. In particular, the change over time represented if a student improved or declined in their mean rubric scores, moving between below and at/above standard, dependent upon if support was provided in each of Grade 3 and/or Grade 6.

Annual Student Achievement

One total score was calculated for each student by summing the scores of the selected response and closed-constructed response items only. The mental math section from 2007-2010 was only completed by a sample of the student population and thus was

not included. Open-constructed items that were rubric scored items were considered in a separate analysis (see Appendix G).

Due to the Department of Education not using standardized scores each year, and to account for the differences in the number of items from year to year, which range from 23 to 74, each total score was represented as a percentage. The percentage score allows one to compare different groups within a year, that being those who were and were not supported.

Means comparisons were performed within each Grade 3 and 6 annual student achievement file using the percentage and standardized total scores as the dependent variables and numeracy support as the independent variable. Then mean differences were calculated between two groups of students: those in schools receiving the most years of numeracy support and those receiving the least years of numeracy support.

Longitudinal School Achievement

Student achievement data at the school level over five years, along with the number of years of numeracy support, was then considered. Thus each school had an annual mean score calculated from the school's students' mean score. The number students in each Grade 3 or 6 who wrote each assessment were tallied. Finally, the numeracy support variables representing if a school received support each year from September 2007 to June 2011 were included.

To compare the data over time, standardized school scores were calculated for each year using the school level achievement data aggregated from the annual student level files from 2007 to 2011. This allowed a comparison of how a school performed in comparison to other schools from year to year even though the assessments varied in the

number of items and difficulty of items. To calculate the annual standardized school scores, the mean and standard deviation were calculated. A negative standard deviation difference indicates a relative decrease in the mean scores of schools receiving numeracy support in one year compared to another; on average those schools' achievement shifted lower relative to those schools that did not receive support. A positive standard deviation difference indicates a relative increase in the mean scores of schools receiving numeracy support in one year compared to a previous year; on average those schools' achievement shifted higher relative to those schools that did not receive support.

Once the standardized scores were obtained, differences were calculated between every two-year combination from 2007 to 2011 in both Grades 3 and 6. For example, the standardized school score difference from 2011 to 2007 was calculated by determining the difference between the standardized scores for each year, accounting for ten two-year combinations from 2007 to 2011.

To determine the effect of numeracy support in any one particular year, means comparisons were then performed with all these combinations, using the standardized differences as the dependent variable and numeracy support in the later year as the independent variable. For example, the standardized score difference between 2011 and 2008, being the dependent variable, and if the school received support in 2011, being the independent variable. Mean differences were then calculated between the two groups of schools: those in schools receiving numeracy support that year and those who did not receive support that year. Results demonstrate how one school moves in rank from one year to the next compared to other schools dependent upon if numeracy support was received. These results reflect particularly on the effect of numeracy support on the

teacher as the students change from year to year, but the teacher in Grade 3 or 6 remains constant for most of the schools.

Part 3: Qualitative Findings of Curriculum Change, Numeracy Support, Achievement, and Interest and Enthusiasm in Mathematics

Qualitative research was conducted to help triangulate the quantitative findings upon reviewing the three goals of the *Strategy*. The first two goals were analyzed using quantitative methods described earlier in this chapter along with qualitative evidence from the focus groups and interviews of the numeracy support teachers and program specialist. The third goal of encouraging an increase in the interest and enthusiasm in mathematics was analyzed solely using qualitative evidence from the focus groups and interviews.

After receiving Human Research Ethics Board approval, three school districts were contacted for approval to conduct focus groups and interviews with their numeracy support teachers and program specialists (see Appendix B). The use of focus groups was used for the explicit access to notion of group interactions, power dynamics and peer pressures (Morgan, 1988). As the principal investigator, I can ask questions, but the conversations among the numeracy support teachers triggers responses and memories that they can bring forward from each others discussions and interactions. Two focus groups and two interviews were conducted to evaluate the change in the mathematics curriculum, the numeracy support provided to teachers and their students, and if there was any increase in interest and enthusiasm in mathematics for teachers, students, and parents. All focus groups and interviews were recorded, transcribed, and member-checked by the participants. All participants were recruited via email to ask for their

consideration in the program evaluation, the purpose of the research, and the ethical considerations of the research. All participants gave written consent to participate.

Participants

Ten of the 21 primary and elementary numeracy support teachers and one mathematics program specialist participated in the focus groups or interviews. Three of the four districts were represented in the focus groups and interviews. The participant sample included numeracy support teachers from both urban and rural regions of the province, and included a range of years of teaching experience. One district's numeracy support teachers were not contacted due to geographical and financial constraints.

Focus Groups and Interviews

Each focus group and interview was lasted 60 to 90 minutes. They were structured with five questions relating to the *Strategy*. The first focus group was conducted with five numeracy support teachers from one district in June 2011 during a workday at a regional district office. The second focus group was conducted with four numeracy support teachers at a later date in June 2011 during an evening in a hotel room where one of the numeracy support teachers was staying due to Department of Education meetings. Three of the four numeracy support teachers were from one district and the fourth was from another district. One numeracy support teacher was interviewed in September 2011 during one evening in a hotel room where the numeracy support teacher was staying due to Department of Education meetings. The mathematics program specialist was interviewed in June 2011 during a workday at a regional district office.

The focus groups and interviews began by reviewing a printed copy of the letter of informed consent. The conversations then followed as they were questioned about their experiences and stories. Although a numeracy support teacher, similar to the others, yet working in higher grades, I did not participate in the conversations, but guided the conversations of others with open-ended questions, allowing others to share their experiences and expand on others comments in each focus group.

The focus group and interview questions of the participants included questions about each of the goals of the *Excellence in Mathematics Strategy* and their direct relation to them. Each of the numeracy support teachers shared their background prior to starting their positions. Then they shared how the positions evolved over the four years of the *Excellence in Mathematics Strategy*. They were asked to share some of their successful experiences with teachers and their students, as well as some of the challenges they were presented within their positions. They were then asked to discuss their thoughts of changes in student achievement over the course of the *Excellence in Mathematics Strategy*. Finally they were asked to share their experiences of any increase in interest and enthusiasm in mathematics in students and their teachers. Sample questions are provided in Appendix C.

Themes

Using a grounded theory approach (Glaser & Strauss, 1967), each transcript was reviewed for emerging themes. The conversations were guided by the questions about the goals of the *Excellence in Mathematics Strategy*; the coding was guided by those same goals. The conversations were open-coded allowing for main themes to emerge. The data

was then coded again using selective coding of the core categories. Excerpts of the participants' stories were then selected to represent the main themes and core categories.

Summary

In summary, this chapter describes the mixed methods approach to the program evaluation of the *Excellence in Mathematics Strategy* using a logic model approach. The first four of the six phases were developed in this chapter; from developing the conceptual model with key evaluation points, developing the evaluation questions and defining the measureable outcomes, developing the evaluation design. This chapter discusses the quantitative process of using means comparisons on the provincial mathematics assessments for evaluating the curriculum change on mathematics achievement, as well as numeracy support on mathematics achievement. It also discusses the qualitative process of evaluating the above along with perceived change in interest and enthusiasm for mathematics. The final two program evaluation phases of analyzing the data and reporting are presented in Chapter 4 Results and Chapter 5 Discussion, respectively.

Chapter 4
Results

The fifth stage of the program evaluation of the *Excellence in Mathematics Strategy* is the analysis of the data collected, according to Wholey (1979). Raw data was checked and prepared for analysis, with the initial analysis based on the evaluation plan, with the finding integrated and synthesized (National Science Foundation, 2002). The results are divided into three main parts: (1) curriculum change and achievement; (2) numeracy support and achievement; and (3) focus groups and interviews. These results assist in evaluating the three goals for the *Excellence in Mathematics Strategy* to improve students' achievement in mathematics; to provide support to teachers, students, and parents; and to encourage an increase in interest and enthusiasm in mathematics.

First, student provincial mathematics achievement results were analyzed following the curriculum change that was both mandated and implemented in 2007. Next, student provincial mathematics achievement results were analyzed based on the number of years schools received numeracy support. Finally, numeracy support teachers and one mathematics program specialist participated in focus groups and interviews to share their experiences of numeracy support, the teaching and learning of mathematics with their teachers and students, and the observations of teachers' and students' interest and enthusiasm of mathematics in the school culture.

Part 1: Curriculum Change and Achievement

The first goal of the *Strategy*, to improve students' achievement in mathematics, was evaluated by analyzing students' mathematics achievement and the relation of the results to the curriculum change that started in 2008 with Grades Kindergarten, 1, 4, and

7, and fully implemented in June 2014 for Grade 12. In particular, the Primary, Elementary, and Intermediate Provincial Assessment results from 2007 to 2012 were analyzed. Within each of these assessments, the proportion of items classified as old, common, or new, was obtained, as well as the nature of the item content based on curriculum outcomes being removed, retained, or added each year. Next, the students' mean percentage scores of the old, common, and new items were considered at each Grade level. Finally, an analysis of the student achievement in anchor items from 2010 onward was considered.

Number and Content of Curriculum Items

The percentage of common items in each of the Grade 3, 6, and 9 assessments vary over time while considering the curriculum change occurring for the 2011 assessments (see Appendix D). Once the curriculum change came into effect, Grade 3 has an increase by approximately 30% of its items to be considered common to both the old and new curricula. The common curriculum items for Grade 6 remained high after the curriculum change, with approximately 65% of the items common to both the old and new curricula both before and after the curriculum change. Finally, the common curriculum items for Grade 9 were approximately half of each assessment both before and after the curriculum change.

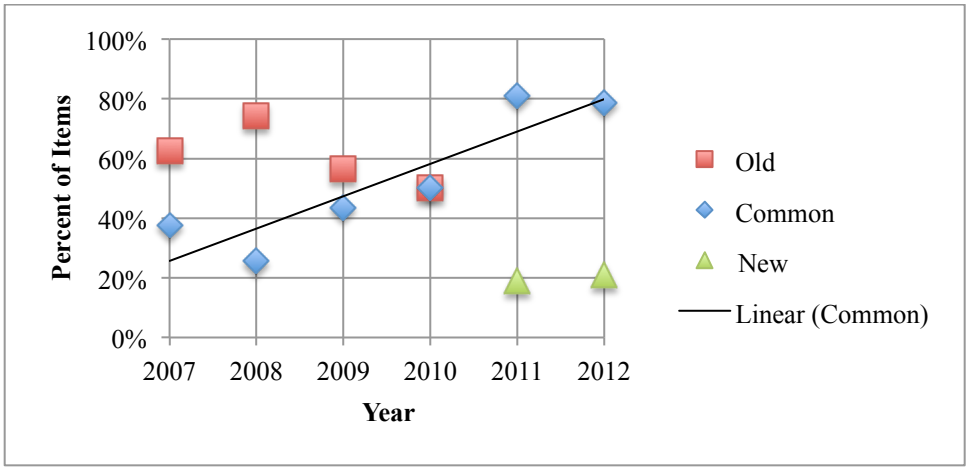
Grade 3

Figure 5 displays the rather wide division of items between common and old curriculum in the Grade 3 assessments for years previous to the curriculum change, as well as the linear trend line of the common curriculum items. After the change, a higher

percentage of items are common. Upon investigation, the content of the items that was considered to be part of the old curriculum were common in content but go beyond the new outcomes. Many of the items from 2007 to 2010 represent the Number strand outcomes such as representation, addition, subtraction, and multiplication of numbers. The reason why many of the items were not considered common was that the items go beyond the scope of the outcomes. For example, working with numerals beyond 1000, adding and subtracting numbers with answers beyond 1000, and multiplying numbers beyond 5 x 5, are all now taught at higher grades. Other items from outcomes in the Shape and Space strand were moved to higher grades also, such as capacity, angles, area, the analog clock, and symmetry.

Figure 5.

Percentage of Grade 3 Curriculum Items



New items in 2011 and 2012 represent outcomes mostly from the Shape and Space strand, including the passage of time, perimeter, and regular and irregular polygons, as well as the Patterns and Relations strand, working with one-step addition using symbols for the unknown. Most of the Number strand items which include the representation of number, addition, subtraction, and multiplication are considered now to

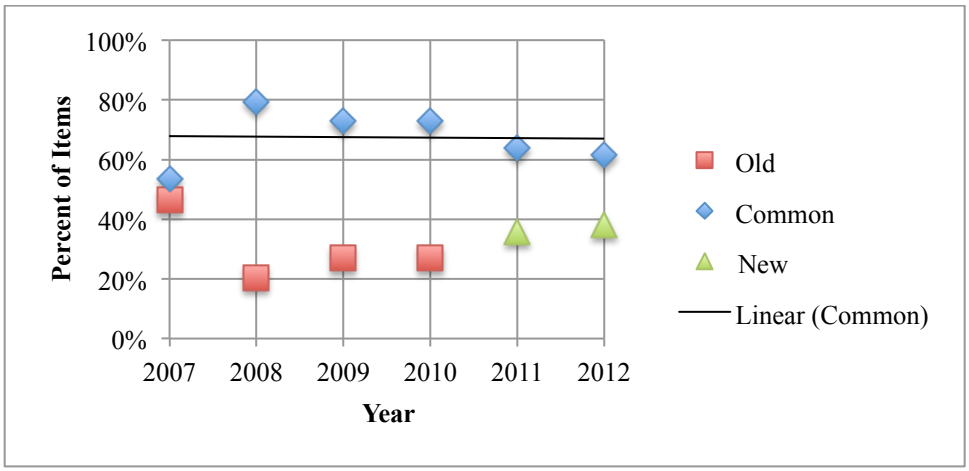
be common because they are within the scope of the old and new curriculum content; i.e. numerals up to 1000, and multiplication facts up to 5 x 5.

Grade 6

In the Grade 6 assessments many items remained common, over the full 6 years, ranging from 54% to 79% of all the items (see Figure 6). Most of the old items prior to 2011, were from content that was moved to higher grades. The Number strand outcomes included working with fractions and decimals, the Shape and Space strand outcomes included quadrilaterals and unit conversions of mass and capacity, were moved to lower and higher grades. Most of the new items in 2011 and 2012 were content moved down from higher grades and pertained to the Patterns and Relations strand where students developed the preservation of equality and linear relations using tables, graphs, and equations. Other topics included integers, angles, and triangles. Many of the items from the Number strand remained common, including place value, ratio, percent, factors and multiples, improper fractions and mixed numbers, and operations with decimals. Shape and Space items which remained constant included working with rectangles and rectangular prisms, polygons, plotting points, and transformations.

Figure 6.

Percentage of Grade 6 Curriculum Items

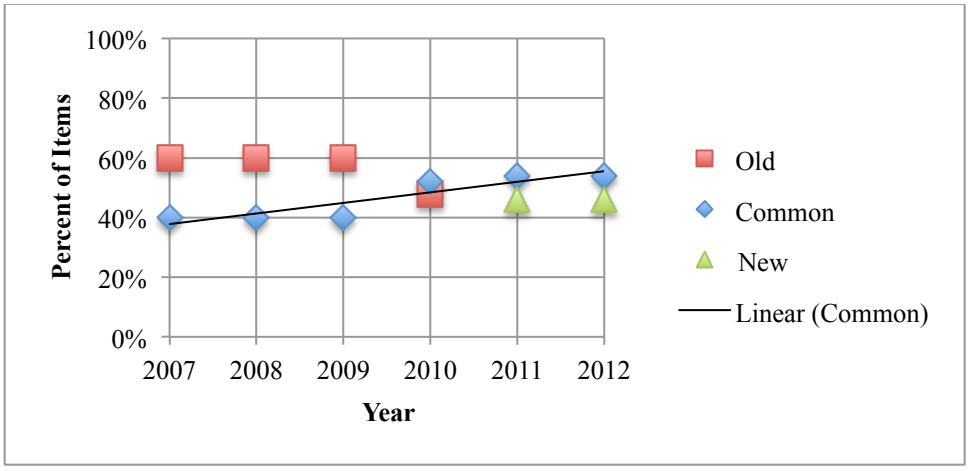


Grade 9

Figure 7 displays the division of items between common and old or new curricula in Grade 9 assessments to be split about evenly over the years, ranging from 40% to 54% of each assessment considered to be common to both curricula. In Grade 9, many of the old items were moved to high school courses, while the new items were from an equal split coming from both earlier grades and high school.

Figure 7.

Percentage of Grade 9 Curriculum Items



Many of the Grade 9 items considered to be part of the old curriculum are items that moved into high school courses, in particular: set notation, irrational numbers, factoring, multiplying and dividing polynomials, working with the line, non-linear relations, surface area and volume of cones and spheres, and congruency of triangles. Some items were removed from the curriculum altogether and found either in post-secondary, such as working with matrices, or in other subjects, such as scientific notation. Content of items considered new to the curriculum coming from higher grades includes: square roots of rational numbers, circle geometry, and sampling and bias. Others come from lower grades include polynomials, scale factor, composite surface area, and symmetry. These movements of content between lower and higher grades, and some even being removed are examples of how the curriculum across the grades allow students to delve into fewer topics more deeply allowing for more understanding, and accounting for less spiralling of the curriculum. As referenced in Chapter 1, WNCP and NCTM both critiqued the first standards-based curricula being "a mile wide and an inch deep" (NCTM, 2006) and this movement of topics allows for more emphasis on teaching fewer topics in more depth (WNCP, 2006).

Achievement of Curriculum Items

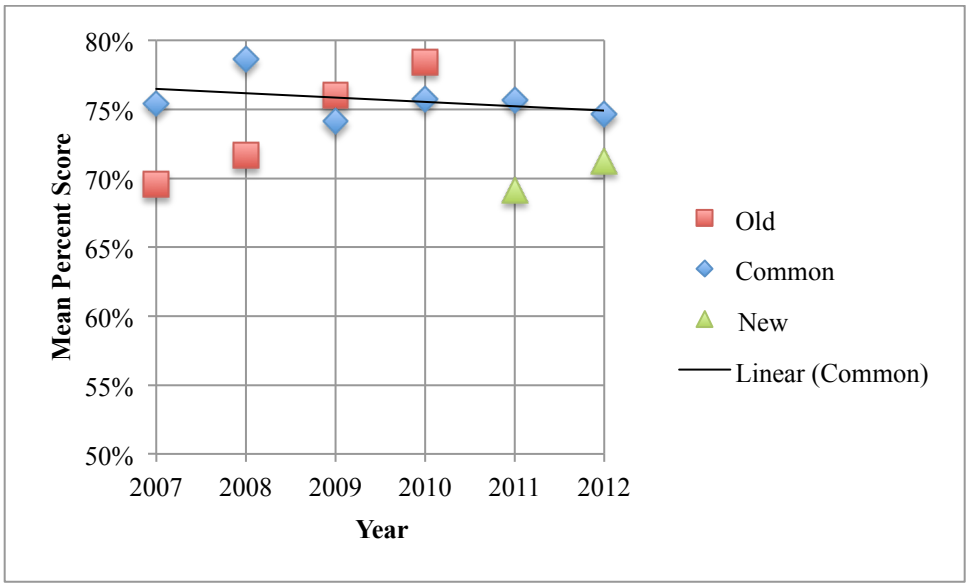
Each of Grades 3, 6, and 9 display varying results of the curriculum items over time. The common items both prior to and after the curriculum change show little effect in Grade 3, a negative effect in Grade 6, and a positive effect in Grade 9.

Grade 3

The Grade 3 achievement results of the common curriculum items demonstrate little effect over time (see Figure 8), as students' mean scores range from 74% to 79% over the 6 years, despite the variance in the number of common curriculum items (see Figure 5). The linear trend line for the common curriculum items has a slope of -0.0031, showing curriculum content having a minimum effect over time. The mean scores of old items were higher than on the new items, with the trend over time increasing for both.

Figure 8.

Grade 3 Mean Percentage Scores for Curriculum Content



Grade 6

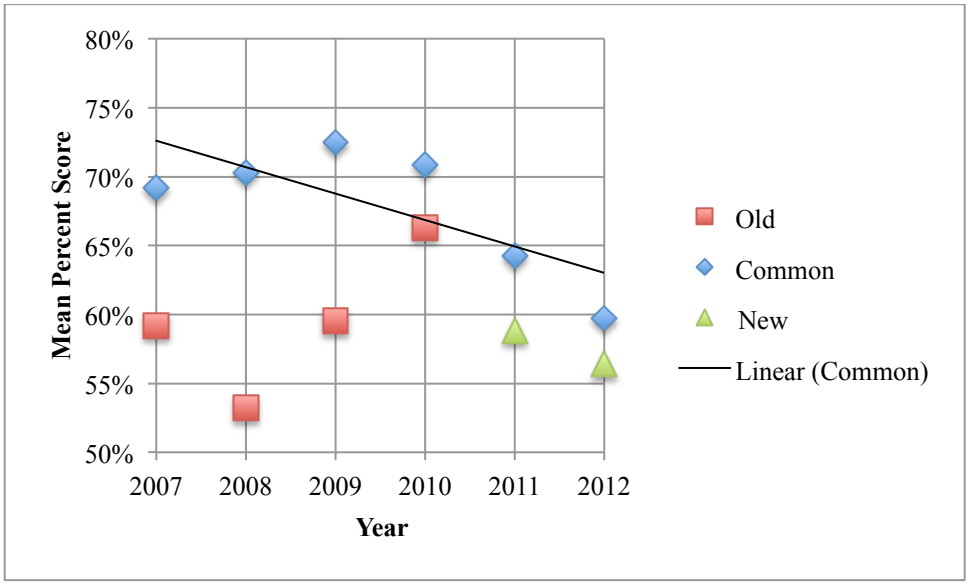
The Grade 6 achievement results of the common curriculum items over time show a greater decline in achievement, as mean scores before the curriculum change, are about 70% over the 4 years (see Figure 9). Following the curriculum change, the 2011 results of the mean score for the common curriculum items drop to 64%, and even further to 60% in 2012. The linear trend line for the common curriculum items has a slope of -0.0192.

The common curriculum items scored higher every year compared to both the old and the new curriculum items. Even after the second year of the new curriculum, scores in both the common and the new curriculum items decreased.

The Grade 6 results demonstrate the curriculum change did not have a positive effect on achievement. A possible explanation for this is that in Newfoundland and Labrador, Grade 6 mathematics is the most difficult mathematics course that can be taught by a primary/elementary teacher who had not specialized in mathematics. The new content of working with linear relations and equations, which were moved from higher grades, might be a more challenging topic for these teachers to understand and teach to students. However, the common concepts that have been part of both the old curriculum and new curricula scored even lower after the curriculum change.

Figure 9.

Grade 6 Mean Percentage Scores for Curriculum Content

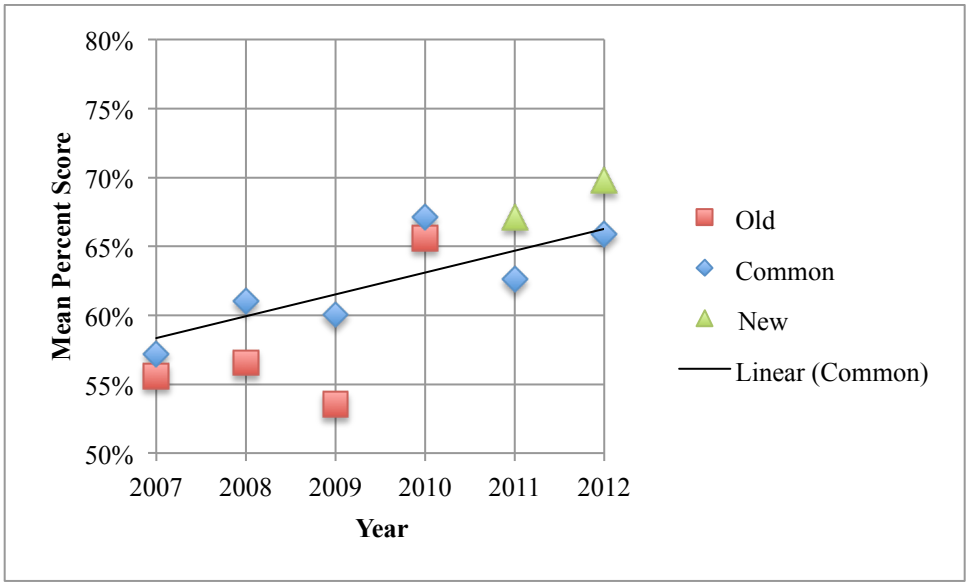


Grade 9

From 2007 onward, the curriculum change had a positive effect in Grade 9 achievement (see Figure 10). The linear trend line for the common curriculum items has a slope of 0.158. Each year prior to the curriculum change, the students scored higher on the common items compared to the old items. Most of these old items were moved into the high school curriculum, having a more algebraic focus. As well, students scored higher on the new items compared to the common items after the curriculum change, with about half of these items were moved from lower grades, and circle geometry from high school.

Figure 10.

Grade 9 Mean Percentage Scores for Curriculum Content



Achievement of Anchor Items

Grade 3, 6, and 9 provincial mathematics assessments had only 6, 3, and 2, items anchored respectively in 2011. Items anchored in the 2011 assessment included all three grades displaying a decrease in achievement following the curriculum change in 2011,

with a decrease in achievement of anchor items from 2010 to 2011 (see Table 7 and Figures 11 and 12). The decease is slight in Grade 9 with a 0.5% decrease in achievement. The largest decrease is in Grade 6 with a decrease of 6.7%. Large achievement differences were found in two Grade 6 items. To write and interpret ratios comparing part to whole had a 9% decrease, and to find the volume of a rectangular prism had a 10% decrease in achievement. All other results were within ± 6%.

The following year in 2012, the number of anchored items for Grades 3, 6, and 9 was 14, 16, and 5 respectively. All three grades had an increase in achievement on the anchor items from 2011 to 2012. The total number of items anchored increased from 2011 to 2012 to more than double across all grades, although the smallest amount of items anchored was in Grade 9. One large achievement difference was found in Grade 6 with an 18% increase where students had to draw a rectangle of a given area. Two Grade 3 items had large achievement differences with a 10% decrease in identifying the value of a digit in a given number, and an 11% increase in explaining how a number was placed on a number line. All other results were within ± 6%.

Even though the all grades have a decreasing result for the students in 2011, these students were the first to be taught the new curriculum that year, and as well the two previous years, as the curriculum implementation from Grades Kindergarten to 9 was a 3-year implementation. Each year these students' teachers were learning the new curriculum outcomes and learning to work with new resources. Upon the second year after the curriculum change, all results display an increase in achievement, albeit minimal. In the second year many of the teachers have had a full year of exposure to the

new outcomes and resources, possibly becoming more confident and knowledgeable in these outcomes and resources.

Table 7.

Achievement Differences of Items Anchored in 2011 and 2012

	2010 – 2011		2011 – 2012	
	Mean Score Difference	Number of Items	Mean Score Difference	Number of Items
Grade 3	-3.00%	6	0.36%	14
Grade 6	-6.67%	3	1.44%	16
Grade 9	-0.50%	2	1.20%	5

Figure 11.

Mean Percent Scores of Items Anchored in 2011

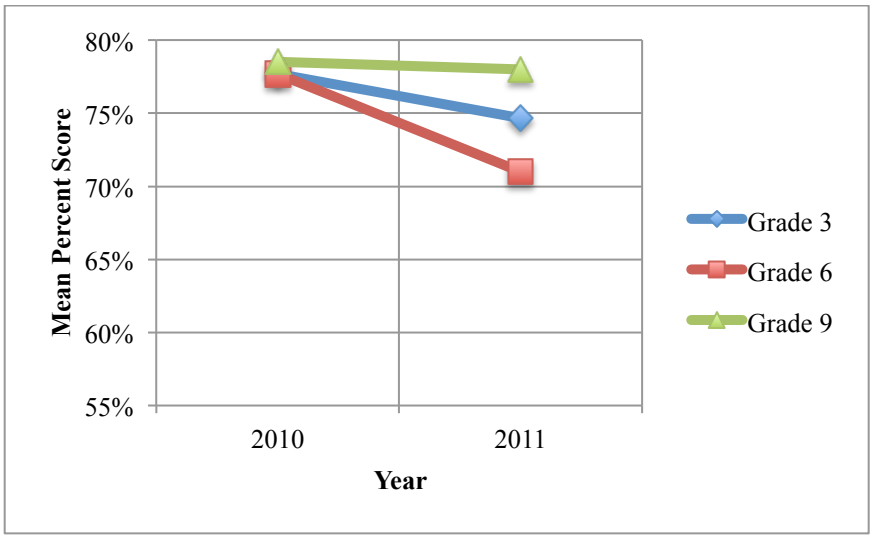
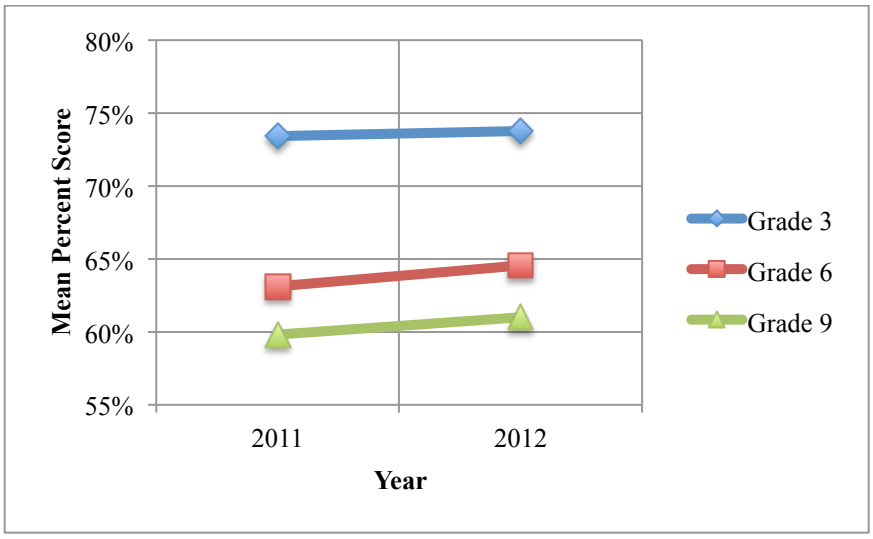


Figure 12.

Mean Percent Scores of Items Anchored in 2012



Part 2: Numeracy Support and Achievement

The second goal of the *Excellence in Mathematics Strategy*, to provide substantial support to students, teachers, and parents, was evaluated by analyzing students' mathematics achievement and the relation of the results for students who were in classes that received numeracy support compared to those who were not.

Three main sections present the results of the analysis of the effect of numeracy support on mathematics achievement. First, a longitudinal analysis of students' rubric scored open-constructed response items over time from Grade 3 to Grade 6 and whether those students were in schools receiving support was completed. Second, an analysis of the annual student achievement scores and whether the school received numeracy support in Grades 3 or 6 each year was completed. Finally, an analysis of the school annual mean achievement scores and whether the school received numeracy support in Grades 3 or 6 each year was completed.

Investigating the Variables

Before calculations were conducted, descriptive statistics were created for the numeracy support variables (See Appendix I). The mean ($\bar{x}$) and the standard deviation ($s_{\bar{x}}$) of the total score and rubric score for Grades 3 and 6 from 2007 to 2011 are calculated (see Appendix F). This data demonstrates the variance in the number and difficulty of items in the assessments each year. The rubric-scored closed-constructed items remained more constant, with the same number of items each year, compared to the selected-response and open constructed-response items.

Effect of Numeracy Support on Student Achievement Over Time

To analyze the effect of numeracy support on a student's achievement, a comparison of each student's rubric-scored items in Grade 3 and then later in Grade 6 was completed. Each student had two sets of scores, one in Grade 3, and one three years later in Grade 6. Students were considered to receive support if they were in a school where numeracy support was provided at their grade level, although they did not necessarily receive support. Each student had 4 rubric scores each in Grades 3 and 6 representing reasoning, communication, connections, and problem solving. For each grade, a combined overall rounded mean score was calculated. Therefore a student could have an overall score ranging from a 1 (very limited) to a 5 (outstanding). Finally, the population was divided into two groups: students scoring below standard (1 or 2); and students scoring at or above standard (3, 4, or 5).

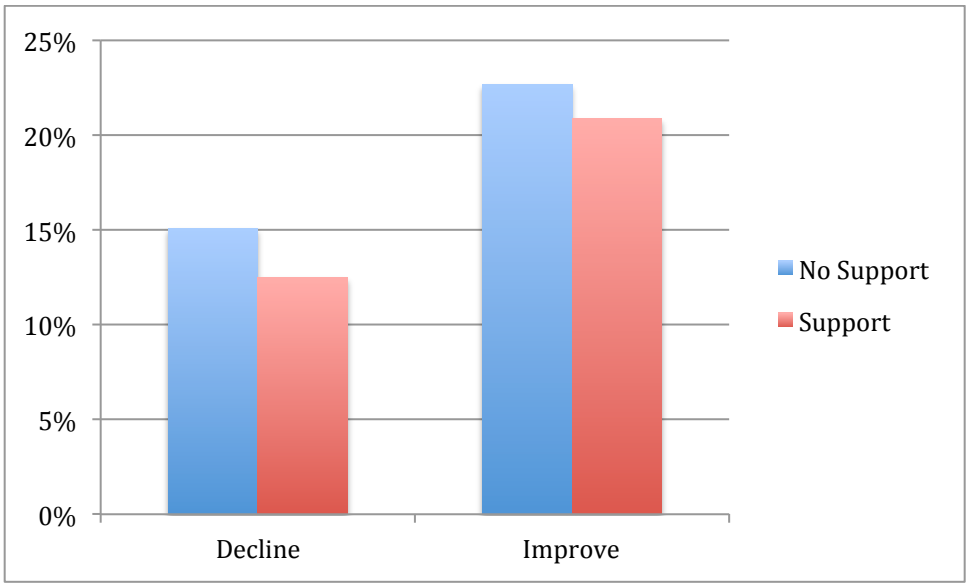
Cross tabulations were performed on these longitudinal results to compare the proportion of students that moved from one group into another, namely showing an improvement by moving from below to at/above standard, or showing a decline by

moving in the opposite direction. Students who remained in the same group were not considered in the analysis.

For students who were in Grade 3 in 2007 and Grade 6 in 2010, the amount of support could be considered only at Grade 6, as support was not available in 2007 (see Figure 13 below and Table 14 in Appendix J). Figure 13 displays the cross tabulations showing that although a smaller proportion of supported students showed a decline in achievement, a smaller proportion of supported students also showed an improvement in achievement in their rubric scores moving to at/above standard.

Figure 13.

Students moving between below and at/above standard from Grade 3 to Grade 6 if support was provided in Grade 6 in 2010



To further analyze the effect of numeracy support on reasoning, communication, connections, and problem solving in the Number Operations strand, the next years group, students who were in Grade 3 in 2008 and Grade 6 in 2011, allowed more comparisons as support was possible in both grade levels. First, to analyze each year of support

separately for 2008 and 2011, the results are similar for both Grades 3 and 6 (see Figures 14 and 15 below and Table 15 in Appendix J). In particular, if numeracy support was provided in either Grade 3 or Grade 6, a greater proportion of supported students improved to at/above standard. Also, a smaller proportion of supported students declined to below standard. Thus, it is to the advantage of students to be supported in either Grade 3 or Grade 6.

Figure 14.

Students moving between below and at/above standard from Grade 3 to Grade 6 if support was provided in Grade 3 in 2008

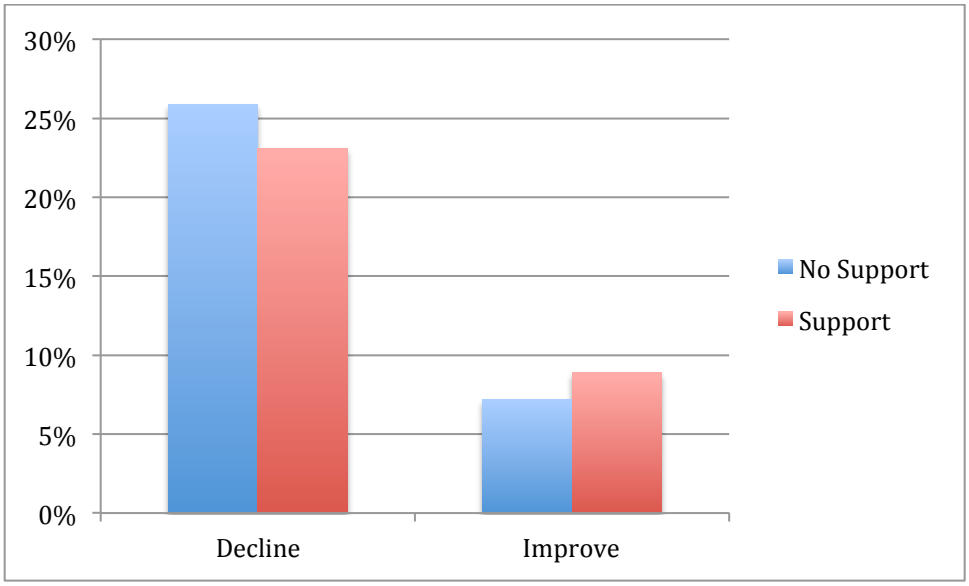
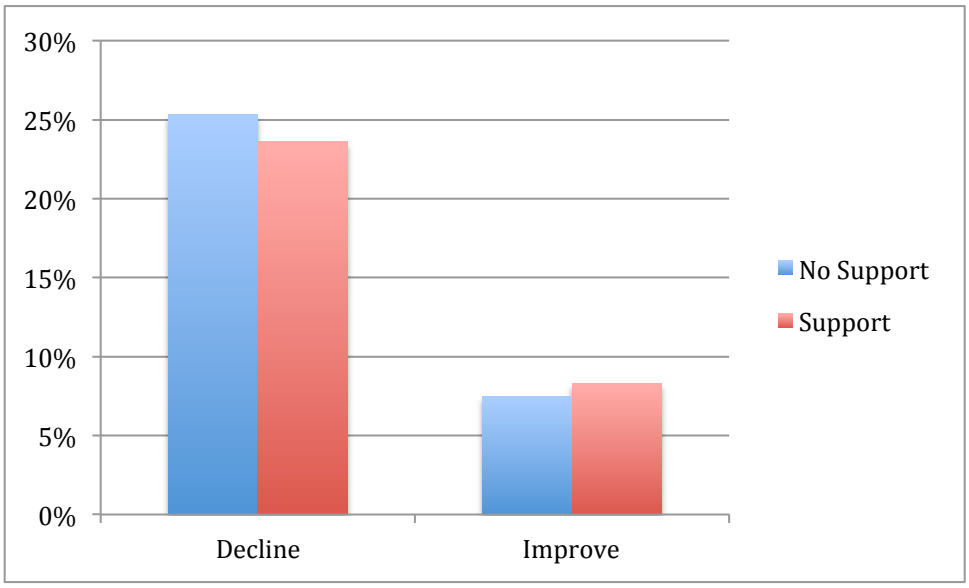


Figure 15.

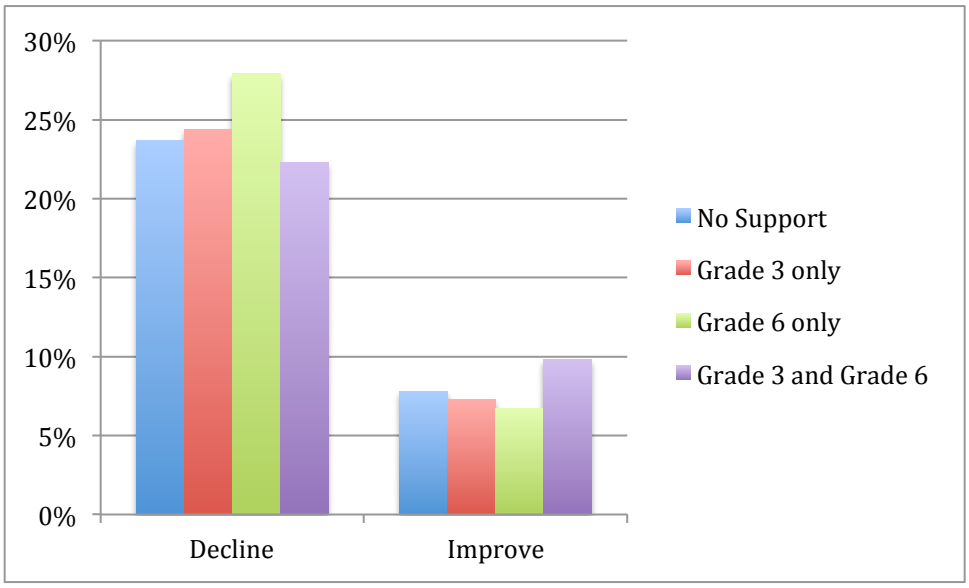
Students moving between below and at/above standard from Grade 3 to Grade 6 if support was provided in Grade 6 in 2011



For final consideration, a look at combinations of support with the 2008-2011 group was conducted. The results show that if support was provided in both Grades 3 and 6, the lowest proportion of students showed a decline in moving to below standard and the highest proportion showed in improvement in attaining at/above standard (see Figure 16 below and Table 16 in Appendix J). If support was only provided in Grade 6, the opposite effect was demonstrated. These results support the notion of the most effective use of numeracy support is to provide it in both Grades 3 and 6, but, if you had to choose only one grade, to put the human resources into Grade 3.

Figure 16.

Students moving between below and at/above standard from Grade 3 to Grade 6 if support was provided in Grade 3 in 2008 and/or Grade 6 in 2011



Effect of Numeracy Support on Annual Student Achievement

Annual Numeracy Support

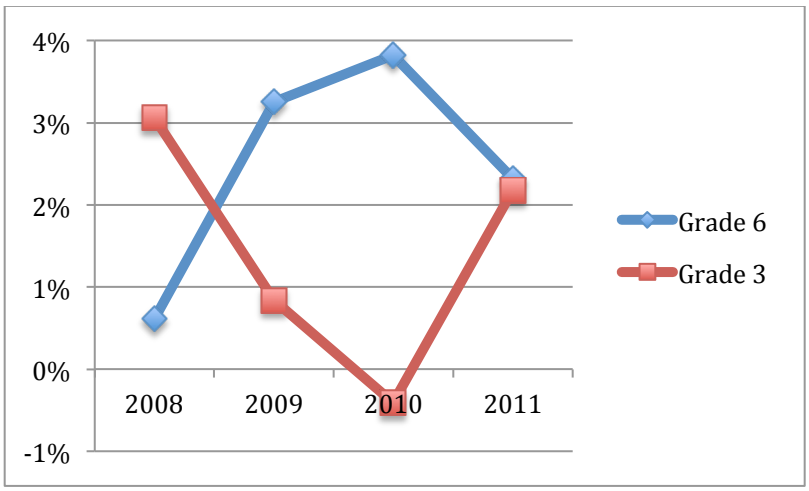
Since the rubric-scored items only represent a small portion of the provincial mathematics assessments, the selected response and closed constructed response items were considered as a student's total score. Numeracy support data were used again as an independent variable, in particular, whether a student was in a school that received support in that grade level. The most basic analysis to evaluate the effect of numeracy support is to compare mean test scores of those who received support compared to those who did not.

Means comparisons were completed on each year of the Grade 3 and 6 student achievement data using the total score percentage as the dependent variable and whether numeracy support was provided to a school in each grade that same year as the independent variable. Mean differences were calculated by subtracting the supported school means from the unsupported school means. Therefore, a positive difference demonstrates the unsupported schools had a higher mean than the unsupported schools.

Figure 17 displays the mean differences between supported and unsupported students (also see Tables 17 and 18 in Appendix J). For both Grades 3 and 6, numeracy support was provided to lower achieving schools each year, with the exception of Grade 3 students in 2010, although the difference is minimal. Over time, the Grade 3 supported group gets closer, and surpasses the unsupported group up to 2010. In 2011, the gap increases again, but not to the original 2008 difference. The Grade 6 supported group has an opposite trend to Grade 3, where the difference increases each year, until 2011, where there is a slight decrease.

Figure 17.

Mean Total Score Differences of Supported and Unsupported Students Annually



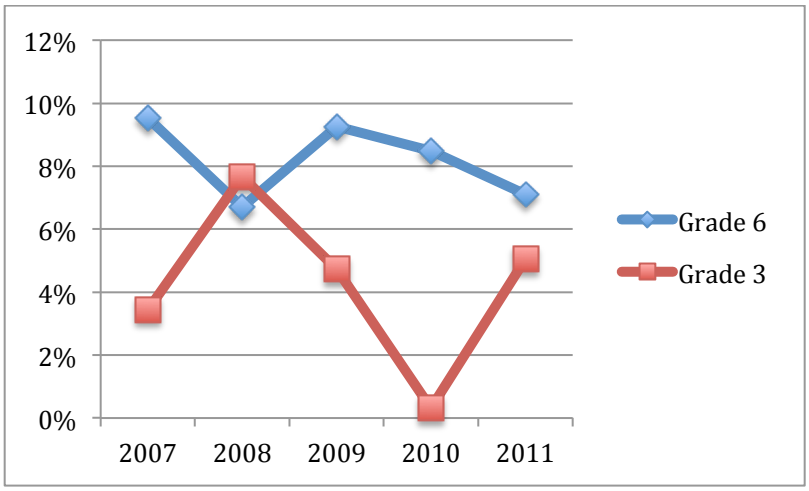
Total Numeracy Support Over 4 Years

Following the annual numeracy support analysis, means comparisons were then performed using the total score percentage as the dependent variable, but this time using the independent variable on how many years Grade 3 or Grade 6 students were in a school receiving support from 2008 to 2011. The results from June 2007 were included to provide a reference point before the full implementation of numeracy support teachers commenced in September 2007. By 2011, schools could have received up to 4 years of numeracy support.

Figure 18 displays the differences between the most and least supported students (also see Tables 19 and 20 in Appendix J). The difference in means for the two extreme groups, that being zero and four years of support, was calculated. The size of these two groups of students differ greatly, as discussed in Chapter 3, because the number of schools receiving no support represent a small number of students being from mainly rural isolated communities. The data supports more numeracy support teachers going to lower achieving schools over time compared to higher achieving schools for both Grades 3 and 6 (See Tables 19 and 20 in Appendix J). Grade 3 students who received no support performed better each year than students receiving four years of support. After 2007, the gap widens in 2008, and then lowers for the next two year. Finally, in 2011, the gap widens again, but not to the same extent at in 2008. The trend in Grade 6 shows a smaller difference every year compared to 2007, although the smallest difference occurs in the first year of support in 2008.

Figure 18.

Mean Total Score Differences of Supported and Unsupported Students over 4 Years



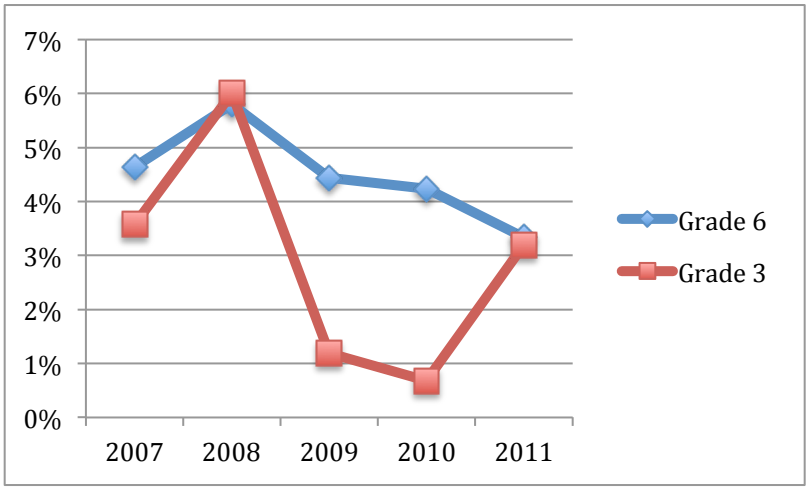
Total Numeracy Support Combining 0 and 1 Years of Support

To account for the mostly isolated schools receiving no support, and that in the first year of support, the Eastern School District gave support to almost all schools, schools which received zero years and only one year of support were grouped together. Means comparisons were then performed using the total score percentage as the dependent variable, and how many years Grade 3 or Grade 6 students in a school received support from 2008 to 2011 as the independent variable (see Figure 19 below and Tables 21 and 22 in Appendix J). Once the zero and one years of support were combined, the Grade 3 and 6 trends parallel each other, up to, but not including 2011. Again, the results demonstrate the lower achieving schools received more support than higher achieving schools (See Tables 21 and 22 in Appendix J). Both grades show an increase in the mean differences of the most supported and least supported students after 2007, but then a decline each subsequent year. One exception occurs in the last year for Grade 3, where the difference rises, but not to the same extent as in 2007.

This data supports the notion of numeracy support being effective on mathematics achievement over time. The student achievement gap between the most and least supported schools close over time. In Grade 6 the 5.8% gap closed to a 3.3% gap over the four years of the numeracy support. In Grade 3, the 6% gap became almost zero in 2010, showing almost no difference between the two groups, but then wider in 2011.

Figure 19.

Mean Total Score Differences of Supported and Unsupported Students Over 4 Years Combining 0 and 1 Years of Support



Effect of Numeracy Support on School Achievement Over Time

To complete the analysis of numeracy support effectiveness on mathematics achievement, a comparison of results was done over time at the school level, by creating school means from the student scores each year and if schools were supported each year. Standardized school scores were created for the comparison since the number and difficulty of items varied from year to year, thus allowing a comparison over time. This analysis reflects the effect of numeracy support of the teacher rather than the student as

the student population changes each year the assessment is written, but the teacher often remains in Grade 3 or 6 from year to year.

Since numeracy support went to lower achieving schools as described previously, an analysis of measuring whether a school moves up in its ranking relative to other schools was completed. Measuring the change in the standardized scores measures whether a school improves compared to other schools. Collectively, each year when the change is positive represents supported schools improved in their ranking compared to unsupported schools, even though those unsupported schools still could have higher results.

Means comparisons were performed on the annual standardized school mean score differences depending on if that school were supported in that year. Differences were calculated between those supported and unsupported schools. These differences are displayed in Tables 8 and 9 below and Tables 26 and 27 in Appendix J.

To expand on how to interpret tables below, a difference of -0.5271 in Table 8 indicates a relative decrease in the mean scores of schools receiving numeracy support in 2008 compared to 2007; on average those schools' achievement shifted lower relative to those schools that did not receive support by slightly more than half of a standard deviation. The following year, a difference of 0.2764 in Table 8 indicated a relative increase in the mean scores of schools receiving numeracy support in 2009 compared to 2008; on average those schools' achievement shifted higher relative to those schools that did not receive support, by slightly more than a quarter of a standard deviation.

Grade 3 supported schools increased their ranking relative to unsupported schools annually in 2009 and 2010, with standardized school score differences of 0.2764 and

0.2603 respectively, but then decrease in 2011, with a difference of 0.0407. Grade 6 results demonstrate a steady movement of supported schools increasing their ranking each year as the standardized school differences are negative in both 2008 and 2009 at -.0053 and -0.0123 respectively, but then increase in 2010 and 2011 to 0.0329 and 0.176 respectively.

Table 8.

Difference in Standardized School Means for Grade 3 Comparing if Support was Provided

Comparison Year		Numeracy Support Year			
		2008	2009	2010	2011
	2007	-0.5271	0.1699	0.2889	-0.0497
	2008		0.2764	0.4269	0.0533
	2009			0.2603	0.1246
	2010				-0.0407

Table 9.

Differences in Standardized School Means for Grade 6 Comparing if Support was Provided

Comparison Year		Numeracy Support Year			
		2008	2009	2010	2011
	2007	-0.0053	0.1058	0.2097	0.2019
	2008		-0.0123	0.0566	0.2129
	2009			0.0329	0.0146
	2010				0.176

The differences show, as you move along the diagonal, from one year to the next, Grade 3 supported schools improve, compared to unsupported schools. One exception is noted in the last year, 2011, which mirrors the annual student achievement results, and the longitudinal student achievement results for Grade 3. For Grade 6, a similar pattern is displayed continually along the diagonal, showing supported schools improve, compared to unsupported schools, from one year to the next, as the standardized difference moves from a -0.0053 difference in 2008 to a 0.176 difference in 2011.

In summary, there is evidence of numeracy support closing the gap between students in schools receiving support and those in schools with no support over time for Grade 6 compared to Grade 3. Schools receiving support were lower-achieving schools compared to schools receiving little to no support. Over time, the best results were if a student received support in both Grades 3 and 6, where a higher proportion of students moved from below standard to at or above standard in the rubric scored items, compared to other groups. Secondly, numeracy support has a positive effect of on student achievement over time. Analyzing separately the selected response items and rubric scored items over time at both the student and school levels resulted in a positive result for numeracy support in classrooms. Finally, schools' standardized scores with support demonstrated an increase in their ranking compared to those without support. The one exception is an opposite effect in Grade 3 in the final year of support, 2011, for both annual student achievement scores and standardized school mean differences.

Part 3: Focus Groups and Interviews

Educational change in mathematics was the main objective of the *Excellence in Mathematics Strategy* with three main goals: to improve students' achievement in

mathematics; to provide substantial support to students, teachers, and parents; and to encourage an increased interest and enthusiasm for mathematics.

Educational change in students' mathematics achievement was brought on through three tangible initiatives by the Department of Education: to implement a new curriculum for K-12 mathematics as recommended by the Math Review (AERC, 2007); to support teachers and their students with numeracy support teachers in their classrooms; and to fund events for the promotion of mathematics throughout the province. Student achievement can be measured with tangible scores in testing, but what is more challenging to measure are the intangible initiatives of how numeracy support is working in classrooms across the province, and how students, as well as their teachers and parents, may have an increase in their interest and enthusiasm for mathematics.

Through focus groups and interviews with ten numeracy support teachers and one mathematics program specialist, they shared why they were interested in numeracy support before they began their new positions. They shared their expectations of numeracy support when they started, and how these expectations evolved over the course of their time in the position. They shared their perceptions of changes in student mathematics achievement in the classroom over the course of their time in their positions. Finally, they shared personal experiences of teachers' and students' interest and enthusiasm of mathematics, as well as challenges upon which they came.

Changes evolved in the numeracy support teachers, the classrooms teachers, and their students. Numeracy support teachers reported becoming specialists in mathematics while establishing professional learning communities with their classroom teachers. Through these professional learning communities, numeracy support teachers created a

collaborative environment for their classroom teachers to improve their teaching and learning of the mathematics curriculum. Through collaboration, learning and practice, numeracy support teachers built capacity in their classroom teachers to continue learning and teaching mathematics with conceptual understanding after the numeracy support teacher was not present. Classroom teachers improved their conceptual understanding of the mathematics they were teaching their students. The teachers had a deeper understanding of the curriculum outcomes being taught and the processes students use to learn these mathematical outcomes. Also, teachers improved how they assessed their students of the curriculum outcomes. Numeracy support teachers reported student achievement to be changing with students becoming better problem solvers and having better communication skills to explain the mathematics they are doing. Finally, initiatives were shared by the numeracy support teachers on how there is an increase in the interest and enthusiasm of mathematics in teachers, students, and parents both in and outside the classrooms.

The principal investigator is represented by PI. The mathematics program specialist is represented by PS. There were five numeracy support teachers in one focus group, represented by NST1, NST2, NST3, NST4, and NST5. The second focus groups consisted of four numeracy support teachers, NST6, NST7, NST8, and NST9. The one numeracy support teacher that was interviewed is represented by NST10.

Change in Numeracy Support Teachers, Classroom Teachers, and Students

While an obvious change occurred in every mathematics classroom over the course of the *Excellence in Mathematics Strategy*, with new curriculum outcomes

accompanied by new curriculum guides, new student textbooks and teacher resources, and new class sets of manipulatives, subtle changes occurred slowly over many classrooms across the province. With the influx of numeracy support teachers, many classrooms had more than one teacher at times to focus on mathematics.

Numeracy Support Teachers

Many of these numeracy support teachers were generalist teachers prior to starting in the positions. They were classroom teachers who were looking for a change from the classroom, and were looking for a new learning experience themselves. They considered themselves not to be an expert in mathematics, but to be a good teacher. "I always loved math. I have always taught math for my full career. So, again, not math trained." (NST8)

Two numeracy support teachers with many years of teaching experience were looking for a different opportunity to share what they had learned:

> Despite the fact that I did not have a math major or that part, but I thought that in terms of the teaching piece, that I will be able to share some of the work that I had done, and I enjoyed being in the classrooms. (NST6)
>
> I was looking at concentrating on math, I had my background I had taught math in a variety of different roles in elementary… I was focusing on the math as a classroom teacher. So when the opportunity to work with other teachers in the area and other students would be a nice change for me and it turned out that it was. (NST1)

On the other hand, two younger, less experienced numeracy support teachers, looked at the position as an opportunity to learn about how to teach mathematics for when they return to the classroom:

> I've been in Kindergarten teaching and I did a bit in Grade 6 but I wasn't overly exposed to too much of the math curriculum so it was more of a … it was good for a learning experience, I feel that you learn a lot in this kind of role because you're working with different teachers and you're learning different strategies and I've learned a lot about the curriculum through this type of job. (NST2)
>
> Well I always enjoyed teaching math so I figured this would narrow my focus… So then when I go back in the classroom, if I do eventually, I'll have a good strong understanding of the curriculum for K to 6 math. (NST3)

With much professional development at the beginning of their positions in 2007, they slowly learned what the position involved, and began focusing on the teaching of mathematics.

The change in the numeracy support teachers was evident in their understanding of the teaching of mathematics as their focus was solely on mathematics with their teachers and students. The numeracy support teachers focused on planning units and how best the mathematics outcomes would be taught to students. They developed and led engaging lessons and activities, which encompassed the scope of the outcomes as indicated in the curriculum guide. Various teaching strategies were modeled with teachers in their classrooms, and the modeling then moved to co-teaching as the relationships with their teachers and students grew over the course of each year. The

numeracy support teachers also focused on how teachers assessed their students' understanding of the mathematics outcomes, and how these assessments vary over the year.

The numeracy support teachers reported a change from being primary and elementary generalist teachers to becoming specialist mathematics teachers in their region. One numeracy support teacher described herself as hating math years before starting this position, but then upon her own professional initiative, enjoyed teaching mathematics:

> Ironically, math was not my forte, it never was, and maybe I shouldn't say it, but I hated math. Absolutely hated math, and hated to teach math. And then we got our new program back in 2000 maybe… I remember making that my personal goal to say, okay, I'm going to really do a good job of trying to figure out how to teach this math program. So over a couple of years math actually became my passion, believe it or not. And so by the time I actually started this job, math was where my head was and I loved to teach it. So I had a complete 180. (NST9)

They reported wanting a new learning experience when they began their positions, and looking for professional development in how to be a numeracy support teacher. They changed from receiving professional development at the beginning of their positions as numeracy support teachers to being the facilitator of others' professional development. The scope of the professional development they offered to others ranged from working with teachers on how they teach and assess mathematics in teachers' individual classroom, to working with a full staff of teachers at staff meetings and professional development days on the teaching and assessment of mathematics. The

largest amount of professional development given by the numeracy support teachers was when the Grades Kindergarten, 1, 4, and 7 mathematics programs were implemented in 2008. Provincial teams of the numeracy support teachers were created to give each K, 1, 4, and 7 teacher two full days of implementation in Spring 2008, prior to the new school year in September. From then onward, until the implementation for Grades 3, 6, and 9 were completed, the K-6 numeracy support teachers were included in some fashion for teachers' professional development:

> We've done a lot of inservice. Regularly you're doing a lot of mini inservices with schools and that kind of stuff. I've been asked by all schools that I deal with to present at various shutdown days that they've had with something in the area around student achievement or the different aspects of math curriculum. So that's part of the role I didn't anticipate but that being part of the role initially but I guess it's evolved into a little bit of that. (NST1)
>
> the co-teaching piece. In a lot of our cases, it's a big piece of the work that we do… and then it doesn't seem like I'm the expert. I don't think it's about having the expertise in a particular area to bring it in, but that we're able to co-teach and work together with people. (NST6)
>
> I just took it as a springboard… as an opportunity to continue sharing and helping these teachers grow in a particular subject area. (NST10)
>
> When I started I didn't have any inclination as to what the role was I just thought it was more or less teacher curriculum support. (NST4)

Also at the beginning, the numeracy support teachers applied for their position because they were looking for a new learning experience, receiving much professional

development from both the Department and their Districts. They soon were facilitators in others' professional development. While on the provincial implementation teams, the support teachers were able to talk to each other and share their ideas, activities, lessons, and successful classroom stories. Upon completion of the implementation, the time to share lessened, and due to geographical constraints, some numeracy support teachers felt isolated, even though they were able to communicate electronically with others. They were wanting more sharing of ideas, activities, and other created resources:

NST8: It's hard to do any personal reflection by yourself. Whereas if you're talking with another colleague and all of a sudden your head space might change as to an idea or something that you were doing.

NST6: That's right. And in your case, you're by yourself and she is by herself in her area. Whereas at least we have some… we can walk back to the office and there's two or three people there, collecting and we're informally, we're talking.

Some regional differences evolved from the numeracy support teachers. Urban numeracy support teachers in one district reported working in classrooms that were based on previous achievement in mathematics determined by the school district, and worked with low achieving Grade 3 and 6 classrooms mainly. These teachers did not choose to work with numeracy support, but were informed by administration they would be receiving numeracy support:

NST9: It's always been at the very beginning it was just go and make yourselves visible in schools. Go to people that you know and sort of get out there.

But then it became more streamlined, more focused. You're working with the Grade 3s and the Grade 6s in these specific schools.

PI: How were those schools determined?

NST8: Mostly by CRT results – or by whether new teachers were in the grade or if the school was a constantly low achieving school.

NST9: Well, that's one issue with being slated for 3 and 6 is that you had to work with 3 and 6 teachers in certain schools, whether they wanted to work with you or not. And it wasn't… we were never given the choice.

NST7: Teachers couldn't self-select.

Rural numeracy support teachers from a different district worked with new teachers and teachers who were struggling with mathematics. They also considered geography a budgetary constraint:

> It's more or less a budget constraint with mine. Every time I travel it's an hour and fifteen minutes to go anywhere and that's what cuts down my visits. (NST2)
>
> My furthest school's almost 282 kilometres return, so you're not getting at that school whereas your base school is reaping the benefits of your support or the schools in that area. (NST5)

The program specialist shared a story of how dedicated one of her numeracy support teachers were to working with their teachers and students in the classroom:

> I have one poor NST, never claimed a lunch any day she was at the school all day, because she said, that's ten more dollars I could put toward kilometres and I can get to them, you know. If I save ten lunches, that's a trip one-way trip to a school.

> Not many people would do that, but that's how much they believed in the role, or were conscious about trying to maximize their budget. (PS)

Regardless of where the communities where these support teachers worked, they all regarded working in longer blocks of time with their teachers to be more beneficial to the teachers' development in their teaching strategies and assessment of mathematics. All of them started with working one day at a time in a school, and not returning to that school for another two weeks. They have moved to working in a school for up to a week, and then not returning for another month or two. The upside of this is allowing their teachers to become more comfortable with various teaching methods and the use of manipulatives, while seeing the progression of teaching a mathematics concept from the beginning through the ability to assess students' achievement of the concept over time. One downside of the block scheduling is the possibility of not returning to the classroom for a long period of time where teachers are not supported in teaching full concepts and units of work:

> My first year it was just one school one day, another school another day, another school another day and you know you're getting to some schools twice a month which wasn't really very effective and then I decided my second year to change it. I would spend a longer block of time at a school, maybe about two or three days which worked well in some schools and other schools not as well just because some schools were more receptive and you had a better relationship with the teachers and other schools weren't. (NST4)
>
> Being at a school for more than a day and then two weeks later being there again it allows for that collaboration and it allows for you to do some analysis of what

actually is going on. You know what works, what doesn't and I think that's important. (NST1)

It was you just go in and you leave again, it's like flying visits. Whereas now… if you spend a week at a school the teachers have to make a promise that they're going to try certain things and then when you get there again you're going to discuss that, how did it go, what went well, what didn't. (NST4)

You get consistency and some of what we're referring to now in terms of is something continuing because you would see it continue while you're developing a particular concept…. If you were using the base ten blocks with multiplication of decimals, you might model one day and then the second day you go back and you want to actually model some of the multiplication. And then the last two days of the week you might be doing some division. So you can almost see the progress, right? (NST6)

But then I realized I wasn't getting back to that school I would touch base with them via e-mail, but it wasn't the same. (NST6)

Sometimes you'd go back five weeks later and they'd have an entire concept covered. An entire unit you hadn't really been part of it in terms of the teaching. (NST9)

I was at a school and we planned a unit and then I might be back in the next day and I'll introduce the unit and then it might be two weeks before I'm back to that school again and the units all done with and finished so I never got to see how they did. I don't see the follow up or anything like that and I didn't even know if they really did what we even planned. (NST3)

Professional Learning Communities

As numeracy support teachers worked in various primary and elementary classrooms across the province, small professional learning communities were established between each teacher and their numeracy support teacher. Some became larger as the numeracy support teachers worked with teachers together at a particular grade level in a school, or brought teachers together from different schools. The one certainty is the constant growing professional relationship between each teacher and the numeracy support teacher in their classroom.

Because of the limited number of numeracy support teachers, particular classrooms were targeted as previously mentioned. Some numeracy support teachers work with new teachers and teachers who were not comfortable teaching mathematics. Others worked with teachers in classrooms that had low achievement results on previous provincial mathematics assessments. Some teachers chose to work with the numeracy support teachers, while others were told they had to work with the numeracy support teachers:

> The classes that we had our NSTs go into… we based that on the teacher need. What teachers are new, what teachers aren't comfortable with a topic in mathematics… We based it on the need of the teacher, not the need of the student, but obviously by helping the teacher, you indirectly help the student. (PS)
>
> NST6: You had to work with (Grade) 3 and 6 teachers in a certain school, whether they wanted to work with you or not. We were never given the choice.
>
> NST7: Teachers couldn't self-select.

NST9: No. We couldn't choose not to work with that Grade 3 or 6 teacher, and they couldn't choose to say, no, I won't work with them.

NST8: I've had a similar experience.

NST9: It's always been, at the very beginning it was, just go and make yourselves visible in schools. Go to people that you know and sort of get out there. But then it became more streamlined, more focused. You're working with Grade 3s and Grade 6s in these specific schools.

PI: How were those schools determined?

NST8: Mostly by CRT results, or by whether new teachers were in the grade or whether there was, you know, if the school was a constantly low achieving school.

Collaborative Culture

These professional learning communities, by providing extended learning opportunities, allowed classrooms teachers to work with numeracy support teachers to develop their collaborative relationship to improve the learning and teaching of mathematics. They had a culture of practice, as they collaborated on the mathematics being taught, ranging from planning unit, modeling lessons, assessing outcomes, and planning larger math events. This intensive professional working relationship grew over time. Numeracy support teachers described their days with teachers as they collaborated on unit planning, creating resources, and discussing and enacting various teaching strategies in the classroom. While some teachers were welcoming of the support, other teachers gave resistance to varying degrees, from struggling to change their own teaching frameworks to no willingness to change their teaching styles.

One numeracy support teacher described her culture of communicating constantly with her teachers about mathematics, and how she is always communicating collaboratively about what the mathematics teachers and their students are doing and what they will do next:

> You're constantly talking about it all the time. "How did that go, how did the kids respond to that? Oh, it didn't go very well. What should we do next time?" Its much more of a team thing and you're getting away from that, "Oh she is the expert. She knows. She's supposed to know everything. She says to do it like this." Then well, you know, its' we're learning together, which is really, it's a lot of, what the word I'm looking for collaboration, yeah. (NST4)

In a focus group, the numeracy support teachers described the relationship changing between themselves and their teachers and how personal the relationships became between them:

> NST8: One thing I notice about the culture, the NST culture … but professionally it became more personal. Because initially starting out you were giving PD to teachers or you were passing out stuff and all of a sudden it evolved to really getting to know a teacher or really co-teaching, planning together, and really hashing out stuff that, well, you know, it's almost like your buddy. And so it became very personal.
>
> NST6: We would spend a lot of with them. I know over the past couple years
>
> NST9: with the same teachers
>
> NST6: with the same teacher. There's some of them that I never would have that relationship with. Anyone, if I was back in my old school probably. But its

just that when you work with them so much and then you're helping them along. They're so appreciative of that. It's almost like you've become very close to them and yet they're strangers in another – you know.

NST7: Well, you wouldn't socialize with them, would you?

NST6: I would never, exactly. Right, you would never – right? But for some reason it's just a very different relationship.

Implementing Curriculum

While each teacher was given professional development days for the new curriculum implementation, the numeracy support teachers gave further support to implement the curriculum at the classroom level:

> They've got the PD. They have some backup, but they just want someone to come in and co-teach. And I think a lot of it is the organization and managing it all. (NST6)

One numeracy support teacher described how one teacher was overwhelmed by the new curriculum implementation. She worked with this teacher to plan a lesson from the curriculum, and the teacher implemented it with great success according to the students, the teacher, and the numeracy support teacher:

> I worked with a Grade 6 teacher and she'd been to the inservice. But of course was overwhelmed. She was brand new and I said "Well, let's do this." So we just planned. That's it. I didn't teach her classroom at all and we planned and I nipped in a couple of days later and they had been doing that lesson and they told her that was the best lesson they ever had, the best math lesson they ever had. I didn't

teach it, she taught it but they had the tiles out and they had a grand time you know. (NST4)

Another numeracy support teacher went into her classes with "amour of activities," as she described her teachers being "overwhelmed with the new curriculum." In particular, overwhelmed with creating the activities from the new curriculum guides, some of which were demonstrated at the professional development days for the curriculum implementation. She described the teaching and activities that were based on the new curriculum as being possible with her working with the teachers. She thought the change in teachers wouldn't occur without the working with them:

PI: So when they created these activities, they

NST10: Actually the activities were done right out of the curriculum guide.

PI: But they used them?

NST10: Yes they did and

PI: Without you there?

NST10: Yes, oh that's exactly, but I don't know if they would have done it on their own, if it wasn't initiated. Whereas, and the reason I say that is because the Grade 4 teachers, for example, did not have the same injection of hand-outs from the curriculum guide and they never ever developed them. So they are developed for them this year, which is now four years later, because somebody's taken the time to do that.

PI: But they're using them?

NST10: They're very grateful to have them, very grateful to have them.

Building Capacity

These numeracy support teachers were building capacity within their teachers, as teachers were given the opportunity to collaborate and allowing them to reinvent their practice. Some of their teachers have reinvented their culture of practice as they learned the mathematical concepts, the conceptual understanding, the processes students need to learn these mathematics outcomes. Some teachers made the change to continue this work not only during the occasions the numeracy support teacher visited with them, but also after they left and the teachers were working by themselves with their students:

> It will take a lot of time putting together these centres and getting your manipulatives and stuff but once you have them I think when they realize once you've got it made and if you have your manipulatives set up in the classroom it's not going to take as much time. (NST3)
>
> I've had that advantage, I go in and work with some teachers for two weeks or more and then back again, okay not back again for another couple of months, but by this time the kids are just going and getting it and using it and they're fine. So it's teachers who've just had more of a chance to just see it in action with me being in there for longer periods of time to see how useful it is for a whole unit not just for one lesson. (NST4)

One numeracy support teacher allowed teachers to visit another classroom where teachers were teaching using various strategies. It was not until the visiting teachers saw the strategies in action that they realized they were possible for themselves:

> They were getting to see what another classroom looked like and I think that some of the teachers had opened their eyes a little bit because sometimes they were

> saying you can't do it but they saw that you could, you could do it with 25 in your class and that kind of stuff because other teachers were doing it. …I know that it really changed the way that they approached teaching the math once they saw they said "okay well I'm going to try that" and then they carried on with the host teacher and they shared a lot of things. (NST1)

Some numeracy support teachers reported giving teachers particular tasks to complete which would be discussed when they would return. Some teachers completed the tasks, while others returned to their former way of teaching. "They have this traditional view point and they're not going to change." (NST5)

> I've heard teachers say "I can never think about going back to the way I used to teach this math now that I'm doing it this way." That's one side of the story. Other teachers you go in and you can do what you want and when you leave class it's just not happening. (NST1)

One teacher described to their numeracy support teacher how she has changed her way of thinking to be more similar to her numeracy support teacher's way of thinking. This teacher has made the jump into a fundamental change in her teaching, and now has the capacity to plan, implement, and assess her students with the focus the curriculum has intended:

> Actually, I had a situation the other day where I've seen classroom management change… I've seen arrangements in classrooms have changed. Like the rows and tables and that. And I've had a teacher say to me the other day, "I'm going to do the things that she did. The activities that we developed this year, I'm doing those again." And she said, "When I'm doing something now, I stop and I think how

would she do that or how would we do that if we were planning together. That's how I run with it now. I stop and think. So she's changed my way of thinking." (NST7)

NST9: Ones who have been on board, I know that it's being, when I leave, it's carried forward. They do it.

PI: How do you know?

NST9: Because if it wasn't, then the kids wouldn't be as familiar as they are with it the next time I go back…. So I know it's being done. And I see that the manipulatives are still in the baggies that we put them in and they're still organized and they're being used because you know, the Ziplocs are getting a little bit worn and torn and … you know, so I do see the evidence.

The program specialist described the numeracy support initiative as building capacity after the numeracy support teachers are not in the classrooms anymore, "At the end of the day, the teacher has to take ownership of it."

Classroom Teachers

The change in teachers' classroom practices evolved over time while working collaboratively with their numeracy support teachers. Teachers changed their conceptual understanding of the mathematics they were teaching, as they developed the big ideas, making connections, and understanding the purpose of using various activities, lessons, and assessments for their students.

Conceptual Understanding

Numeracy support teachers reported how a teacher's conceptual understanding of the mathematics being taught developed through their professional learning communities. Many began with a traditional approach to teaching a mathematics concept with first demonstrating the algorithm, then allowing their students to practice the algorithm. Slowly, some changed their teaching practice to understanding the main concepts being taught, and allowing the students to develop the concepts through problem solving and making connections to previously learned concepts.

One numeracy support teacher described the change in the perception of some of her Grade 3 teachers from students creating their own word problems:

> They said, "I would never have thought of doing it in that way." Of making up their own word problems first instead of teaching them the concepts and then... like I said it isn't new, it's nothing new it's just… It's what the curriculum guide says to do you know." (NST4)

She further described the problem-based learning environment of the students in the mathematics classroom:

> Years ago I would have said, well no, you teach the concepts first and then you get them to interpret a word problem. But if they can't interpret the word problem because they haven't had any experience with that type of word problem. (NST4)

Another describes his Grade 4 teachers changing their teaching to introduce the algorithms last after students have had time to develop the concept first:

> I've had a few Grade 4 teachers say "We haven't done division yet. How are we going to do that?" and I said "Well, we're going to set up some problems solving

> situations where in order to solve problems children are going to have to share and then we're going to discuss how to share with using base-ten materials. The last thing we're going to do is introduce the division algorithm. So that will be the last step, not the first step. It's a bit of a different approach and when teachers see it, once they see it done they realize that it can be done. (NST1)

In contrast, one numeracy support teacher reported how some of her teachers did not develop the conceptual understanding of the big ideas in mathematics, but were having their students engaged in mathematics lessons and activities without knowing the purpose of them, demonstrating a lack of understanding.

> I think the biggest frustration I have is that people are haphazardly going through the math program and not really having a focus as to why they might be doing something in the classroom… They don't have a clear vision of why they're doing something. Therefore they don't know how to evaluate it, because they're just doing it because it's part of the unit. But they don't know why they're doing it. Mrs. So and So was doing it, or Mrs. So and So has this activity. I'm going to do this activity. But they still don't know the rationale behind the activity. … They get caught up in, "This is what I've always done. There are the tests I've used and they're in my filing cabinet. I'm going to use them." But they don't really know what they're testing, other that the fact that this is the one that I've used for the last ten, fifteen years. (NST10)

Curriculum Outcomes

The numeracy support teachers reported how teachers were first referring to the lessons by referring to pages or sections of the student textbook teachers without

referring to the mathematical concept being taught. Much of the numeracy support teachers' focus was on changing the teachers' culture of practice to knowing the mathematical outcomes the students are required to learn. To come to this understanding, the numeracy support teachers used the Department of Education's curriculum guides as their main resource. In these documents are listed the curriculum outcomes, their accompanying achievement indicators, elaborations on these outcomes and indicators with strategies for teaching and learning, and accompanied with suggested assessment strategies, and associated resources. The numeracy support teachers used these documents as the framework for their unit planning, teaching of individual lessons, engaging students in accompanying activities, while simultaneously assessing students on the mathematics they were engaged in.

Some teachers were reinventing their culture of practice, from solely using the student text to using the curriculum guide as their framework to teach and assess the main mathematical outcomes, while changing their classrooms to being a more student-centred environment.

One numeracy support teacher described how his teachers are moving to teaching the outcomes to students rather than a page in a textbook, and how this allows teachers to see the long term planning and learning for students rather than teaching one page at a time to students:

> I think some teachers are finally seeing beyond 355 pages in the textbook and realizing what they're teaching is the outcomes. Once they plan the units looking at what the outcomes of the units are, rather than what's on lesson one, what's on

> lesson two. And that's a big thing that I've been pushing like the unit part and you know trying to stay a month ahead rather than just a day ahead. (NST1)

Another numeracy support teacher describes how her teachers change their perception of the curriculum guide and the student text as resources:

> I've had a few comments as well from teachers saying, "I now actually feel that the curriculum guide is the place to look first and that the textbook is just a secondary resource. (NST4)

One numeracy support teacher described the pacing struggles of teachers who focus on the student text rather than the outcomes intended for the student to learn:

> Some of the Grade 6 teachers are struggling and they'll talk to me in March and say "I'm never going to get stuff finished." You sit down with them and say "Let's look at what outcomes you can best cover." A lot of cases they're looking at the book and what units, but you look at the outcomes and then plan the outcomes and go through that. There should never be a problem finishing the curriculum. (NST1)

One numeracy support teacher describes the frustrations she has had with teachers having the student text as a resource:

> I personally think that handing teachers a resource, you give them a crutch…. Our philosophy is children learn by doing, teachers learn by doing. They're never going to learn if they're just handed this resource. And I think that was the very biggest mistake that was ever made. (NST4)

Process Standards

One encompassing focus on all of the mathematical outcomes in the curriculum guide is the process standards, being how the students engage in the mathematics to learn the specific outcomes. For example, students can communicate their reasoning by journaling their understanding how to solve a mathematics problem. Or a student can represent a problem using various manipulatives to organize their thinking while solving a mathematics problem. One numeracy support teacher reported how all teachers have to use these process standards because they have to assess student's process on the District's term report cards to parents:

> The change in the curriculum and the direction that's steering the curriculum I think its forcing teachers to look at the way math is being taught differently. Now, was that always there? Yes it was, it was always there. This is not something completely new, but I think the focus is so much now on the process standards that teachers can't avoid it anymore. (NST10)

While there are manipulatives in the schools, the goal of the numeracy support teachers was to have these manipulatives regularly accessible to students. The numeracy support teachers would model the use of these manipulatives to teach a mathematical concept. Also they would model to their teachers how to organize them and make them easily accessible for their students. Many teachers knew that manipulatives were useful, but did not feel confident in using them until the numeracy support teacher modeled them, while teaching a lesson, where teachers could visualize the logistics of how this would work in their classroom:

> But I think some teachers when they saw what and saw the kids so engaged and the learning was more authentic than the textbook they've been a little bit more open up to it. (NST5)

The use of manipulatives increased with teachers and their students in the classrooms. Numeracy support teachers spent much time modeling lessons with manipulatives, allowing teachers to visualize how they would organize the manipulatives so that students could have easy access each day, and also being able to work with the manipulatives to allow students to develop their mathematical understanding of the concepts being taught. One numeracy support teacher described how after spending a small amount of time with the teacher with using the manipulatives in various ways, the teacher then uses them with comfort and understanding:

> A lot of teachers weren't comfortable with using the manipulatives. I have a lot of success stories. Just take the pattern blocks for instance. A lot of teachers are still stuck on the fact that they can only do halves, thirds and sixths with those pattern blocks. But I say to them "You can make those pattern blocks talk." You sit down and you spend 15 or 20 minutes with them and then the teacher just takes it and runs with it. It's just great to see that they get something out of it. Same thing with the base ten blocks. (NST5)

Another numeracy support teacher adds his thought about teachers using manipulatives, and how it extends into students' learning and problem solving:

> I would agree there too with that. I think that's something that with some teachers I'm finally seeing that they are taking. You're going into classrooms now and you're seeing children using various manipulatives without having to have the

> teacher tell them to use it. And of course that's the goal: that students will be able to move around the class and see what's there available for them to solve the problems. … So the new curriculum has made people more aware of the process standards… I think (teachers) are realizing a lot more now the importance of children being able to communicate and represent what they're doing rather than just come up with an answer to a question. (NST1)

Student Assessment

Assessment of the mathematics achieved by students varied across classrooms. All teachers and students were aware of the provincial testing in Grades 3 and 6 with the criterion reference tests at the end of the year. Also teachers were aware of having a cumulative test at the end of a unit, sometimes created by the teacher, and other times taken directly from the publishers' teacher resources that accompanied the student text.

Numeracy support teachers focused on other ways teachers can assess their students, focusing on assessment of the students' learning. Through ongoing assessment throughout a unit, numeracy support teachers worked with their teachers on how to question and interview students, how to use portfolio assessments, and how to use various activities to assess students' knowledge of an outcome as described in the curriculum guide. Numeracy support teachers often developed and used various assessment strategies listed that supported the mathematics outcomes in the curriculum guides.

One focus group discussion reported a variety of types of assessments used by their teachers, such as using observation notes and checklists while moving away from

using only traditional unit tests. Students were excited to be assessed in these different ways:

NST8: You're seeing a lot of teachers now not even using unit exams. Not using them, just don't see the point.

NST6: and a lot of observations, and a lot of anecdotal notes. And I think that's really positive, right?

NST7: And you know, the whole complete checklist. Like, our kids last week, because we always have, when we do centres, one centre is an assessment centre we call it the Mrs. (name) Centre, that's the classroom teacher. And the kids love to get to that centre. The whole time they're at Mrs. (name)'s Centre, they're being, you know. She's checking off things as she's making notations. But they think its' wonderful to get to work with Miss.

NST6: and she's interviewing or

NST7: she doing. Right? So we always have a Mrs. Whatever centre when we're doing work.

Following this conversation, one numeracy support teacher discussed the use of portfolio assessment in one of her schools, and how this is motivating for the students, as well as herself, compared to using unit tests:

They do the portfolio assessments. So at the end of each unit per se the kids have that collection of work that they have criteria that they use to select pieces of work that they put in their actual assessment portfolio that then is used for assessing how they did on that particular unit. And you know, they're one of the groups that have come out on top, in my mind, as being the most motivated and

> the strongest group in math. … That really sort of motivated me. I see the potential for using or the success in using the portfolio assessments as a huge chunk of your assessment for the whole year, as opposed to just those unit tests. (NST9)

Numeracy support teachers took much time to develop many of the assessment ideas and accompanying activities described in the curriculum guide. First, they completed them alone, and demonstrated them to their teachers and students. Then allowing the teachers to put the assessment tasks and questioning of students to practice as they worked with their teachers together in collaboration to plan other activities. The hope of the numeracy support teachers was for their teachers to gain the skills, confidence, and allow time to develop the assessment tasks and carry through with them on their own, thereby building capacity. One numeracy support teachers describes her role in teachers developing the practice of ongoing assessment:

> But I think in terms of assessment, not the CRT, but I think in term of our classrooms now, there's more ongoing assessment happening than what I saw when I walked in four years ago. There is more ongoing assessment, whether it be through centres or through some of the assessment tasks from the curriculum guide. It's like teachers are not waiting until the end of the chapter or the end of a unit. But it's more ongoing and I think we're certainly helping with that role. (NST6)

Teachers found the development of these assessments tasks and activities overwhelming and time consuming. But once completed, some would use them again later in the unit, and intended to use them in following years when teaching the course

again. One numeracy support teacher was going on leave for part of the year, and provided resources for her teachers. Her teachers were looking for more resources to be given while she was on leave, demonstrating the lack of capacity at that point for the teachers to develop and implement more assessments tasks on their own:

> I had provided the teachers probably the first two units, had taken all the activities from the curriculum guide and had done them up as activities, so that they had them. All they wanted to know before I left was, are you going to be able to do the rest of them till the end of the year, while you're gone? But they would use whatever I gave them, but they were overwhelmed, I think, with a new curriculum being… creating, or even having the time to do them. (NST10)

The provincial assessments are viewed by numeracy support teachers to be a representation of the curriculum outcomes. If teachers are teaching their students the mathematics outcomes as represented in the curriculum guides, then they are teaching their students to be prepared for the provincial assessment as it is a representation of the outcomes. In a focus group, two numeracy support teachers discussed teachers' perceptions of the provincial assessment, and its direct relation to the curriculum guide and the mathematical outcomes:

> NST9: I say, well, look, if you doing what's in your curriculum guide, if you are taking those exact assessment questions from the curriculum guide, that is what the CRT is all about. That is exactly what the CRT comes from. So if you're doing everything in that curriculum guide then you are preparing those kids 100% for what they will see on a CRT.

NST7: I often say, you know, you hear a teacher say, of so-and-so down the hallway is teaching to the CRT. I said "Good for her. Go down and pat her on the back." And they kind of look at me. I said "If she's teaching to the CRT, it means she's teaching the outcome. So if she's teaching the outcomes, then there's not an issue."

Student Achievement

Although all Grade 3 and 6 students write a provincial mathematics assessment at the end of each year, the numeracy support teachers and the program specialist were all asked about their views and observances of any change in student achievement in their classrooms, day to day, over the course of their work with their classroom teachers and students. Many reported seeing differences how students are able to communicate better about the mathematics they are working with. One numeracy support teacher describes how students are being prepared to solve problems outside of school that are practical as they build their own "learning network":

I think there's going to be a difference in the fact or in the sense that kids are building their own learning network. They're constructing knowledge and they're going to take that beyond school. Those problem-solving strategies for instance. Being able to sit down and solve a problem, a practical problem too. (NST5)

Another numeracy support teacher then expands his thoughts into how teachers and students are more open to a variety of strategies and how they can communicate more easily about these strategies:

There is a huge difference now from when I first started to now. How children can talk about how they're doing things in their head, not just mental math but

> anything what they may have written down. There is a lot more teachers and children being open to new different ways or different strategies. And they are able to talk about it. I'm not saying they're going to do better on the CRTs but they're talking about it in the classroom and there is a deeper understanding. (NST4)

One numeracy support teacher described the reasoning and communication skills of Grade 1 students improving as they strategize about addition. She believed the skills were stronger for students in the new curriculum compared to older students who were not in the new Grade 1 program:

> When I'm working with the students that are in elementary who weren't in Grade 1 when they brought in the new program and I talk to Grade 1 students now, there's some students who before that if you were talking to about addition strategies, they don't know what they're talking about. When I go into a Grade 1 classroom now and a child is adding together seven and four and you ask them "How did you know that?" They look up at you and say "Well, I can take three from my four, add it to my seven to make ten, one more than that is eleven." Or for example six and seven, "I know that six plus seven is thirteen because six and six is twelve, one more is thirteen." There's a lot of that. When I got to the grades that are higher, like maybe Grade 4 and things like that where they haven't had this same program in Grade 1 and you ask them to talk about the strategies, the communication is not there as much as it is now. (NST2)

In one of the focus groups, the numeracy support teachers discuss the change in students' problem solving skills and how that is due to the new curriculum

implementation and its accompanying professional development, which was focused on how the mathematics is being taught, with engaging activities for students:

NST1: I've seen a change with the students. I think students now are more knowledgeable than they were say generally speaking, more knowledgeable than they were back ten years ago… They can deal with it in context. They're better equipped to solve problems than they were, when before they were better equipped to do an algorithm that was placed in front of them. I think today they're better equipped to solve problems that are placed in front of them.

NST2: I think it's more away from the "It is because it is. Two multiplied by three is six because it is." Now they can kind of see it more.

PI: What's the largest factor, the strongest thing, that you think is making this change?

NST2: I think the change in the curriculum.

NST4: And the inservices that came along.

NST1: The change in the curriculum and the direction that's steering the curriculum I think its' forcing teachers to look at the way math is being taught differently.

One numeracy support teacher reported how the lower achievers in one classroom are more engaged in the mathematics and volunteer to participate in the questions and activities to the surprise of their teacher when the students do not have to sit down and complete drill and practice only:

> When I come in the classroom, and the [Pathway] 3 and [Pathway] 4 programming kids for math have got their hands up volunteering to do the activities, volunteering an answer, and the teachers are like "Holy God, where is this coming from?" But showing them that math … is more engaging, more fun. …We're opening up the world to those kids, when before it was "You can't do that. Get a book that had pen and paper, drill. Give it to them. Let them drill themselves to death. (NST7)

Two numeracy support teachers questioned and discussed the mathematical content of students' answers to questions in Grades 3 and 6 mathematics classrooms, and how this has changed over years while they worked as numeracy support teachers. One reports seeing more conceptual work while the students work with manipulatives to develop the mathematical concepts:

> NST6: Do you think our kids in Grade 6 or Grade 3, in terms of what the content is of those answers?
>
> NST8: Well, I've seen improvement in comparison to what it was.
>
> NST6: Well, I think there's improvement. I think we see it within the Grade 3s that I work with now and the Grade 6s, because their hands are on manipulatives and because they're… the concept is being developed.

One numeracy support teacher reports some lack of improvement in student achievement due to the inconsistency from year to year as students work with a different teacher each year. Some teachers have changed their teaching and assessment strategies, while others have not:

> I don't think that we're there yet, because I think you have pockets of teachers who are following the curriculum guide and are engaging the students in the activities to the fullest potential that they possibly can and then the students could get in one grade level, they don't get it the next grade level… the consistency isn't there…. I don't think everybody's bought in to it. (NST10)

Interest and Enthusiasm

The third goal of the *Excellence in Mathematics Strategy* was to encourage an increased interest and enthusiasm in mathematics. This was done by not only by providing much support for teachers in their classrooms, but also by financially supporting proposals from schools and districts for math events, such as the event in Clarenville, For the Love of Math (Newfoundland and Labrador Department of Education, 2008d). The Minister of Education congratulated "the teachers, staff and parents of Clarenville Middle School on a unique effort to get students excited about math and encourage increased interest and enthusiasm for the subject." This fair, and others across the province from Spring 2008 through to 2011 were funded under the *Excellence in Mathematics Strategy*. Having been the numeracy support teacher to work with the teacher at Clarenville Middle School to prepare the proposal, create a budget, plan the mathematics activities, and follow through with the regional event, it was a large positive learning experience for everyone involved.

The program specialist described many events that have occurred over the years with the *Excellence in Mathematics Strategy*. Some were at a local school level, and others at a district level to encourage an interest and increase enthusiasm in students and

teachers who could not have numeracy support at the intermediate level or due to being in a small school where the population or isolation did not warrant numeracy support.

The program specialist described how the intermediate math events built capacity for intermediate teachers to have future engaging activities for their students:

> We decided to run fourteen events and we had the kids come in. We went to fourteen different locations and bussed the kids into the nearest location and modeled what a math day would look like at the intermediate level, and all the activities were curriculum related. We gave the teachers everything that we did. They had access to everything and then the next year, the number of proposals that came in from intermediate teachers was higher and now, even today, teachers are using some of the same activities that we modeled. So the modeling does work. (PS)

For small schools with no numeracy support, the program specialist described a three-day and two-night math event for students and their teachers in these schools:

> PS: We took all those kids from those nine schools who never had numeracy support. All the elementary kids, and took them to (name) Camp for two nights, three days and did math activities. So they got to work with each other, because some of them are from schools where they're the only kid in elementary, so they came by themselves.
>
> PI: Have you ever seen that child or that teacher more than once, in terms of they came to an event and did you see them the following year?
>
> PS: Of yes, as a matter of fact, when we had our math, we called it a Mathematical Adventure, but the kids called it a math camp. I had a parent

phone me this year from the school, wanted to know if we're going to have math camp this year.

PI: So they want it, they were looking for it again?

PS: They were looking for it again.

Many of the numeracy support teachers described math events, both large and small, that they helped with the proposal writing, planning, and implementing the day. They varied from building a shed and using all the mathematics involved (PS) or having "a storybook walk at the beach incorporating math and all the outcomes" (NST5). All the numeracy support teachers reported the math events being successful in increasing the interest and enthusiasm of mathematics in their teachers and students.

Teachers

Much of the work with the numeracy support teachers working with their classroom teachers helped keep teachers interested in teaching mathematics, and to keep up their enthusiasm in teaching their students.

One numeracy support teacher reported about the motivation teachers had to change their teaching strategies to use more manipulatives in their classrooms:

> I found some teachers buy into it, some teachers say "Okay. I'm going to do this" and they say, "I haven't used the manipulatives as much as I should. I'm going to start." I've heard teachers say "I can never think about going back to the way I used to teach this math now that I'm doing it this way." (NST1)

Another numeracy support teacher reported how teachers changed their interest in the way mathematics was taught after the teachers saw how engaged the students were in their learning of mathematics:

> But I think some teachers when they saw what and saw the kids so engaged and the learning was more authentic than the textbook they've been a little bit more open up to it. (NST3)

Teachers became more comfortable to ask for help of the numeracy support teachers because of their ease of accessibility of them:

> They're a bit more eager to learn and to ask and I guess too they know who to ask a bit more now that these positions have come in. They have someone else by that they can address their concerns with as opposed to having to go to the board or to a head honcho. They can get to someone who's relatively close by. (NST2)

At first, the numeracy support teachers went to teachers who they knew personally, and were accepting of them in their classrooms. But over time, the acceptance of the numeracy support teacher grew and teachers were looking for support instead of the numeracy support teacher looking to go into a classroom:

> We went to our friends. We went to the people who we knew we could get in their door…. And your friends would have you in and they'd have you back. Whereas now over the four years, the thing is the perception of "Oh, this works." … So instead of having to just ask our friends "Can we come in?" we had people calling us and asking us. (NST7)

One numeracy support teacher reported "You heard the enthusiasm and you would hear sharing and everything happening from other." (NST6)

Teachers began to have a positive outlook on teaching mathematics after working with the numeracy support teachers. The teachers became more confident in teaching the

math, and felt they knew how to teach mathematics whereas before working with the support teachers, they did not and would avoid teaching mathematics:

> I've had some good responses from some of the teachers that I've worked with that have said "Oh my gosh. I hated teaching math to begin with. I didn't like how I taught math. I didn't know how to teach math and I avoided it." … "I feel like I can't wait to do math. I feel so much more confident to teach math now that I've been through this." (NST9)

Two numeracy support teachers discussed how teachers were excited to share the student work completed while the numeracy support teachers were away from the classroom. One further described the change in how one teacher assesses her students without using unit tests as she has developed her conceptual understanding of the outcomes:

> NST8: Whenever I would go where there was enthusiasm with the teachers, which was 90% of where'd you go, the first thing they'd want to show is, okay when you get there, look at this assessment.
>
> NST6: "Look what we did."
>
> NST8: "Look at the exit cards. Look what the kids did." Or "Oh my God, look, we did this and they didn't do." Oh, you know. But it was proof that obviously they were doing some activities and they said "Look at this." They're enthused to say, let's do up some activities so I can enjoy, I'm going to revisit this. So all of a sudden their headspace changed. And I can remember this one teacher I had this year, first time in Grade 6, taught the curriculum guide, fell in love with it and said "I'm changed. Next year is

> going to be so different for me. It's going to be so different for me. This unit stuff, this is gone." And just seeing the big picture in math, seeing the strands, seeing the big ideas, how it all ties together.

While there are positive accounts of an increased interest and enthusiasm of teaching mathematics in teachers, some numeracy support teachers reported meeting resistance to change. One numeracy support teacher reported no matter how much effort they put into working with some teachers, there is little change happening. Therefore the numeracy support teacher has decided to put her efforts elsewhere with other teachers:

> I've gone in and tried to work with teachers and I know that they're not going to change and regardless of how much time I spend in that class or no matter how much time I spend planning with that teacher they're going to carry on doing whatever way they want to do it. So I don't spend time with them anymore. (NST1)

Another numeracy support teacher described the differences between newer teachers and more experienced teachers in one school, and how the older, more experienced teachers would intimidate the younger teachers as to the type of teaching strategies to use in their classrooms:

> At one school in particular, and you've got five or six streams going through and you might have a couple of newbies that are on there, fresh and they're all energetic and they're excited and you can see that they probably have been given the background with regard to a more child-centred approach to teachers. And then you've got your more senior teachers, who would basically intimidate these younger teachers and then they end up curtailing their teaching strategies, or their

> delivery, to meet the standard of the same teachers, which may not be the route that you are trying to pursue. (NST10)

Students

Students were reported to be excited about having the numeracy support teachers in their classrooms, sometimes referred to as "The Math Lady" (NST9 and NST6). This could be due to the change numeracy support teachers brought into the learning environment for the students by bringing in and facilitating engaging activities.

One numeracy support teacher shared some student comments on her presence in the classrooms might take on a different meaning compared to when she is not there.

> "Are you coming into our classroom today? Are you coming in to do math today?" It's like they're all excited when they see you come in because math maybe takes on a little bit of a different meaning when you're in there. That is really good. (NST9)

Teachers' classrooms are reported to be more engaging for students due to the presence of numeracy support teachers in the classrooms.

> I think classrooms are more engaging now than they were. … I think certainly its because of … the changes in terms of these positions. … I think the classrooms out there, the kids are more engaged in the math that they're doing. (NST6)

One group of numeracy support teachers discussed how students are proud of their personal independent learning and want to show others their work.

> NST9: One child came up to me and said "Miss, did you see what I did? I redid that activity. Did you see? Did you see what I did? I answered your question." And I thought, oh my gosh, she wants to make sure I really see

what's in that. She was so excited for me to look in her portfolio to see the growth that she had shown in her work.

NST6: What an independent learner though, hey? Isn't that phenomenal? That's really good, eh?

NST8: It's engagement all right.

NST9: Taking responsibility, being accountable for your own work.

Another numeracy support teacher shared her experience modeling a lesson in the classroom so the teacher could focus on assessing her students. The teacher lost focus on her task because she was amazed at how engaged her students were in the assessment tasks:

> I've gone in and modeled different lessons with the class, and the kids were saying, "Oh this is so much fun… Oh, I really like doing this" … The kids are so engaged with the particular activity, sometimes the teacher, who I'm trying to get engaged, has lost focused as to what they're supposed to be looking for, because they can't believe that the kids are so engaged in the activities. (NST10)

She then expands on what her role is as a numeracy support teacher to overcome the "negative umbrella of math" by "trying to motivate" and how mathematics can be "an engaging fun way… that children could enjoy math":

> I think what I've tried to do over the years when I've been in this position, is motivate the students to enjoy math, because I think there is such a negative umbrella over math and not just from students… well, it is from students and its from parents. You know, I hate math, yeah, I don't want to do math. I think I've taken on the role of trying to motivate and try to show students and teachers and

> parents, that it can be an engaging fun way, not necessarily all games, but there's an engaging way that children could enjoy math. There's ways that you can introduce it and there's ways that you can stimulate it in a more engaging way that's motivating. Often kids don't even know that they're doing math, when they're doing it. (NST10)

The program specialist reported how a principal perceived the curriculum change being an improvement to the old curriculum. The program specialist accounts the improvement to the new curriculum coming from the work of the numeracy support teachers in the classrooms:

> I had a conversation with the principal yesterday who said to me "This new curriculum, oh my gosh, its' so much hands on, it's just fabulous. My daughter's in Grade 6 and I see what she's doing, which is wonderful and everything makes sense and it's excellent. And you know, compared to the old curriculum.
>
> I said "Hang on now, I've got to set you straight, because the philosophy of the curriculum has not changed. What has changed is content has been reorganized and you kind of do more with less and it's a bigger focus on deepening this number sense, then working about some of the other things that we used to worry about; the data management and all that."
>
> So I said "The hands-on part, that hasn't changed."
>
> "Really" he said.
>
> I said, "No, that was always hands-on."
>
> And he said, "But I just see more of it."

> And I said, "Well, you know all the inservices that have happened over the years with the curriculum we just got rid of … Do you know what, when this curriculum came in, the NSTs were in the building and when the other curriculum came in, they weren't."

The program specialist reported how when students are enjoying an engaging mathematics activity, they do not think that they are doing mathematics:

> When kids enjoy something, they don't feel like they're learning, or doing math. I mean, you have kids say, "I hate math." You say, "Did you do math today?" "Well no, we didn't really do math, we just played a game." They don't realize they're doing math, so if you get kids to like what they're doing and like learning, they will eventually learn to like the subject. (PS)

The program specialist then reported a conversation she had with her assistant director of programs and how he saw more students in classes across the district saying they enjoyed mathematics compared to other years:

> Our assistant director of programs has said "Whenever I go into a class, I talk to the kids, and who here loves math? And I'm finding there's more and more kids raising their hand." He was in a class and he was surprised at the number of kids that said they like math. (PS)

Parents

Parents were supported in *Excellence in Mathematics Strategy* through funding of math events for parents and their children in schools. While many numeracy support teachers facilitate Kinderstart sessions for parents during the school day, they also facilitate evening events for parents and their families. Administrators, numeracy support

teachers, and their classroom teachers hosted these family math nights. These events allowed parents and their children to experience the engaging nature of their children's classroom. The numeracy support teachers discussed the events that have occurred in their regions along with the positive reception from parents:

NST8: I've taken it upon myself to do a lot of parent meetings in the evenings and do presentations on, okay, this is what a Grade 3 classroom looks like, this is what a Grade 6 classroom looks like. And just a positive feedback from the parents…

NST7: I've been doing a lot of math nights up and down the coast, all in (community). And on the coast I get about 100% attendance.

NST6: Wow

NST7: In (community) I get about 80, 85% attendance, and I have five classrooms per grade. I had to do it by grade level. So I'd have about 160 people there at a Grade 1 night.

NST6: Wow

NST9: I was really surprised when how many schools are having family math nights, where families come in and they do some of those hands-on activities.

One numeracy support teacher describes his initiative to have the parents learn the difference between having parents teaching an algorithm to their child without teaching for understanding with the conceptual knowledge could hinder their child's learning:

A lot of times (parents) are doing what they think is some good stuff with their kids and it's basically a negative impact on not only the child, what they're doing,

> but with the teacher as well. They're teaching straight traditional algorithms right off the bat without the child even understanding any conceptual… no conceptual understanding at all. (NST8)

Another numeracy support teacher discusses the challenges they and their teachers face as she discusses parents hearing negative comments in the media about the mathematics program, as she references a local author, Dr. Sherry Mantyka. She is the Director of the Mathematics Learning Centre at Memorial University and published *The Math Plague: How to Survive School Mathematics* in 2007.

> We are having parents in. We have math days where they come in during the day, and they have math nights at night with the family. Then I've also been doing parent meetings, math meetings. It has been really a focus of ours. … All parents heard was from Sherry Mantyka telling us we had a bad math program and all the money that was put into this was useless. All we heard, parents heard was that. (NST6)

Through the *Excellence in Mathematics Strategy*, the government has facilitated an increase in interest and enthusiasm through funding the numeracy support positions, release time for the numeracy support teachers to work with classroom teachers, and through the funding of a variety of mathematics events across the province. Teachers are more interested in teaching mathematics in an engaging learning environment. Students are more engaged in their mathematics, and are enjoying mathematics. Parents are also learning about the curriculum changes their children are learning in their classrooms.

Summary

In summary, this chapter displayed the results of the program evaluation of the *Excellence in Mathematics Strategy*. There is quantitative evidence of an increase in student achievement due to the curriculum change in Grade 9, a decrease in Grade 6, and little change in Grade 3. There is quantitative evidence of numeracy support increasing student achievement in lower achieving schools in both Grades 3 and 6, and the most effective increase is when support was given to students' in both grades 3 and 6. Finally, there is qualitative evidence to support change in the teaching and learning of mathematics in Newfoundland and Labrador classrooms. In particular, with the implementation of the new curriculum and numeracy support in the classroom, along with funding the promotion of mathematics, some teachers changed their culture of teaching mathematics in the classroom, thereby directly impacting their students' learning of mathematics. These initiatives had some positive reports of teachers' and students' increased interest and enthusiasm for mathematics both in and outside the classroom.

Chapter 5
Summary

This study is a program evaluation of the Newfoundland and Labrador's *Excellence in Mathematics Strategy* with a focus on the impact of numeracy support as a means to change the learning and teaching of mathematics in classrooms. The *Strategy* had a government investment of $11.3 million over three years and it's aim was to improve student mathematics achievement in the Kindergarten to Grade 12 school system. It was in reaction to the pressure and complaints from parents and the frustrations from teachers of the mathematics curriculum being too much based on conceptual understanding rather than skill development in mathematics through drill and practice. To facilitate the aim of an increase in students' mathematics achievement the Government implemented numeracy support teachers to provide support to teachers, students, and parents to help and encourage an increased interest and enthusiasm for mathematics.

The *Strategy* included a review of the mathematics curriculum in Newfoundland and Labrador that recommended a curriculum change to align with the WNCP curriculum and resources (AERC, 2007). There was also significant and sustained professional development for teachers and the hiring of numeracy support teachers. These numeracy support teachers had a primary role in this professional development as they not only assisted in implementing the K-9 curriculum, but also continually worked with teachers and their students to improve the teaching and learning of mathematics in classrooms. Finally, the *Strategy* included funding for the promotion of mathematics where schools and districts received financial assistance to offer mathematics events for students and parents.

The research literature demonstrates curricula across Canada and the United States were reaching a balance of incorporating both conceptual understanding and development of basic skills (WNCP, 2006, NCTM, 2006). Curricula have become more focused with fewer outcomes at each grade level and having these outcomes explored more deeply within each grade level. This un-spiralling of the curriculum allows students to have more time to develop, practice, and understand the mathematics outcomes each year.

While Newfoundland and Labrador students performed below most provinces in both international and national testing, they also scored lower when compared to previous years (CMEC, 2013, 2011). On provincial assessments, Grade 3 and 6 students demonstrated a declining achievement over time, while Grade 9 students demonstrated an increase over time on selected-response and closed-constructed response items.

The research literature points out that in order to increase students' achievement in mathematics there must be an increase in teachers' mathematics knowledge for teaching (Ball et al. 2005; CBMS, 2012; Hill et al., 2008; Ma, 1999; NMAP, 2008). Teachers' knowledge and actions make a difference in student achievement. Teachers' learning and continuous professional development are paramount to improving teachers' mathematics knowledge for teaching. As well, students' beliefs about the importance of effort in learning mathematics relate to greater engagement in mathematics learning.

To bring about this educational change in teachers' mathematics knowledge for teaching, longitudinal sustained professional development with teachers observing one another's practice would help change the culture of classrooms (Desimone, 2009; Fullan, 2007; Sowder, 2007). Numeracy support teachers, or mathematics coaches, could assist

in producing these changes by working in collaboration with classroom teachers (Campbell & Malkus, 2013; Valente, 2103). Traditional professional development does not address the needs of teachers unless it is continual and coherent (CBMS, 2012; Fullan, 2007; Stigler & Hiebert, 1999). While these numeracy support teachers effect change in teachers' classroom practices, strategies, perceptions, and beliefs about the teaching of mathematics, these numeracy support teachers also improve students' learning and achievement, and help teachers have a better understanding of the curriculum.

This mixed-methods study considered the student results from the Newfoundland and Labrador provincial mathematics assessments from 2007 to 2012 to assess the effectiveness of the curriculum change on achievement. It used results from 2007 to 2011 to assess the effectiveness of numeracy support on student achievement. Two focus groups and one interview with numeracy support teachers and one interview with a mathematics program specialist was conducted to gather qualitative evidence regarding the effectiveness of both the provincial curriculum change and numeracy support teachers on student achievement. Finally, the numeracy support teachers and mathematics program specialist shared their experiences with teachers and students with regard to increasing interest and enthusiasm for mathematics.

Conclusions

This study of the *Excellence in Mathematics Strategy* considered the investment inputs for a new curriculum, for numeracy support teachers, and for promotion of mathematics events. The outputs include how the above affected teachers, students, and parents as well as how students performed on the provincial mathematics assessments.

Outcomes of change in teachers' mathematics knowledge for teaching, in student achievement, and in teachers' and students' interest and enthusiasm for mathematics were considered. Four questions with regards to change in student achievement after the curriculum change, a change in student achievement when numeracy support was provided to schools, and a change in teachers' and students' interest and enthusiasm in mathematics were considered in the analysis of the outcomes.

First, were students' achievement scores on Newfoundland and Labrador Primary, Elementary, and Intermediate Mathematics Assessments significantly different for students who had taken the newly implemented curriculum compared to those who had taken the previous provincial curriculum? While research on Newfoundland and Labrador students' achievement on international testing on PISA 2012, and national testing on PCAP 2010 demonstrate decreasing results for mathematics achievement, one must consider that the student population writing the assessments were in the first year of implementation of the new curriculum at each grade level. This study found that on the provincial mathematics assessments for Grades 3, 6, and 9 the means scores on the common curriculum items demonstrate inconsistent results. In particular, Grade 3 students' scores on common curriculum items remained level over 6 years, while Grade 6 students' scores decreased, and Grade 9 scores increased from 2007 to 2012. After the first year of the WNCP-based curriculum in 2011, all three grades showed an increase in achievement of anchored items in 2012.

Second, were students' achievement scores on Newfoundland and Labrador Primary, Elementary, and Intermediate Mathematics Assessments significantly different for students who were in classrooms that received numeracy support compared to those

who did not? Current research demonstrate that the use of mathematics specialists in the classroom increase student achievement when in place for more than one year (Campbell & Malkus, 2013). This study found in Newfoundland and Labrador schools with numeracy support in Grades 3 and 6 for all four years, being lower-achieving schools, had achievement results become closer over time to those schools receiving one or no years of numeracy support, closing the achievement gap between those two groups. The presence of numeracy support teachers helped close the achievement gap over time of lower-achieving schools that received four years of support to higher-achieving schools that received one or no years of numeracy support. Over time schools that received support in both Grades 3 and 6 had the highest proportion of students moved from scoring below standard on open-ended response questions to at/above standard.

Third, what qualitative evidence was there for a change in student achievement due to the (a) newly implemented curriculum and (b) numeracy support? Research demonstrates that Newfoundland and Labrador has one of the highest uses of unconventional assessment methods, such as self-assessment, peer assessment, journals, portfolios, and group work (CMEC, 2013). But these unconventional assessment methods have a negative effect on achievement on standardized tests compared to conventional methods of tests, quizzes, and homework (CMEC, 2013). This study found the focus groups and interviews with numeracy support teachers shared many examples of these unconventional assessment methods being using in Newfoundland and Labrador classrooms. The numeracy support teachers shared their observations of students' increase in communicating, reasoning, problem solving, and strategizing about mathematics. Lower-achievers were more engaged in the mathematics classroom using

these unconventional assessment methods. The use of manipulatives by students in their problem solving has increased. Some numeracy support teachers indicated that although students were being assessed in a variety of ways to their knowledge and understanding of the mathematics outcomes, the understanding did not necessarily come forth for all students on a paper test during the day they wrote the conventional provincial mathematics assessments.

Fourth, what qualitative evidence was there for an increased interest and enthusiasm for mathematics? Fullan (2001) describes the improvement of relationships as one of the keys to successful change. Following Fullan's (2007) idea of educational change, this study found numeracy support teachers' work with teachers and students were intensive and sustained over several years helping to make changes to teachers' and students' increase in interest and enthusiasm for mathematics. Not only did numeracy support teachers witness physical changes in teachers' and students' learning of mathematics through the use of resources, manipulatives, and teaching and assessment strategies, they also witnessed attitudinal changes in teachers' interest and enthusiasm for teaching mathematics. Through their methods of planning, modelling, co-teaching, and reflecting with teachers, they helped change the culture of students' classrooms. The program specialist shared that the goal of the numeracy support teachers through collaboration, was to build capacity in their teachers so that they will continue with the learning and teaching of mathematics in their classrooms by changing their beliefs and habits. Although many teachers changed their beliefs and habits, others were resistant.

Limitations of the Research

The effect of the *Excellence in Mathematics Strategy* on student achievement was limited by the use of the provincial mathematics assessments. Until 2010, all provincial assessments were accessible to the public, therefore items could not be anchored and reused. The number and difficulty of the assessment items were not constant from year to year, therefore the analysis of the assessments could only be compared within each year. To enable analysis from year to year, standardized scores were created.

As being both the primary investigator and a numeracy support teacher, I was a key stakeholder in the results of the program evaluation. Therefore only primary and elementary numeracy support teachers were considered in the focus groups. Program specialists, senior education officers, and assistant directors with whom I worked along with Department of Education personnel were not considered for interviewing as they were in a position of power over the principal investigator, although they may have been key stakeholders in the *Strategy*.

Recommendations

Newfoundland and Labrador's Department of Education began phasing out the numeracy support teachers after three years and began changing the positions to be literacy-numeracy support teachers in September 2010. As of September 2013 all the K-6 positions were literacy-numeracy support, and the number of positions was reduced to 11. Three positions remained as numeracy but they focused on the secondary grades. As the focus for Newfoundland and Labrador's Department of Education has shifted the support of teachers to include both literacy and numeracy, one must be cautious not to lose the focus on numeracy in the primary and elementary grades. Since one of the main factors

influencing student achievement in mathematics is teachers' mathematical knowledge of teaching one must continue with sustained professional development to improve the culture of the mathematics in the classroom (CBMS, 2012).

Most Newfoundland and Labrador secondary mathematics teachers have a strong background in mathematics (AERC, 2007) and since this study demonstrates stronger mathematics achievement results in Grade 9, it is recommended for Newfoundland and Labrador to not have numeracy support teachers in secondary grades. Newfoundland and Labrador should stay the course with supporting teachers with numeracy in the teaching and learning of mathematics in the primary and elementary grades.

The reality of financial constraints limits the numeracy support model across Newfoundland and Labrador classrooms. Without these constraints, ideally, every primary and elementary classroom teacher, as well as non-mathematics secondary teachers teaching mathematics courses, wanting to work with a numeracy support teacher would benefit from this ongoing professional development, regardless of school size or distance from the base school of the numeracy support teachers.

While the Newfoundland and Labrador numeracy support model had these teachers work full time as a numeracy support teacher, there are other Canadian educational jurisdictions such as the Greater Victoria School District where each school has a literacy-numeracy support teacher, but only totalling of 10% of each teaching position. Due to geographical constraints of Newfoundland and Labrador, and the allocation restraints of the Greater Victoria School District, one must find a balance where numeracy support teachers can devote time to work with their classroom teachers. The model of numeracy support teachers working solely with other classroom teachers

instead of having to teach their own classroom of students allows for a stronger focus into changing the culture and practice of other mathematics teachers in their classrooms.

Recommendations for Further Research

As this study did not include any work with the newly implemented high school curriculum in Newfoundland and Labrador, it is recommended to analyze the results of the Grade 12 Newfoundland and Labrador public examinations from June 2014 onward, it being the first public examinations of the newly implemented WNCP-based curriculum. Also one can compare the public examinations results to Memorial University's mathematics placement tests and calculus placement tests which students write each spring and fall prior to commencing first year university. Memorial University's mathematics placement test remained consistent through the curriculum change, and could be a constant measure to compare students' achievement for those who followed the new curriculum.

The PCAP 2010 and PISA 2012 were assessments of students who followed the new curriculum but only of the first year of its implementation. Further analysis of Newfoundland and Labrador's ranking is recommended for the further rounds of international and national assessments.

As the Newfoundland and Labrador provincial mathematics assessments are now given every second year due to budgetary constraints, it is recommended to analyze these results over time to see any changes related to the newly implemented curriculum in Newfoundland and Labrador. This study included only the first two years of the new curriculum, 2011 and 2012. How do these achievement results compare to the students writing in 2014 and onward? Because the provincial assessments are now secure from the

public and there is an increased use of anchor items, one may be able to make statistically stronger comparisons of students from 2011 onward for changes to mathematics achievement.

Since the model for numeracy support has changed to combine literacy and numeracy, an analysis of the provincial assessment results in 2014 for classrooms which received support compared to those which did not receive literacy-numeracy support should be considered. One can then compare the language arts results in 2015 for those classrooms that did and did not receive literacy-numeracy support.

Summary

The goal of Newfoundland and Labrador's *Excellence in Mathematics Strategy* was to increase student achievement in mathematics. Though there were curriculum changes and numeracy support teachers added to classrooms, an increase in student achievement in Newfoundland and Labrador was inconclusive. Achievement results on the common curriculum items of the old and new curricula on provincial assessments remained level for Grade 3, decreased for Grade 6, but increased for Grade 9 from 2007 to 2012. After the first year of the new curriculum in 2011 all three grades showed an increase in achievement on the 2012 anchored items. The achievement gap closed over this four-year period between the lower-achieving schools receiving the most numeracy support and the higher-achieving schools receiving the least numeracy support. Over time schools that received support in both Grades 3 and 6 had the highest proportion of students moved from scoring below standard on open-ended response questions to at/above standard. Numeracy support teachers and the mathematics program specialist shared their observations of students' increase in communicating, reasoning, problem

solving, and strategizing about mathematics. Lower-achievers were reported to be more engaged in mathematics classrooms. There was reported an increase in manipulatives in the classrooms by students when problem solving.

Through the work of numeracy support teachers with classroom teachers and students and through funding of promotion of mathematics events, the *Excellence in Mathematics Strategy* was successful in encouraging an increased interest and enthusiasm for mathematics. The work with teachers was intensive and sustained over four years. Physical changes were reported in teachers and students learning of mathematics through the use of resources, manipulatives, and teaching and assessment strategies. Attitudinal changes were reported in teachers' interest and enthusiasm for teaching mathematics. Numeracy support teachers' work with teachers to plan, model, co-teach, and reflect on lessons helped change the culture of students' classrooms. Numeracy support teachers built capacity through collaboration among most of their teachers. However some others were resistant to change their beliefs and habits.

The teaching and learning of mathematics is an ongoing process for both teachers and students in Newfoundland and Labrador. As the mathematics program specialist stated, our goal is for students to "love math and for teachers to enjoy teaching math." We must keep growing professionally to improve the mathematics learning of the students. "There are children at stake" (NST10).

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Appendix A
AERC Recommendations to the Department of Education

AERC made 15 recommendations under four key areas, all of which the Department of Education accepted:

Area 1: New curriculum, adopted from the WNCP, which will follow a three-year implementation schedule;

1. The Western and Northern Canadian Protocol Common Curriculum Frameworks for Mathematics K-9 and Mathematics 10-12 (WNCP, 2006 and 2007) be adopted as the basis for the K-12 mathematics curriculum in this province.
2. Implementation begin with Grades K, 1, 4, 7 in September 2008, followed by Grades 2, 5, 8, in 2009, and Grades 3, 6, 9 in September 2010.
3. The senior high school program be implemented on the same schedule as now proposed for the Western and Northern jurisdictions, starting in 2010.
4. The proposed revised program not be piloted but that an effort be made to learn from the initial experiences in other jurisdictions implementing the program in 2007-8.

Area 2: New textbooks for all grade levels;

5. Textbooks and other resources specifically designed to match the WNCP and frameworks be adopted as an integral part of the proposed program change.

Area 3: Significant initial and sustained professional development for teachers;

6. Implementation of the proposed changes to the mathematics curriculum be accompanied by an introductory professional development program designed to introduce the curriculum to all mathematics teachers at the appropriate grade levels prior to the first year of implementation.
7. At least partial support for professional development be negotiated with publishers as part of a textbook adoption package.
8. Numeracy support teachers have a primary role in the delivery of professional development for primary/elementary teachers.
9. The responsibilities of mathematics department heads in intermediate and high schools include facilitating introductory professional development sessions and follow up of these sessions.
10. In the short term, numeracy support teachers assigned to Grades K – 6 be considered as lead teachers for mathematics in the schools for which they are responsible.
11. The work of numeracy support teachers be systematically monitored for at least two years, using methods designed to assess the impact on fidelity of implementation and on outcomes.
12. Following this period, a determination be made whether this program should be continued or whether the resources world be better utilized to support lead teachers at the individual school level.

13. The Department of Education reinforce, through reference in its curriculum documents and professional development activities, well established features of effective teaching: maximizing student engagement in academically meaningful work, high expectations, maximizing content coverage, monitoring and using assessment to improve learning.

Area 4: Development of guidelines for the assignment of homework.

14. The Department of Education reinforce the value of homework, establish guidelines on the amount and type of homework to be assigned, especially in the early grades, and develop and disseminate a parent guide to homework.
15. Any revisions to the model for providing services to special needs students include opportunity for remedial work for those students requiring additional time to meet grade level expectations.

Appendix B
Human Research Ethics Board Certificate of Approval

University of Victoria

Human Research Ethics Board
Office of Research Services
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Victoria British Columbia V8W 2Y2 Canada
Tel 250-472-4545, Fax 250-721-8960
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Certificate of Approval

PRINCIPAL INVESTIGATOR:	**Karen Moore**	**ETHICS PROTOCOL NUMBER:**	**11-235**
UVic STATUS:	**Ph.D. Student**	ORIGINAL APPROVAL DATE:	02-Jun-11
UVic DEPARTMENT:	**EDCI**	APPROVED ON:	02-Jun-11
SUPERVISOR:	**Dr. Leslee Francis Pelton**	APPROVAL EXPIRY DATE:	01-Jun-12

PROJECT TITLE: **Student Achievement and Newfoundland and Labrador's Excellence in Mathematics Strategy**

RESEARCH TEAM MEMBERS: None

DECLARED PROJECT FUNDING: **None**

CONDITIONS OF APPROVAL

This Certificate of Approval is valid for the above term provided there is no change in the protocol.

Modifications
To make any changes to the approved research procedures in your study, please submit a "Request for Modification" form. You must receive ethics approval before proceeding with your modified protocol.

Renewals
Your ethics approval must be current for the period during which you are recruiting participants or collecting data. To renew your protocol, please submit a "Request for Renewal" form before the expiry date on your certificate. You will be sent an emailed reminder prompting you to renew your protocol about six weeks before your expiry date.

Project Closures
When you have completed all data collection activities and will have no further contact with participants, please notify the Human Research Ethics Board by submitting a "Notice of Project Completion" form.

Certification

This certifies that the UVic Human Research Ethics Board has examined this research protocol and concluded that, in all respects, the proposed research meets the appropriate standards of ethics as outlined by the University of Victoria Research Regulations Involving Human Participants.

Dr. Rachael Scarth
Associate Vice-President, Research

Certificate Issued On: 02-Jun-11

11-235 Moore, Karen

Appendix C
Sample Focus Group and Interview Questions

Introduction

1. Please introduce yourself. Explain to me some background about your position, including which region you worked in, the schools you visited, as well as how many teachers and grades you worked with.
    a. How long have you worked with these teachers and their students?
2. Explain to me some of your roles and responsibilities as a numeracy support teacher (or mathematics program specialist).

Numeracy Support

3. How does your role provide support for the teaching and learning of mathematics in the classroom?
    a. Can you explain some successful support you provided to teachers?
    b. Were there any unsuccessful experiences with teachers?

Student Achievement

4. Grades 3, 6, and 9 writes a provincial mathematics assessment in June of each year which measures student achievement. This year was the first Criterion Reference Test (CRT) assessing the curriculum change in mathematics. Apart from the CRT results, do you think there is an increase in student achievement, compared to students who were learning the older curriculum?
    a. To compare achievement this year to last year?
    b. Unit tests? Communication? Reasoning? Problem Solving?

Numeracy Support and Student Achievement

5. How do you think the role of Numeracy Support Teachers supported any increase in student achievement?

Interest and Enthusiasm for Mathematics

6. Over the course of the Excellence in Mathematics Strategy (about four years), can you explain any initiatives that may have increased interest and enthusiasm for mathematics?
    a. Either with students or with teachers?
    b. Were these initiatives effective?
    c. Did you experience any time where there are no increase in interest and enthusiasm for mathematics?

Conclusion

7. Is there anything else you would like to share?

Appendix D
Curriculum Content Mean Percent Scores and Percent of Items

Table 10.

Curriculum content mean percent scores and percent of items.

			Year					
			2007	2008	2009	2010	2011	2012
Grade 3	Mean Percent Score	Common	75%	79%	74%	76%	76%	75%
		Old	70%	72%	76%	78%		
		New					69%	71%
		Total	72%	73%	75%	77%	75%	75%
	Percent of Items	Common	38%	26%	44%	50%	81%	79%
		Old	62%	74%	56%	50%		
		New					19%	21%
Grade 6	Mean Percent Score	Common	69%	70%	72%	71%	64%	60%
		Old	59%	53%	60%	66%		
		New					59%	56%
		Total	65%	67%	69%	70%	62%	59%
	Percent of Items	Common	54%	79%	73%	73%	64%	62%
		Old	46%	21%	27%	27%		
		New					36%	38%
Grade 9	Mean Percent Score	Common	57%	61%	60%	67%	63%	66%
		Old	56%	57%	54%	66%		
		New					67%	70%
		Total	56%	61%	56%	66%	65%	66%
	Percent of Items	Common	40%	40%	40%	52%	54%	54%
		Old	60%	60%	60%	48%		
		New					46%	46%

Appendix E
Student Data Files Received from the Department of Education

Student Level Files Received:

- Primary and Elementary Provincial English and Mathematics Assessment 2007
- Primary and Elementary Provincial Mathematics Assessments 2008 – 2012
- Intermediate Provincial Mathematics Assessments 2007 – 2012
- Longitudinal Student Rubric Data, Primary 2007/Elementary 2010
- Longitudinal Student Rubric Data, Primary 2008/Elementary 2011

Appendix F
Variables Created

Numeracy Support (Independent Variables):

SupportTotal = total number of numeracy support years

SupportYY = numeracy support given in year YY

Support01_2_3_4 = SupportTotal recoding 0, 1 = 0; 2 = 1; 3 = 2; 4 = 3

Support01_2_34 = SupportTotal recoding 0, 1 = 0; 2 = 1; 3, 4 = 2

Annual Student Achievement Data (Dependent Variables):

TotalScore = total score of selected response and constructed response items only

RubricTotal = rounded mean of rubric scores

ZScore = standardized score of TotalScore

ZRubric = standardized score of RubricTotal

Longitudinal Rubric Data (Independent Variables):

SupportTotalGr6 = SupportTotal for Grade 6

SupportTotal08_10 = SupportTotal, Grade 6 only, from 2008 to 2010

SupportYY_GrX = numeracy support in year YY for Grade X

Support3and6 = numeracy support in Grade 3 and/or Grade 6

Longitudinal Rubric Data (Dependent Variables):

RubricMean3 = rounded mean of rubric scores for Grade 3

RubricMean6 = rounded mean of rubric scores for Grade 6

Rubric3 = RubricMean 3 recoding 1, 2 = 0; 3, 4, 5 = 1

Rubric6 = RubricMean 6 recoding 1, 2 = 0; 3, 4, 5 = 1

ChangeTime = Rubric6 – Rubric3

Longitudinal School Achievement Data:

ScoreYY = mean school score of TotalScore for year YY

StudentYY = number of students writing assessment in year YY

ZScoreYY = standardized score of ScoreYY

ZDiffXXYY = ZScoreXX – ZScoreYY

Appendix G
Students' Total Score Calculation

Table 11.

Number of items used to calculate a student's total score.

Grade	Year	Selected Response	Closed-Constructed Response	Total Score
3	2007	23	0	23
	2008	24	15	39
	2009	24	15	39
	2010	32	20	52
	2011	36	23	59
6	2007	28	0	28
	2008	24	15	39
	2009	24	13	37
	2010	33	15	38
	2011	38	36	74

Table 12.

Number of items used to calculate a student's total score by strand.

	Number Concepts		Number Operations		Patterns and Relations		Shape and Space		Mental Math	Total
	Selected Response	Constructed Response	Selected Response	Constructed Response	Selected Response	Constructed Response	Selected Response	Constructed Response	Constructed Response	
Year	Grade 3									
2007	8	Rubric	10	Rubric	n/a		5	Rubric	Sample	23
2008	10	7	8				6	8		39
2009	10	7	8				6	8		39
2010	10	9	12				10	11		52
2011	14	6	11				11	11	6	59
Year	Grade 6									
2007	11	Rubric	11	Rubric	n/a		6	Rubric	Sample	28
2008	10	6	7				7	9		39
2009	10	7	7				7	6		37
2010	11	8	12				10	7		48
2011	10	14	8		7	6	13	6	10	74

Appendix H
Means and Standard Deviations of Scores

Table 13.

Means and Standard Deviations of Total Scores and Rubric Scores

		Total Score		Rubric Score	
Grade	Year	$\bar{x}$	$s_{\bar{x}}$	$\bar{x}$	$s_{\bar{x}}$
3	2007	74.9%	18.4%	2.40	1.00
	2008	73.1%	18.9%	2.72	0.75
	2009	74.8%	18.4%	2.75	0.81
	2010	76.8%	17.9%	2.75	0.74
	2011	70.8%	18.3%	2.85	0.85
6	2007	64.6%	20.7%	2.34	0.94
	2008	68.3%	19.8%	2.52	1.11
	2009	68.8%	18.6%	2.23	0.96
	2010	69.4%	20.4%	2.63	0.96
	2011	61.6%	21.7%	2.63	0.92

Appendix I
Histograms of Numeracy Support Variables

Figure 20.

Number of schools receiving numeracy support in Grade 3 over four years.

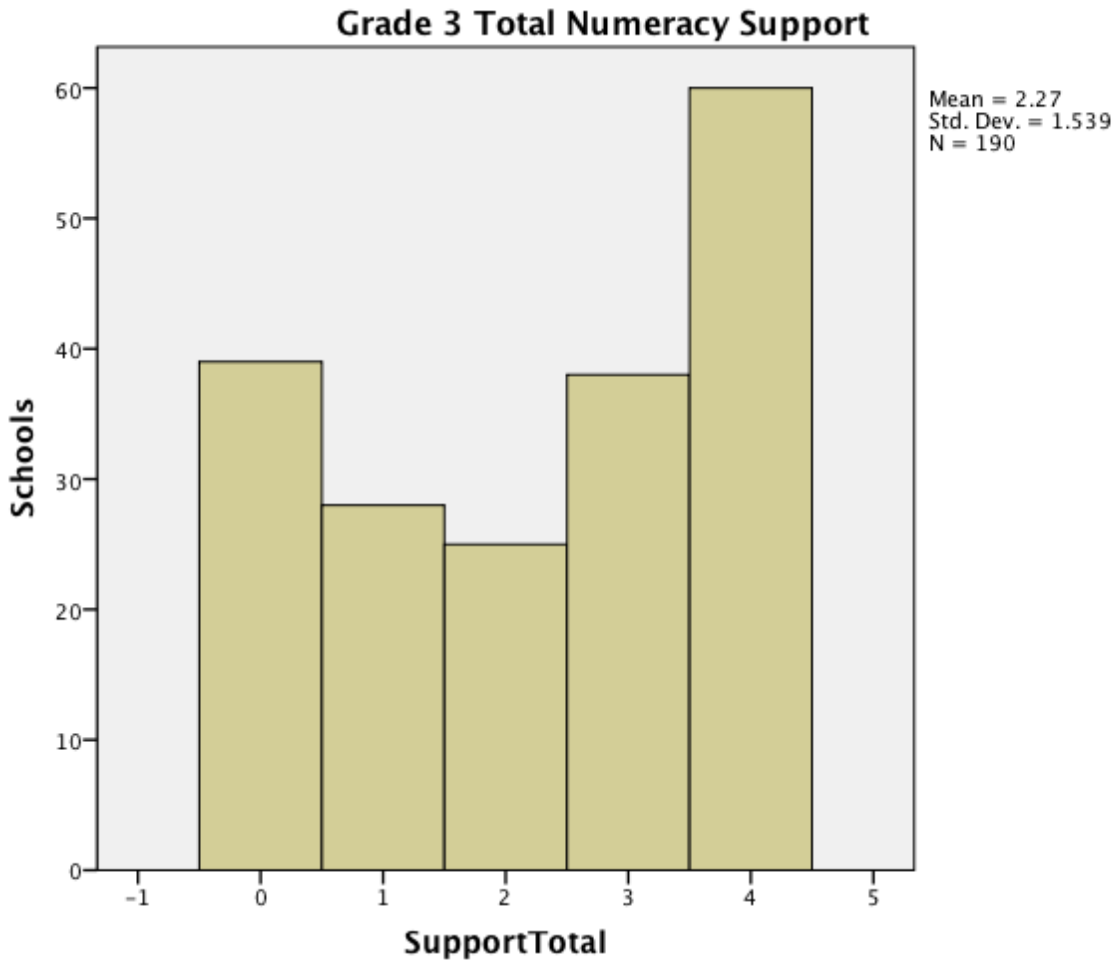


Figure 21.

Number of schools receiving numeracy support in Grade 6 over four years.

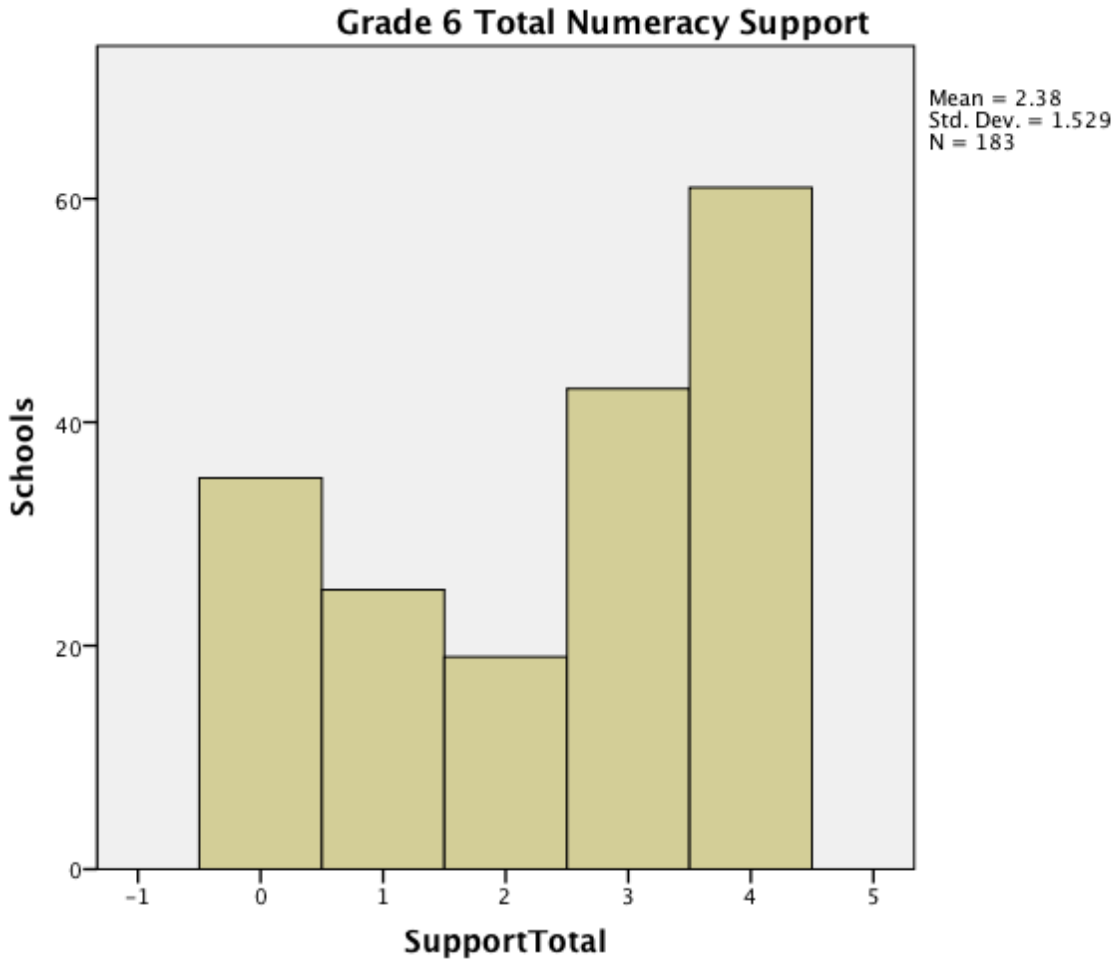


Figure 22.

Number of Grade 3 students in 2008 in schools receiving numeracy support over four years.

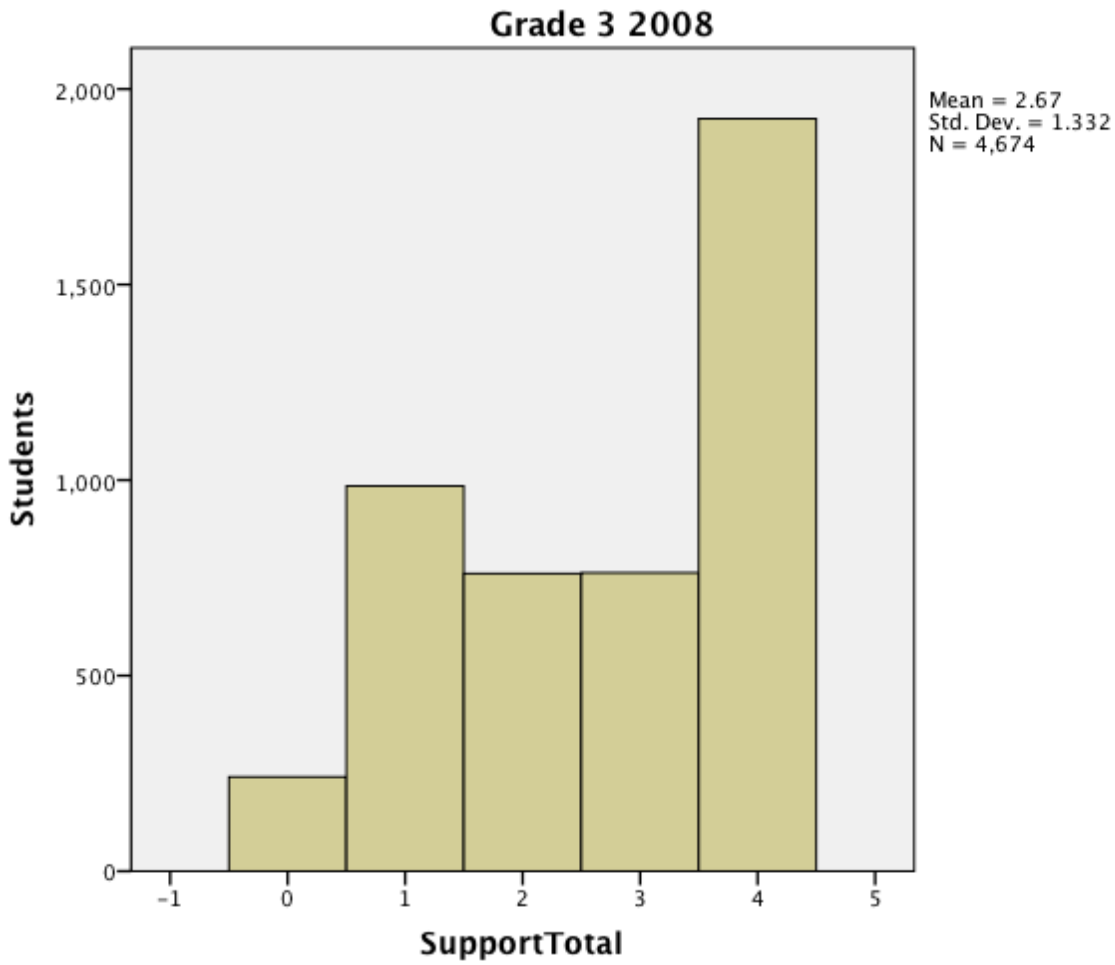


Figure 23.

Number of Grade 3 students in 2009 in schools receiving numeracy support over four years.

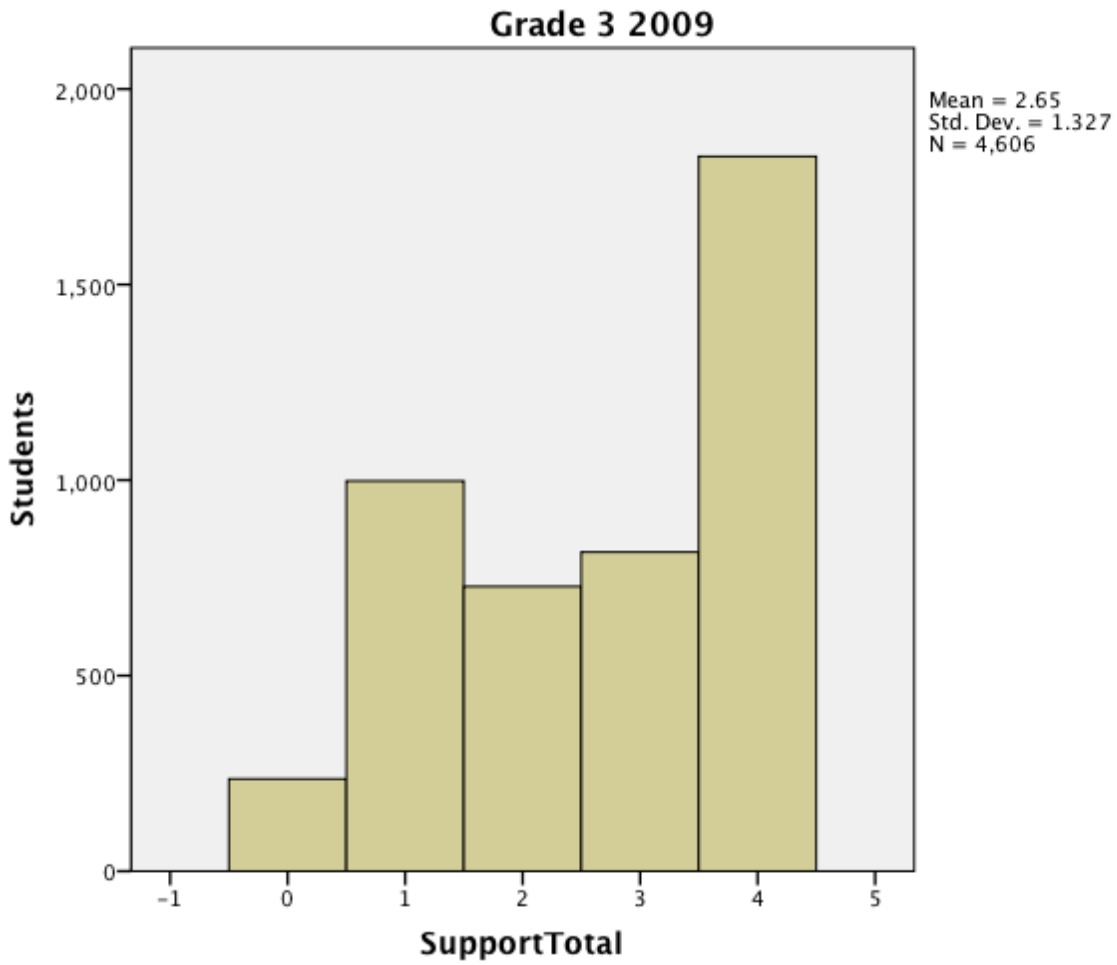


Figure 24.

Number of Grade 3 students in 2010 in schools receiving numeracy support over four years.

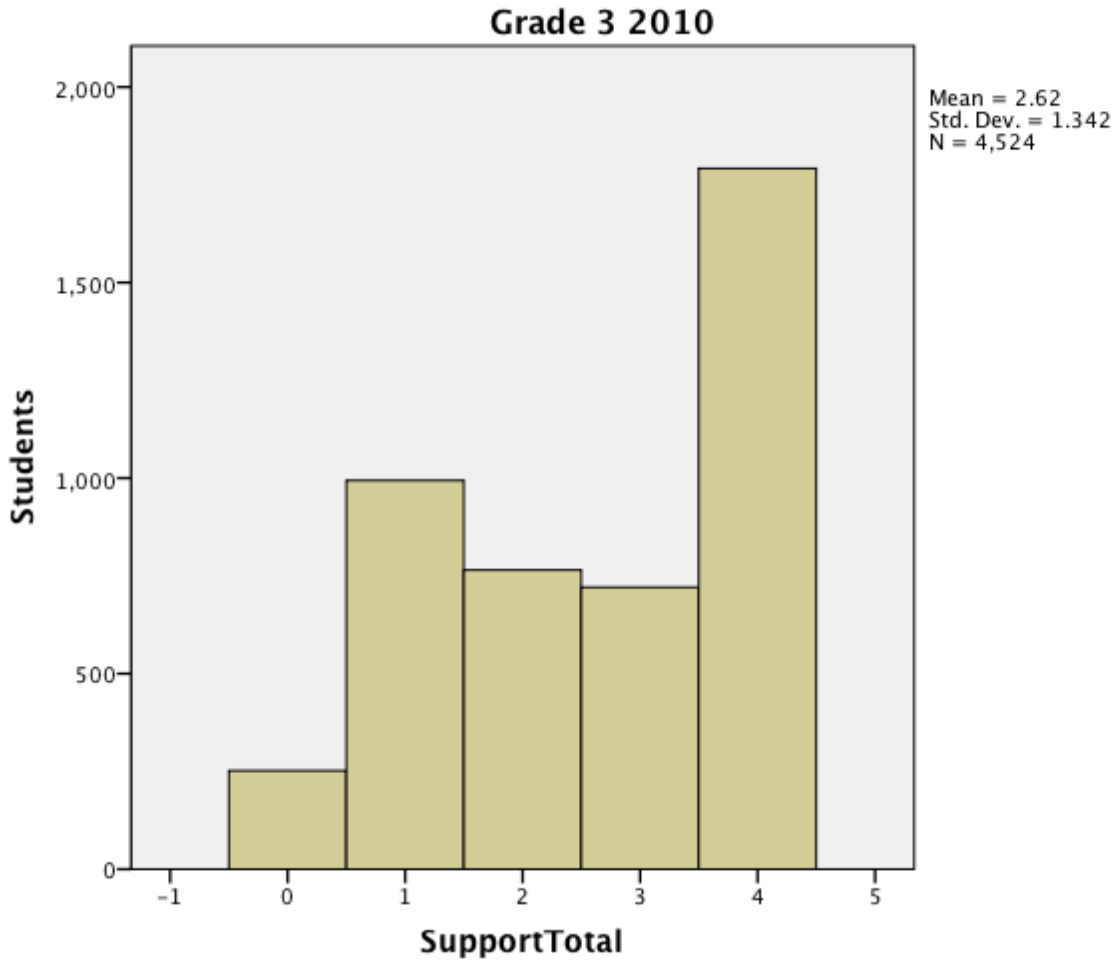


Figure 25.

Number of Grade 3 students in 2011 in schools receiving numeracy support over four years.

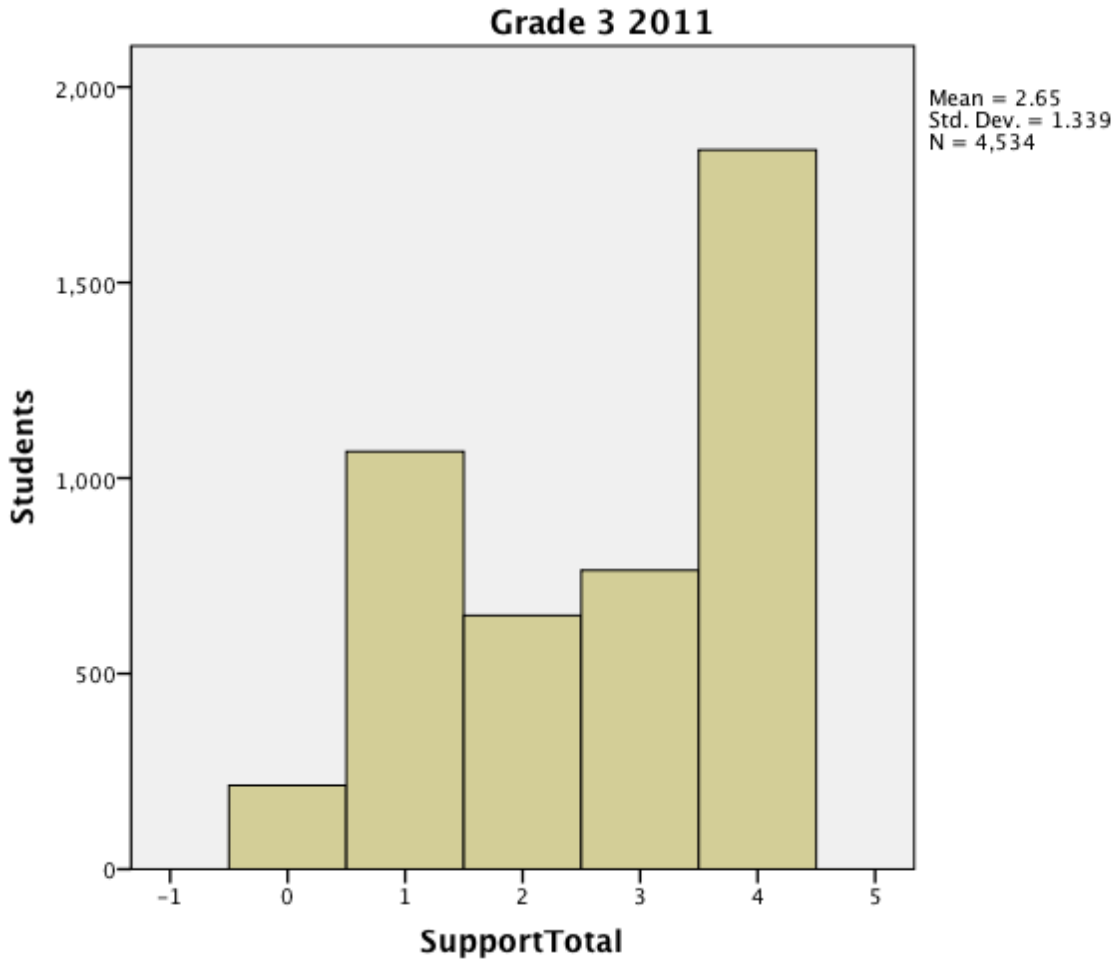


Figure 26.

Number of Grade 6 students in 2008 in schools receiving numeracy support over four years.

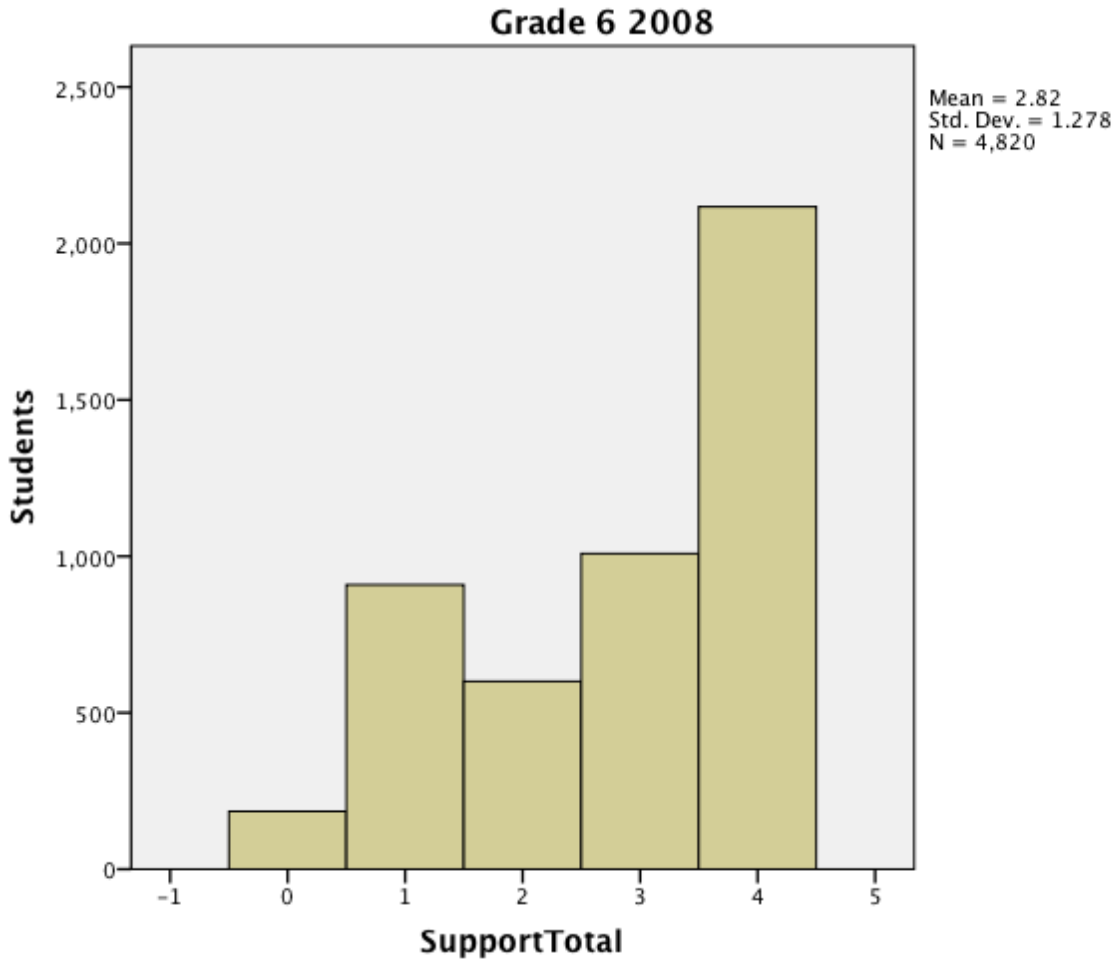


Figure 27.

Number of Grade 6 students in 2009 in schools receiving numeracy support over four years.

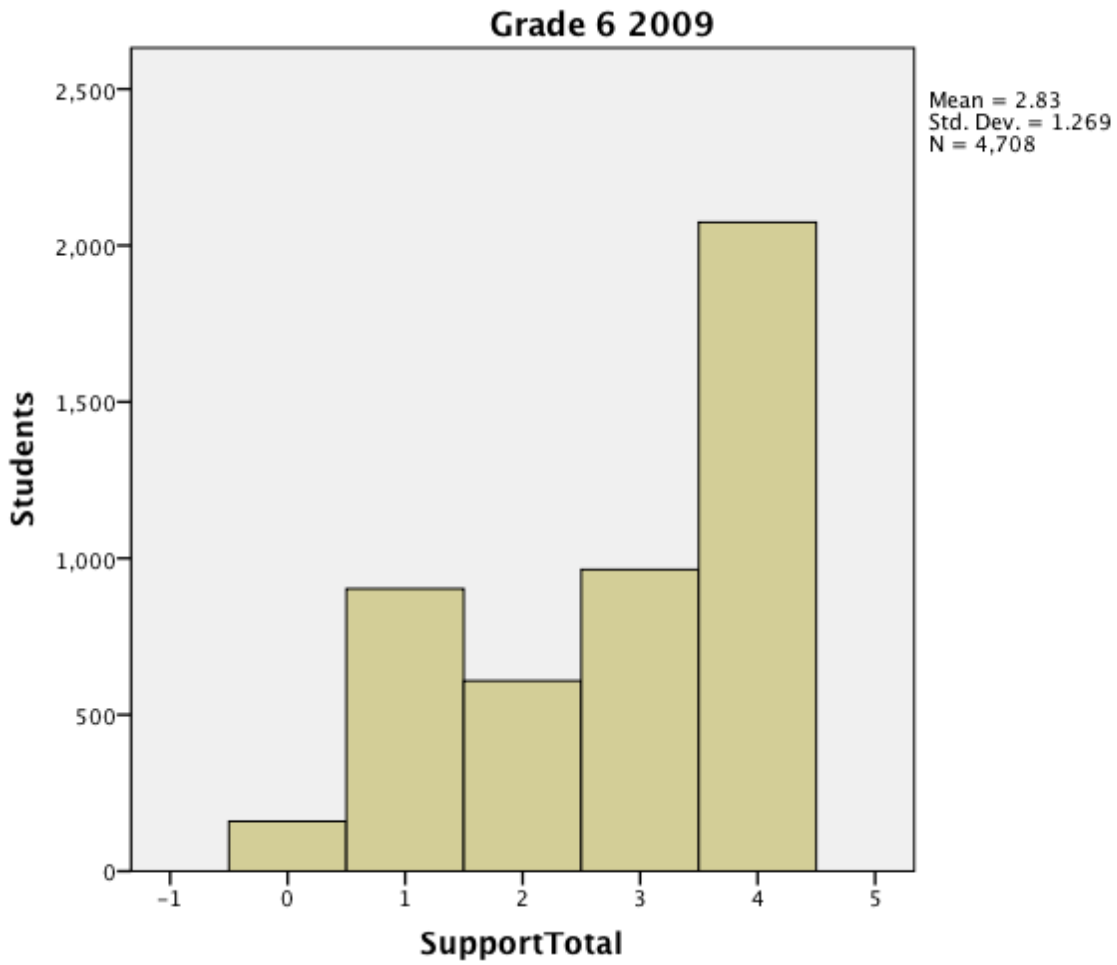


Figure 28.

Number of Grade 6 students in 2010 in schools receiving numeracy support over four years.

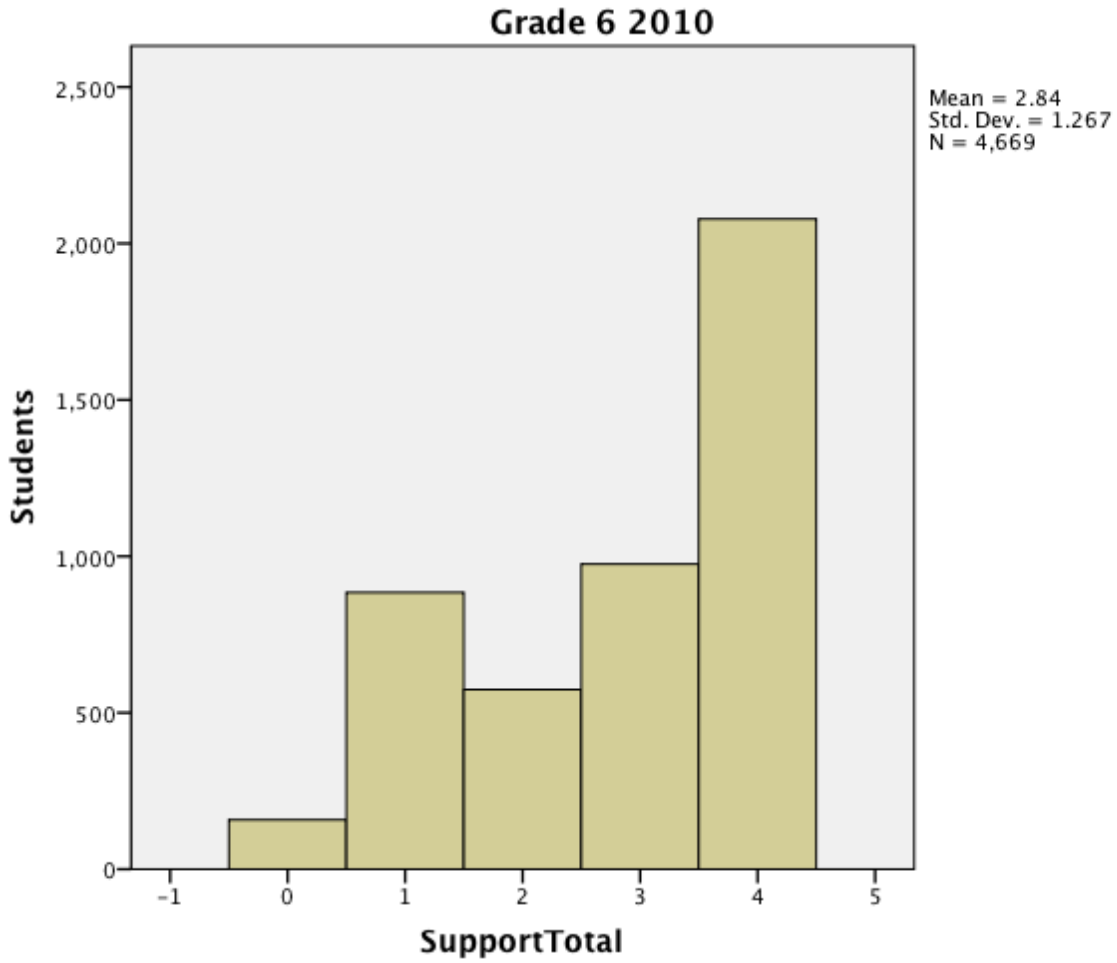


Figure 29.

Number of Grade 6 students in 2011 in schools receiving numeracy support over four years.

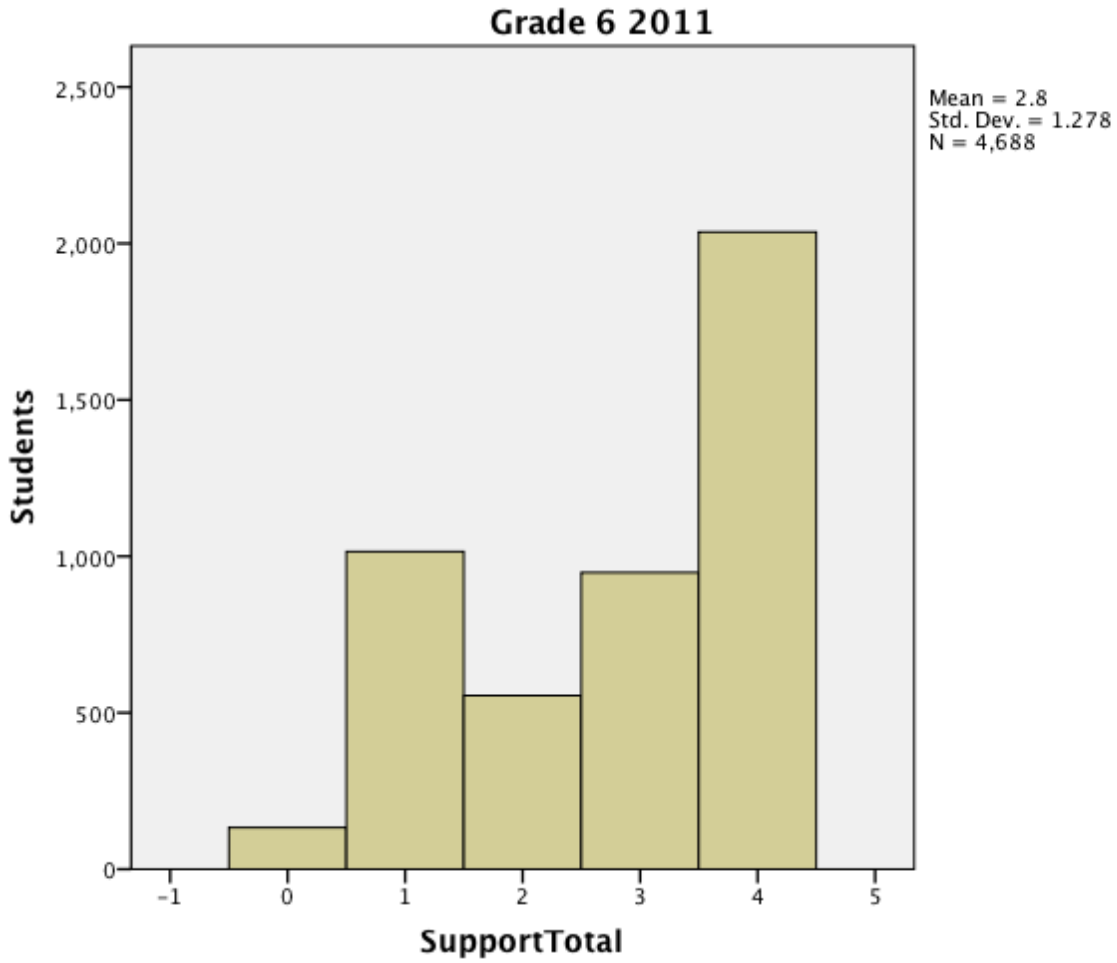


Figure 30.

Number of schools receiving numeracy support in Grade 3 in 2008.

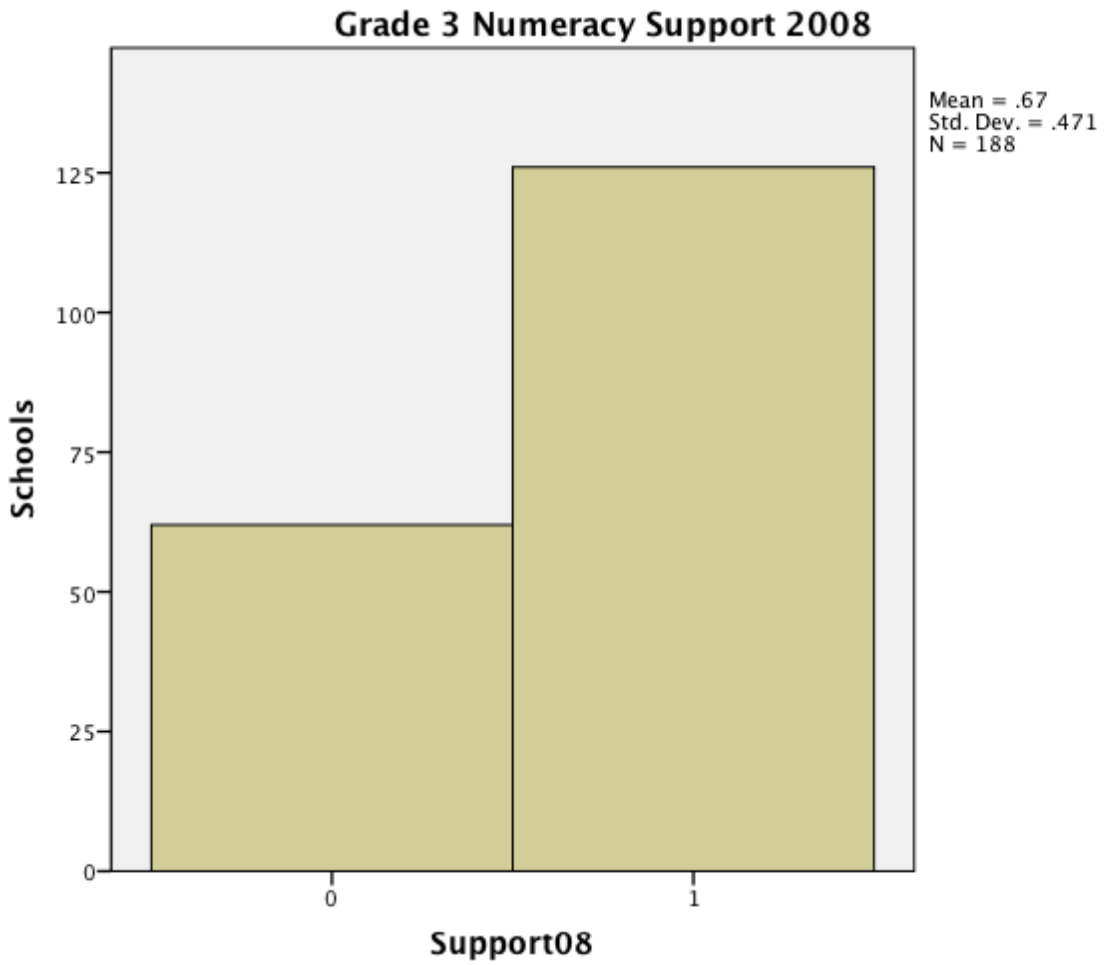


Figure 31.

Number of schools receiving numeracy support in Grade 3 in 2009.

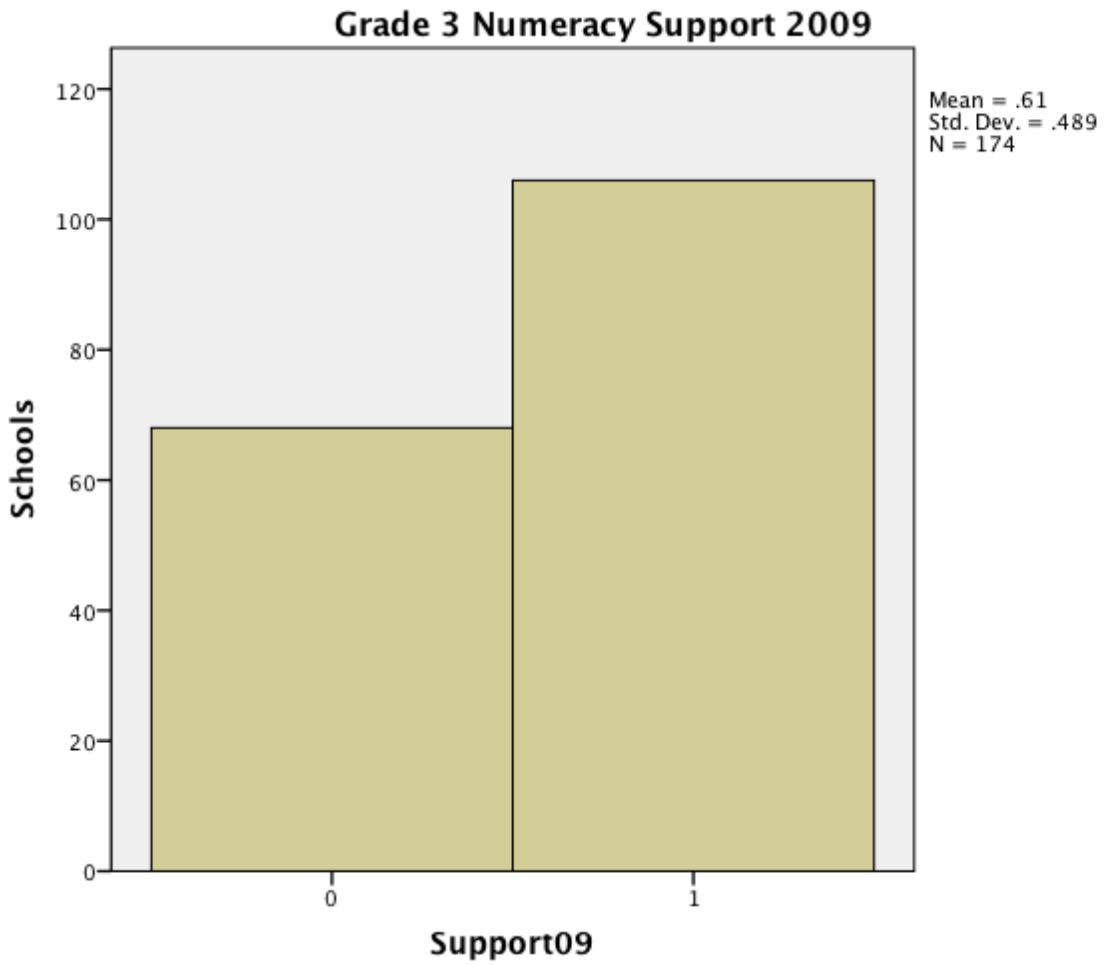


Figure 32.

Number of schools receiving numeracy support in Grade 3 in 2010.

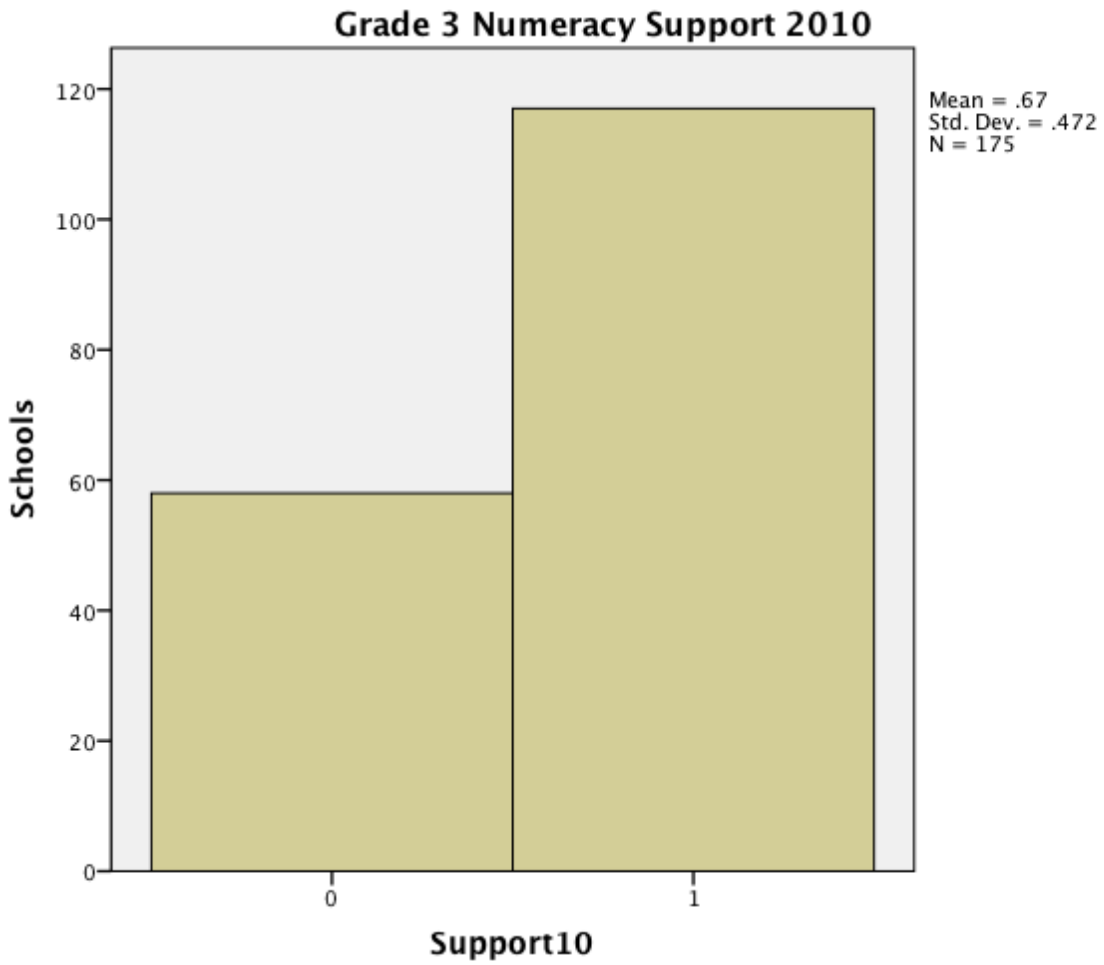


Figure 33.

Number of schools receiving numeracy support in Grade 3 in 2011.

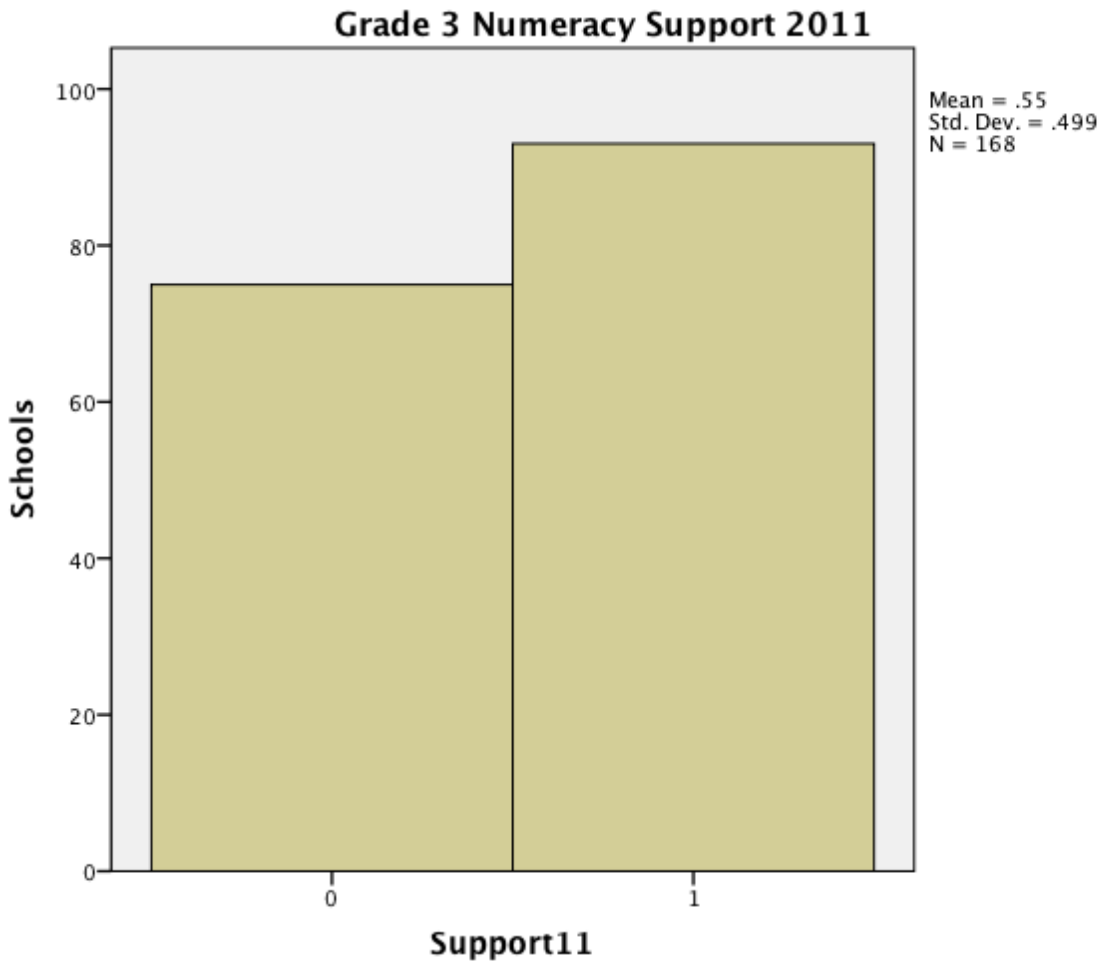


Figure 34.

Number of schools receiving numeracy support in Grade 6 in 2008.

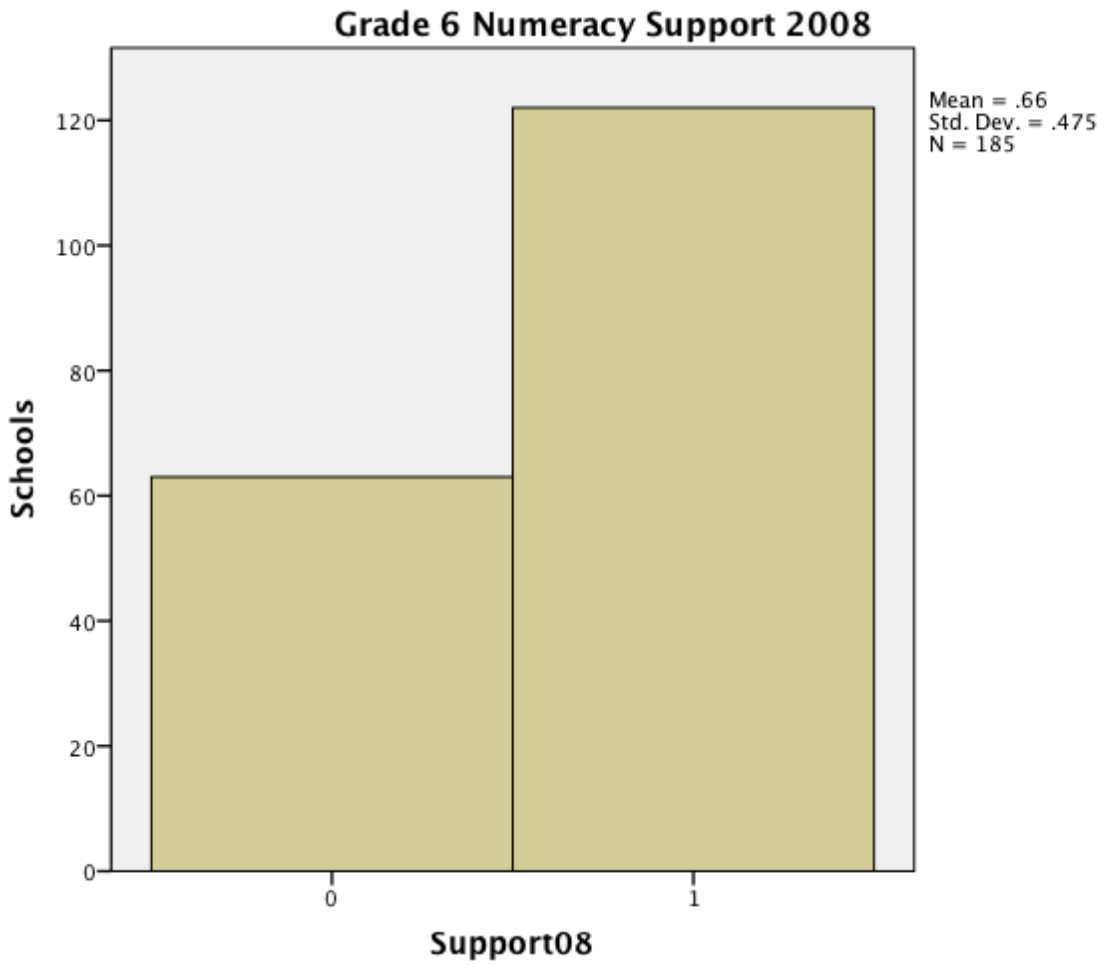


Figure 35.

Number of schools receiving numeracy support in Grade 6 in 2009.

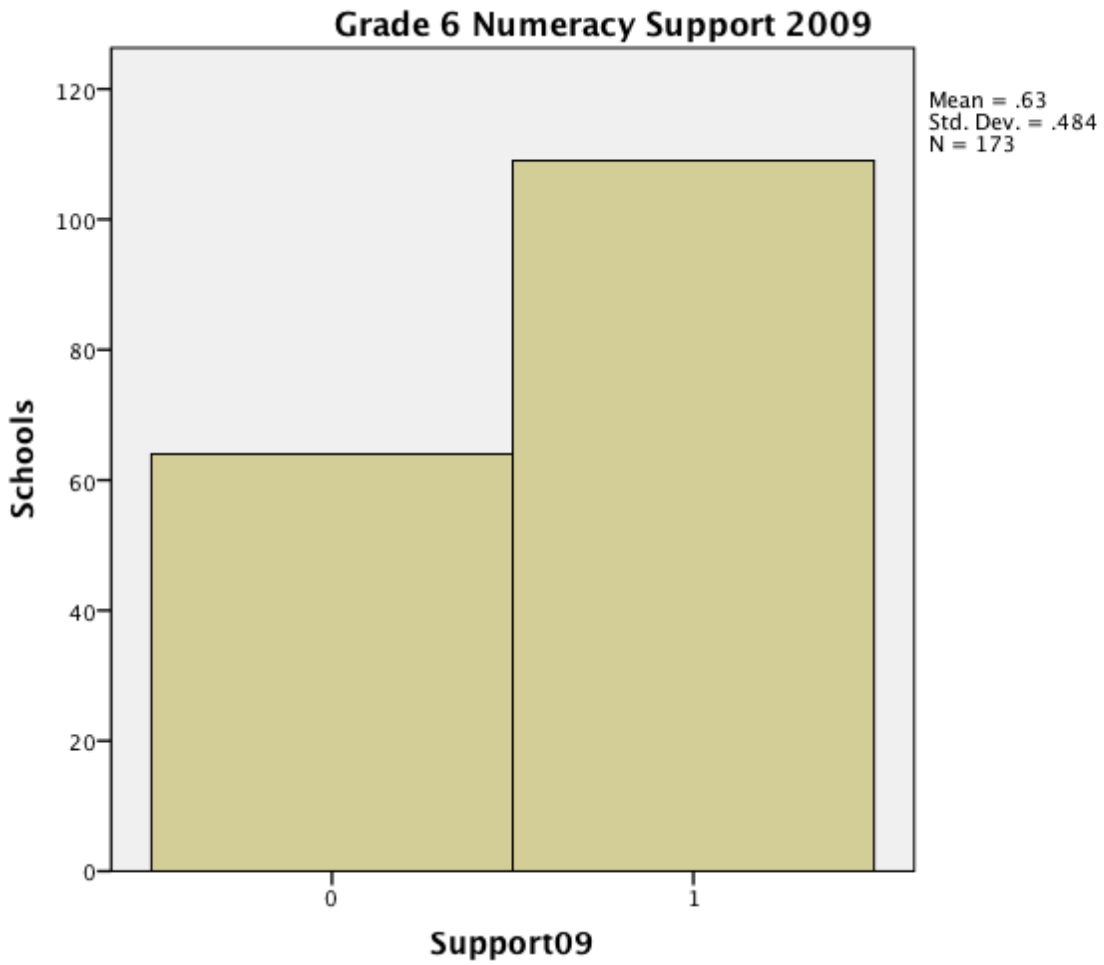


Figure 36.

Number of schools receiving numeracy support in Grade 6 in 2010.

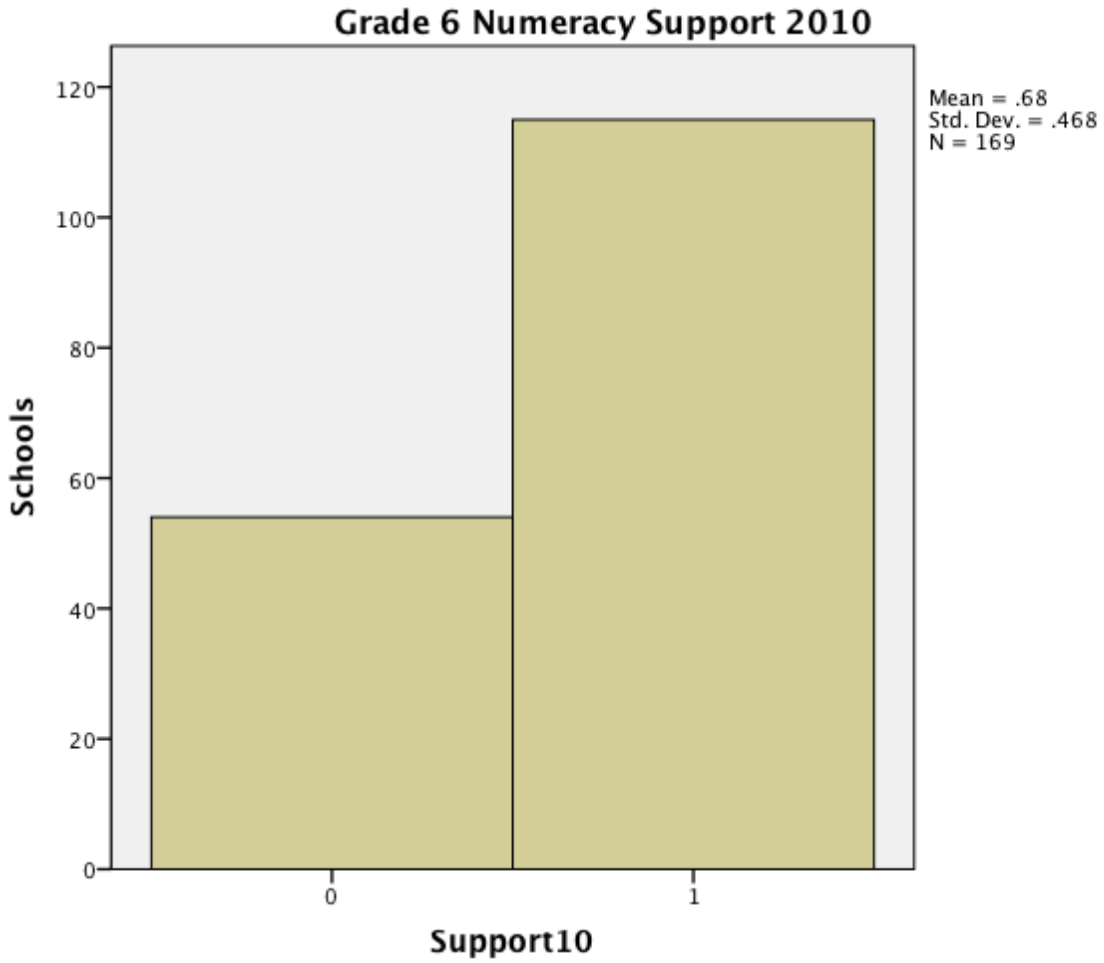


Figure 37.

Number of schools receiving numeracy support in Grade 6 in 2011.

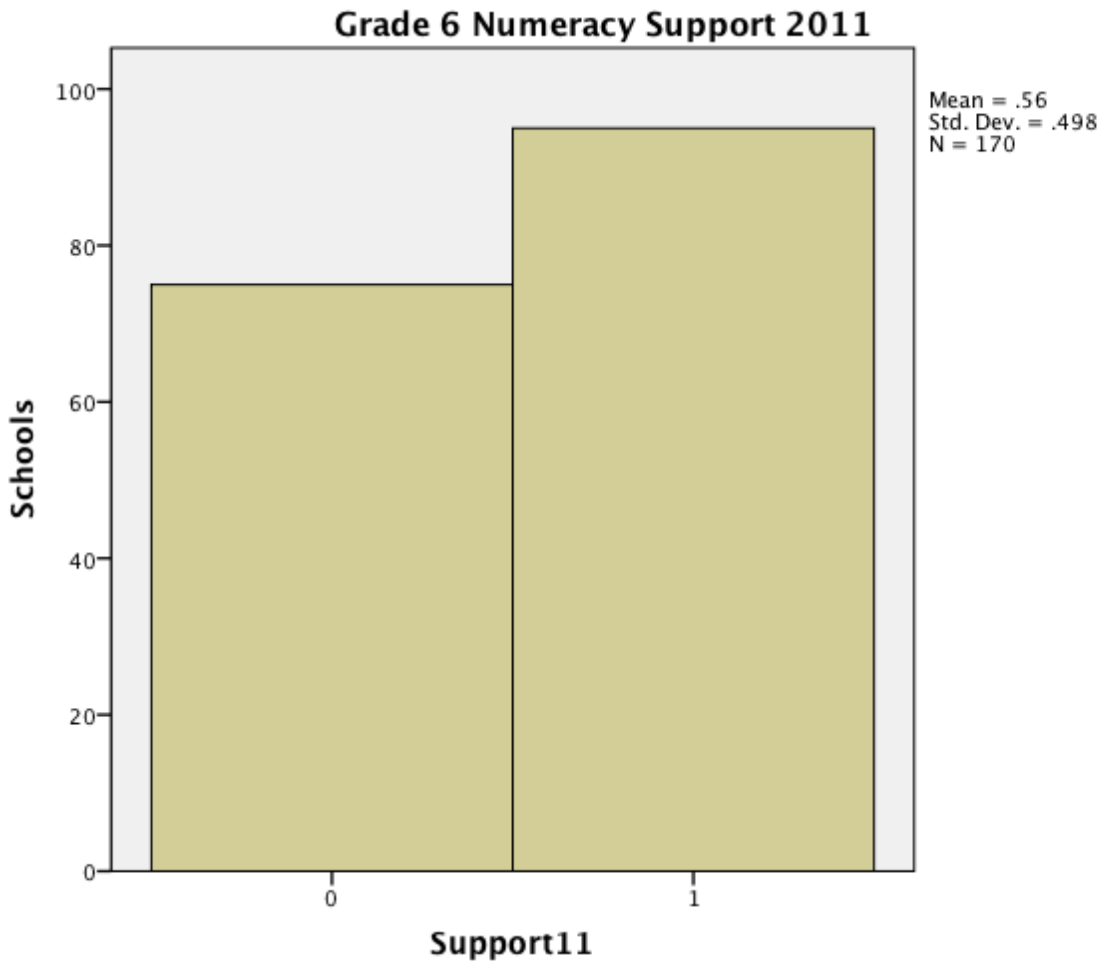


Figure 38.

Number of Grade 3 students in 2008 in schools receiving numeracy support.

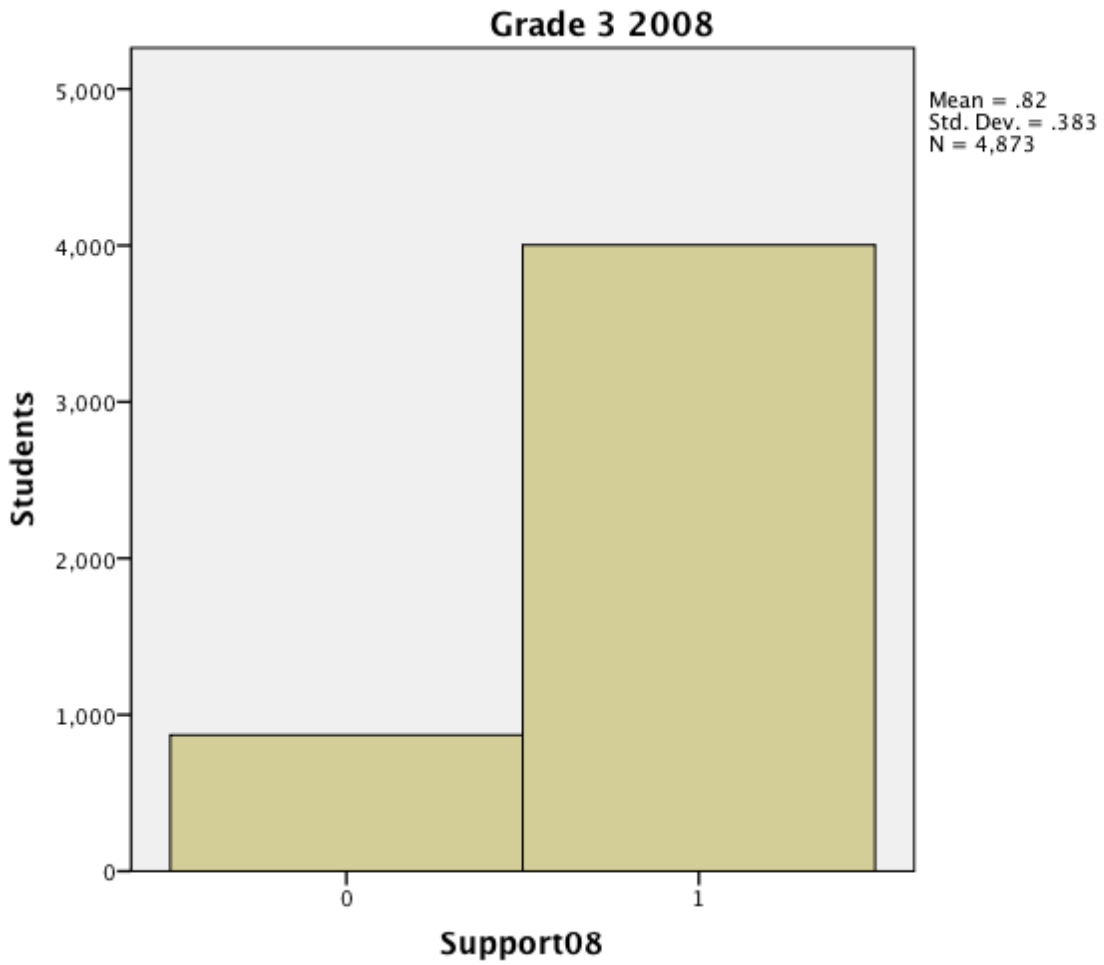


Figure 39.

Number of Grade 3 students in 2009 in schools receiving numeracy support.

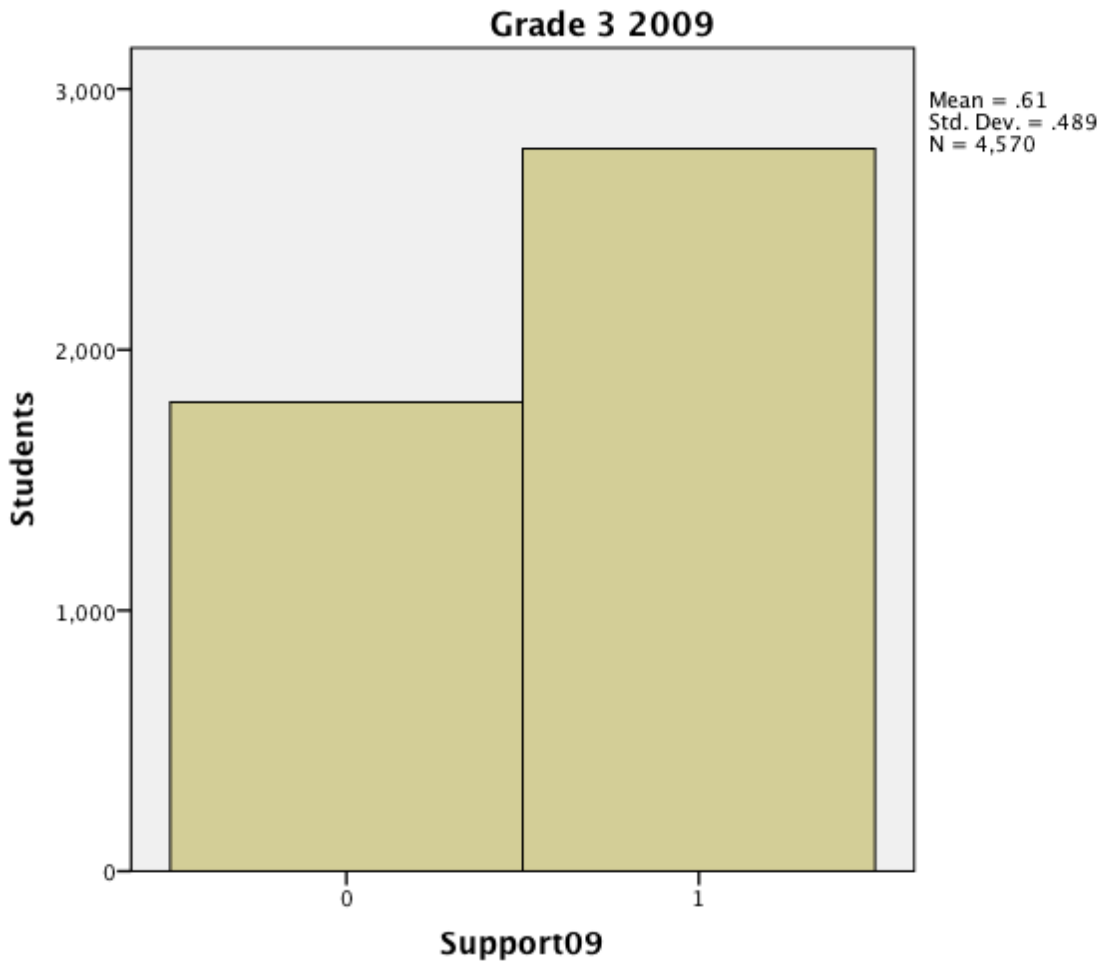


Figure 40.

Number of Grade 3 students in 2010 in schools receiving numeracy support.

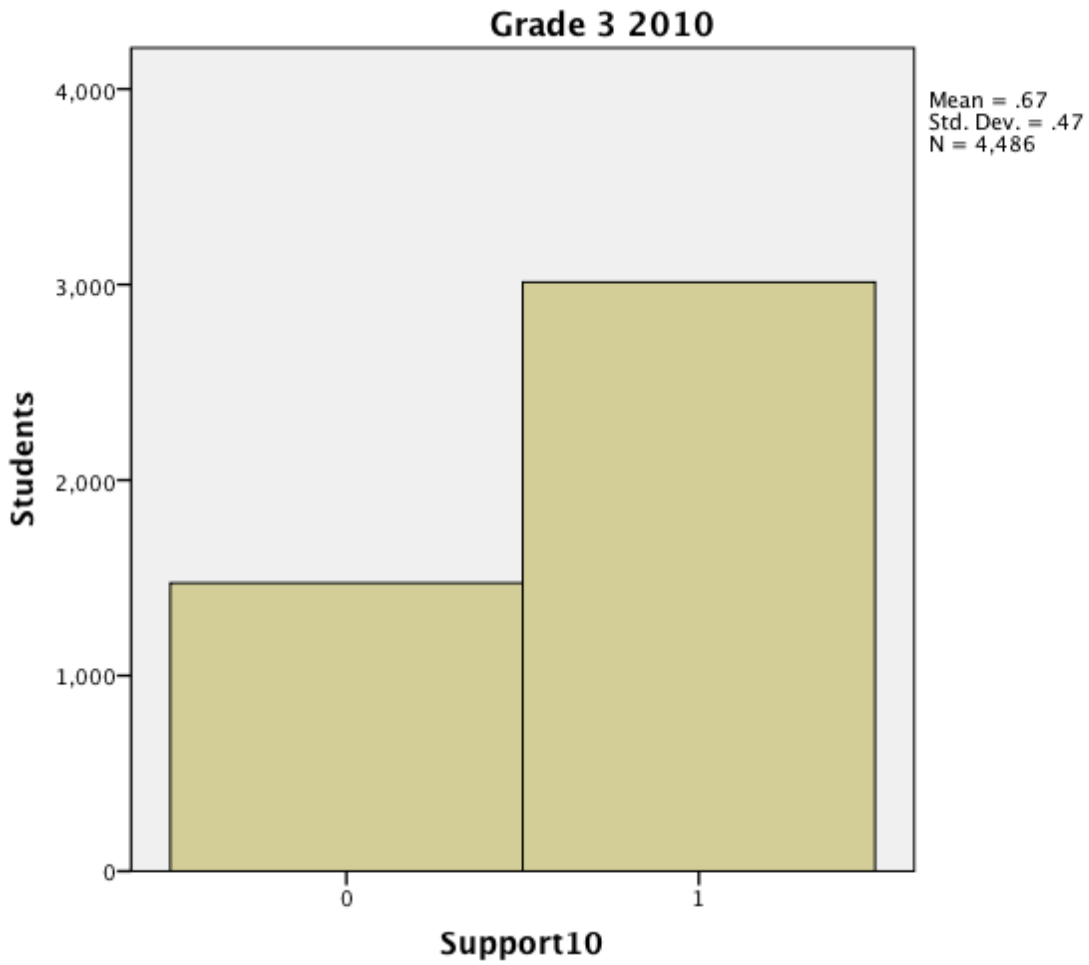


Figure 41.

Number of Grade 3 students in 2011 in schools receiving numeracy support.

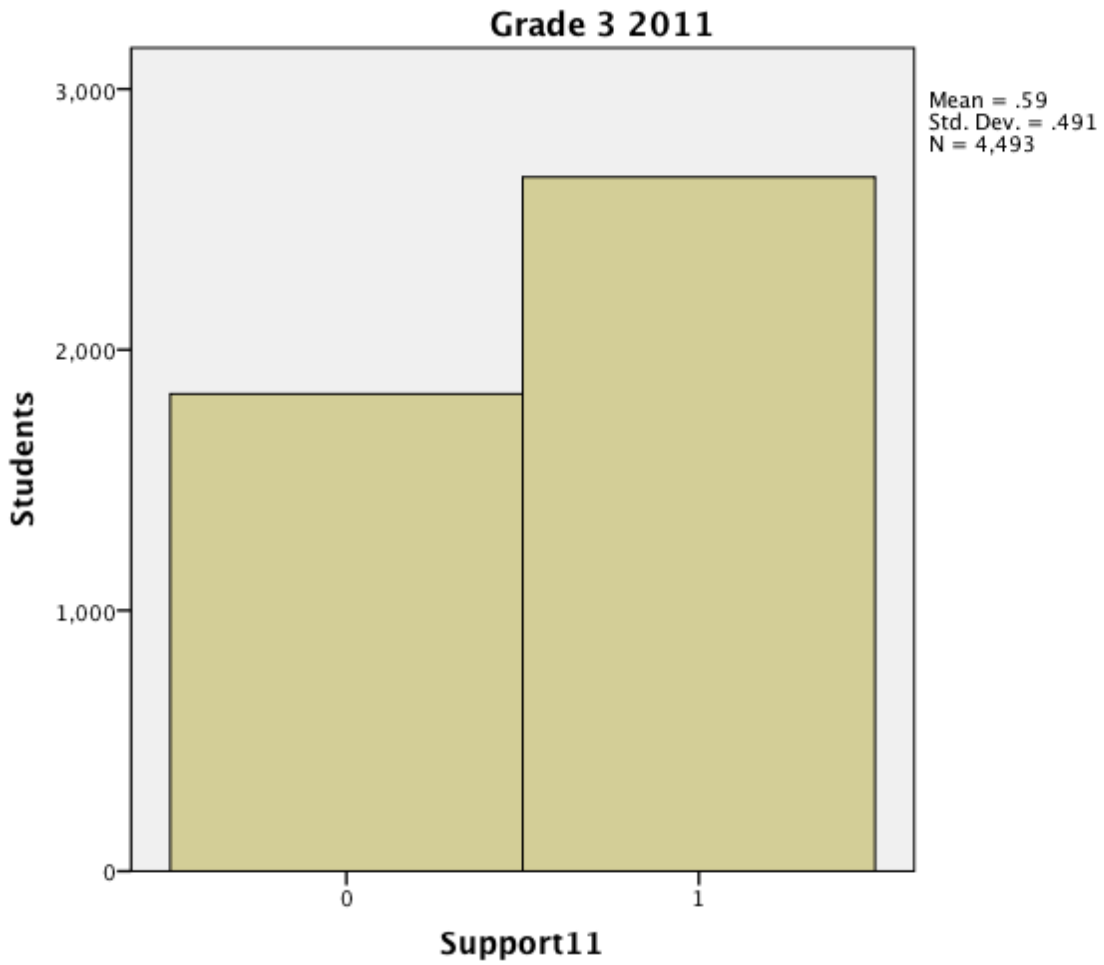


Figure 42.

Number of Grade 6 students in 2008 in schools receiving numeracy support.

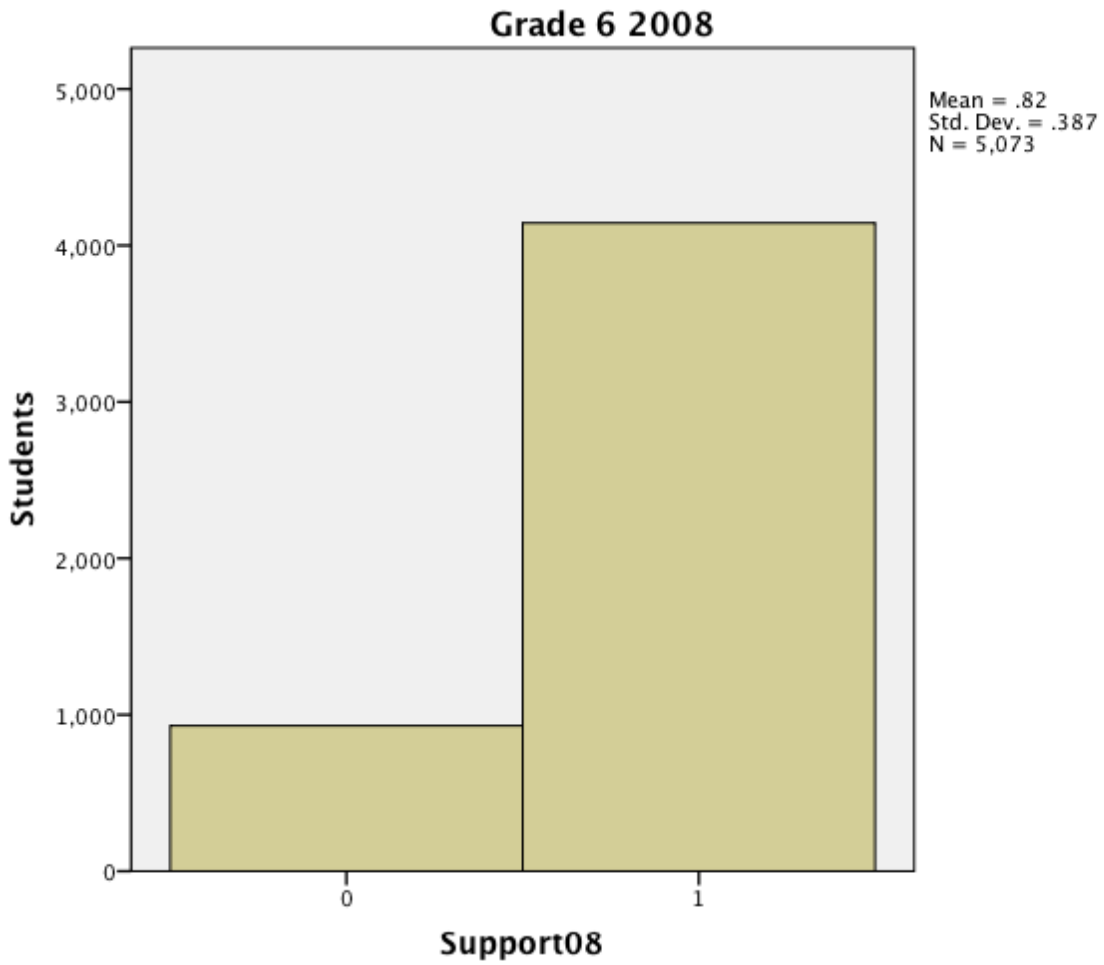


Figure 43.

Number of Grade 6 students in 2009 in schools receiving numeracy support.

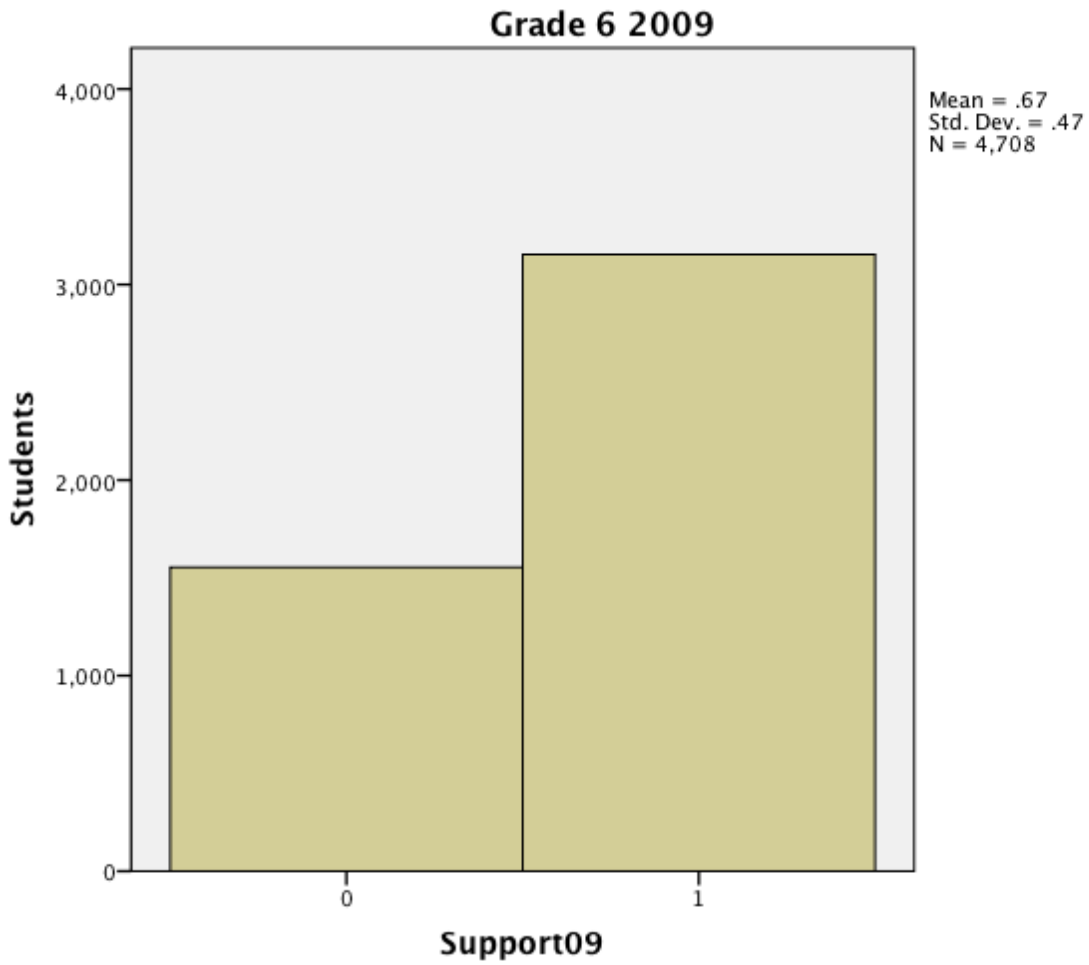


Figure 44.

Number of Grade 6 students in 2010 in schools receiving numeracy support.

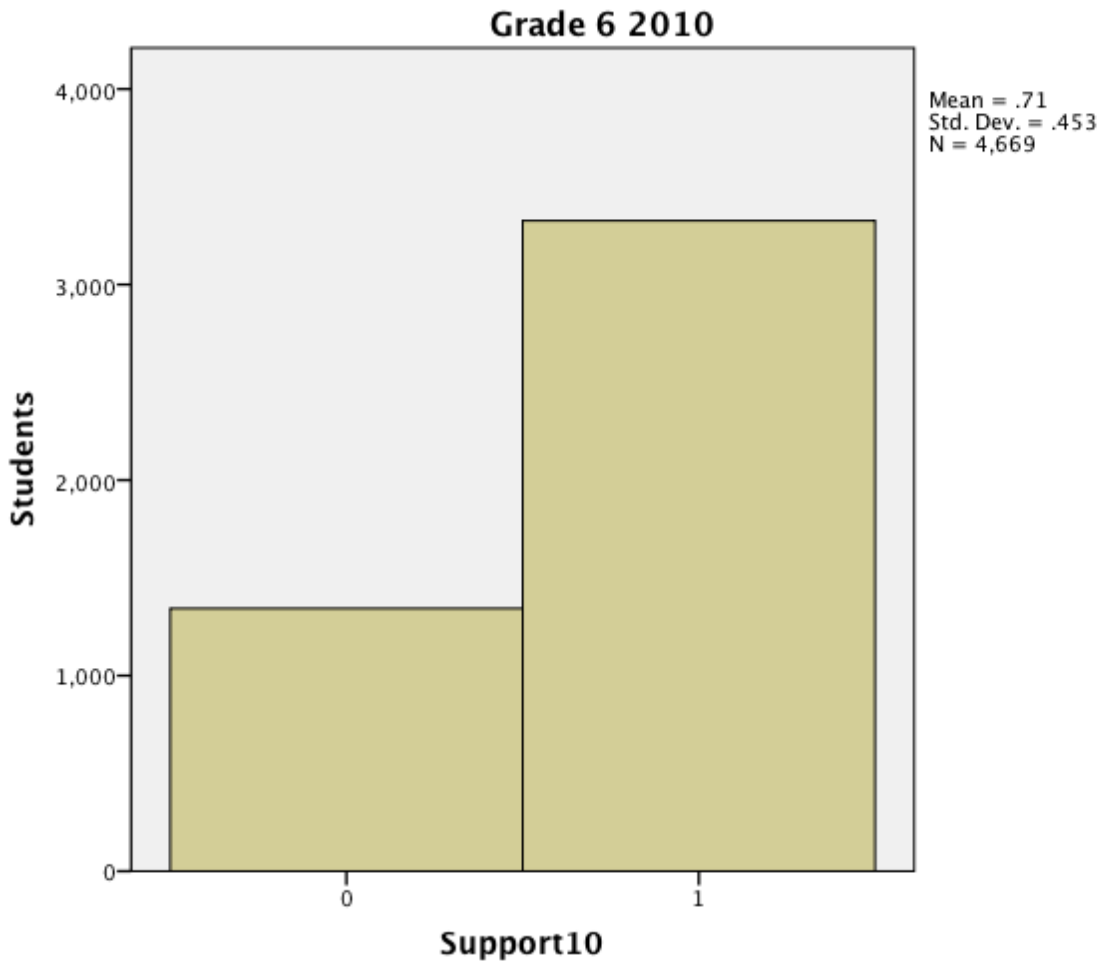
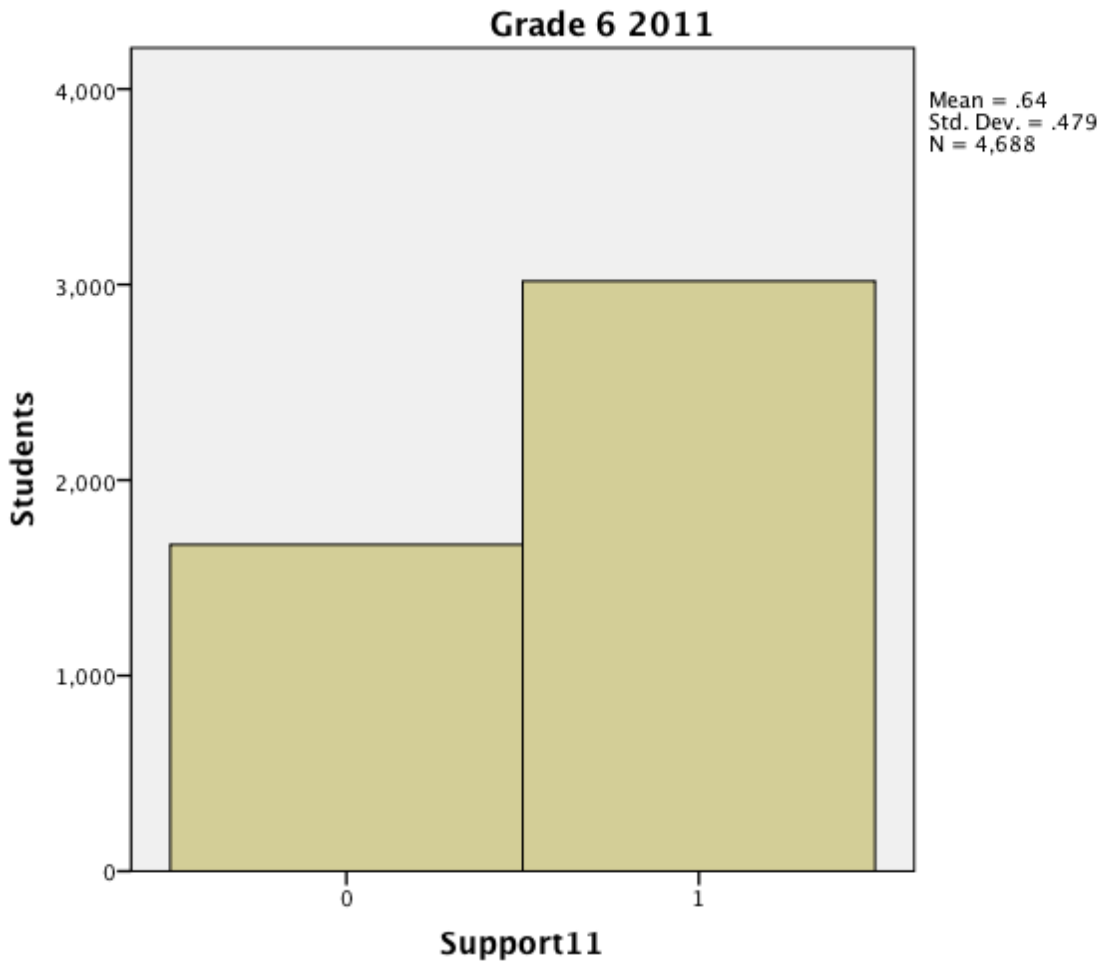


Figure 45.

Number of Grade 6 students in 2011 in schools receiving numeracy support.



Appendix J
Student Achievement Results Effected By Numeracy Support

Table 14.

Students moving between below and at/above standard if support was provided in Grade 6

Change over time from Grade 3 in 2007 to Grade 6 in 2010		
	No Support	Support
Decline (at/above in Grade 3, below in Grade 6)	15.10%	12.50%
Improve (below in Grade 3, at/above in Grade 6)	22.70%	20.90%

Table 15.

Students moving between below and at/above standard if support was provided in each Grade

Change over time from Grade 3 in 2008 to Grade 6 in 2011				
	Grade 3 in 2008		Grade 6 in 2011	
	No Support	Support	No Support	Support
Decline (at/above in Grade 3, below in Grade 6)	25.90%	23.10%	25.30%	23.60%
Improve (below in Grade 3, at/above in Grade 6)	7.20%	8.90%	7.50%	8.30%

Table 16.

Students moving between below and at/above standard if support was provided in Grades 3 and/or 6

Change over time from Grade 3 in 2008 to Grade 6 in 2011				
	No Support	Grade 3 only	Grade 6 only	Grade 3 and Grade 6
Decline (at/above in Grade 3, below in Grade 6)	23.70%	24.40%	27.90%	22.30%
Improve (below in Grade 3, at/above in Grade 6)	7.80%	7.30%	6.70%	9.80%

Table 17.

Grade 3 Mean Total Score by Annual Numeracy Support

Numeracy Support	2008	2009	2010	2011
No Support	75.62%	75.31%	76.61%	72.07%
Support	72.56%	74.48%	77.01%	69.89%
Difference	3.06%	0.84%	-0.41%	2.17%

Table 18.

Grade 6 Mean Total Score by Annual Numeracy Support

Numeracy Support	2008	2009	2010	2011
No Support	68.72%	70.90%	72.21%	63.01%
Support	68.11%	67.64%	68.38%	60.69%
Difference	0.61%	3.26%	3.82%	2.32%

Table 19.

Grade 3 Mean Total Score by Numeracy Support over 4 Years

Numeracy Support (years)	2007	2008	2009	2010	2011
0	77.16%	78.74%	78.67%	76.30%	73.87%
1	77.31%	76.65%	74.30%	76.76%	71.64%
2	73.28%	72.66%	75.42%	77.04%	73.54%
3	75.99%	72.59%	75.83%	79.40%	70.77%
4	73.71%	71.06%	73.94%	75.99%	68.82%
Extreme Difference (0 – 4)	3.45%	7.68%	4.73%	0.31%	5.06%

Table 20.

Grade 6 Mean Total Score by Numeracy Support over 4 Years

Numeracy Support (years)	2007	2008	2009	2010	2011
0	72.93%	73.54%	76.87%	76.54%	67.26%
1	67.09%	72.46%	71.20%	71.52%	62.99%
2	65.65%	71.08%	69.38%	72.81%	64.92%
3	61.77%	65.13%	67.02%	67.60%	60.08%
4	63.40%	66.84%	67.61%	68.05%	60.15%
Extreme Difference (0 – 4)	9.53%	6.70%	9.26%	8.49%	7.10%

Table 21.

Grade 3 Mean Total Score by Numeracy Support over 4 Years Combining 0 and 1 Years of Support

Numeracy Support (years)	2007	2008	2009	2010	2011
0 and 1	77.28%	77.06%	75.14%	76.67%	72.01%
2	73.28%	72.66%	75.42%	77.04%	73.54%
3	75.99%	72.59%	75.83%	79.40%	70.77%
4	73.71%	71.06%	73.94%	75.99%	68.82%
Extreme Difference (0,1 – 4)	3.57%	6.00%	1.20%	0.68%	3.20%

Table 22.

Grade 6 Mean Total Score by Numeracy Support over 4 Years Combining 0 and 1 Years of Support

Numeracy Support (years)	2007	2008	2009	2010	2011
0 and 1	68.04%	72.64%	72.05%	72.28%	63.49%
2	65.65%	71.08%	69.38%	72.81%	64.92%
3	61.77%	65.13%	67.02%	67.60%	60.08%
4	63.40%	66.84%	67.61%	68.05%	60.15%
Extreme Difference (0,1 – 4)	4.64%	5.80%	4.44%	4.24%	3.33%

Table 23.

Grade 3 Standardized School Score Differences, Comparing if Support was Provided

Support Year	2011	2011	2011	2011	2010	2010	2010	2009	2009	2008
Comparison Year	2010	2009	2008	2007	2009	2008	2007	2008	2007	2007
Support	0.0582	-0.0758	0.0581	0.0581	-0.2078	-0.292	-0.2104	-0.13	-0.0479	0.3933
No Support	0.0175	0.0488	0.1114	0.0084	0.0525	0.1349	0.0785	0.1464	0.122	-0.1338
Difference	-0.0407	0.1246	0.0533	-0.0497	0.2603	0.4269	0.2889	0.2764	0.1699	-0.5271

Table 24.

Grade 6 Standardized School Score Differences, Comparing if Support was Provided

Support Year	2011	2011	2011	2011	2010	2010	2010	2009	2009	2008
Comparison Year	2010	2009	2008	2007	2009	2008	2007	2008	2007	2007
Support	0.0011	-0.0352	0.0638	-0.0348	0.0086	0.0497	0.003	-0.0187	-0.0413	-0.1041
No Support	-0.1749	-0.0498	-0.1491	-0.2367	-0.0243	-0.0069	-0.2067	-0.0064	-0.1471	-0.0988
Difference	0.176	0.0146	0.2129	0.2019	0.0329	0.0566	0.2097	-0.0123	0.1058	-0.0053