CONTENT AND CONTEXT: PROFESSIONAL LEARNING COMMUNITIES IN MATHEMATICS

by

Lyn Patricia Vause

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Graduate Department of Curriculum Studies and Teacher Development
University of Toronto

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Content and Context: Professional Learning Communities in Mathematics
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Lyn Patricia Vause
Department of Curriculum, Teaching and Learning,
University of Toronto

Abstract

This is a case study of a mathematics professional learning community. It illustrates the experience of eight Grade 2 teachers as they collaborate to improve their students' understanding of mathematics. In this inquiry, I worked as a participant-observer with the teachers over the course of five months as a witness to their expanding understanding of mathematics and learning. The case study describes two manifestations: the experiences of the teachers as they develop their knowledge of the mathematical learning of young children; and secondly, the teachers' growth as a professional learning community committed to improving the mathematical understanding of their students and of themselves.

Collectively, the findings from this study extend other conversations on both professional learning communities and the development of teachers' knowledge about mathematical learning (often called pedagogical content knowledge). This work shows that opportunities for professional learning that are self-directed, context and content specific, within a milieu that is collegial and supportive, enable teachers to bridge the elusive gap between theory and practice.

The specific questions addressed are as follows:

1. How does participation in a professional learning community affect teachers’
pedagogical content knowledge and their understanding of students’ learning of mathematics?

2. How do primary teachers develop an effective mathematics professional learning community?

In mathematics, professional development often focuses on the creation of effective lesson design. This study differed in some key ways. Although good lesson design was valued and employed, the stimulus for teacher learning was the observation of the students as they struggled with new complex concepts. From these observations, the teachers became astute at recognizing particular consistencies and inconsistencies in the mathematical learning of the one hundred plus students they each observed within this project. Together, as a professional learning community, the teachers became adept at using external resources such as research and other resource materials to search the reasons and solutions for students’ difficulty with mathematical concepts. Teachers’ cognitive dissonance as they tried new instructional approaches and shared successes and failures with their colleagues provided the foundation for their growth in pedagogical content knowledge.
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Special thanks go to my faculty advisor, Dr. Linda Cameron, whose joyful spirit and tender heart has sustained me through many years at OISE. She has been both a mentor and a friend, enthusiastically shepherding me through the hills and valleys of this journey. I know I would not have finished it without her gentle prodding. The first course I took with her many long years ago rekindled my love of teaching and opened my eyes to the power of play to engage the minds of children not only in reading, her favourite area, but also in mine, numeracy and I will be forever especially grateful for that.

I would also like to thank Dr. Juanita Copley. Her writing and research nourishes my own love of teaching mathematics to young children. She has the wisdom to see children as the mini mathematicians that they are and the gift to help them see it themselves and probably just as importantly, to help teachers see it also. My moment of greatest pride will forever be Nita’s enthusiasm for my research at my oral defence. It took me away from the stress of the moment as we enjoyed the mutual pleasure of talking about children’s learning of the subject we both love.
I would also like to express my appreciation to my committee members, Dr. Clare Kosnik, Dr. Douglas McDougall, and Dr. Lee Bartel. Clare’s steadfast encouragement and friendly face bolstered my waning energy in the last lap of this journey. I have known Clare for a fairly long time and have admired her research and her dedication to the education of new and graduate students. I was truly honoured that she accepted the request to be on my committee. Thank you also to Doug for his skilled and tactful feedback that went beyond the call of duty. I learned a lot from his keen-eyed attention to detail and his substantive background in mathematics research. Lee generously stepped in as an alternative on the committee. In the short time he was part of the committee, he provided valuable advice for which I am very greatly indebted.

Special thanks to the teachers who participated in this research. They opened their classroom doors to each other and to me. It was a gift to be in their presence. Their care for their students and their dedication to their profession make me optimistic about the future of mathematical education for our youngest students.
Dedication

I would like to dedicate this thesis to Dr. Linda Cameron. Your help, friendship, and encouragement have made this journey a stimulating and joyous adventure.
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Chapter One: Connecting Past and Present

"…ultimately, the growth of students will go no farther than the growth of those who teach them." (Eisner, 2002, p. 384)

We want and need children to excel in mathematics. It is a cultural and economic sieve, sifting out the many who do not adequately meet its abstract demands, and limiting their opportunities for careers in our technology driven world. But there are also other gifts offered by mathematics. Gifts ensconced within the nature of number itself. Mathematics has a logic, pattern, and function. It holds the stories of cultures seeking to bring order out of the chaos of time, location, and commerce. It informs the artists, the philosophers, and the pragmatists. Its power is simple; its simplicity powerful.

However, despite these virtues, it remains a fearsome enigma to many adults and the scourge of secondary school students. With the logic of the fearful, many in our culture passively accept a self-imposed label of mathematic incompetence, willingly ascribing such defect to the nature of their genes rather than the nurture of their educational experience.

How does this happen? Young children are naturally inquisitive meaning makers and pattern seekers. Give children a bucketful of blocks and a problem, and they will indulge in the task with delight and persistence of Gaussian proportions. Their native mathematical disposition is intriguing. It contrasts with the phobic pessimism that greets later mathematics learning. Anecdotally, educators attribute this attitudinal shift to the mathematics becoming too complex, too soon for many.

Personally, I find it hard to fathom that the child I watch immersed in complex play-based problem solving in kindergarten becomes the disillusioned mathematics student of
later years. Where does this disconnect occur? Is it really the strain of sophisticated mathematics suitable for a select few? Playing mathematics with children is fun; playing mathematics with students is not.

Mathematics becomes serious business at a very early grade. From my experience, the pivot point is grade two. In the rush to acquire the abstract algorithmic concepts in the grade two curriculum (multi-digit addition and subtraction; multiplication and division), math confidence wanes.

There are opportunities for the interception of negative messages about mathematical proficiency. Effective instructional practices nourish budding mathematical promise rather than conceding to the pragmatism of “covering the curriculum.” Whether children’s mathematical brains become sated or starved depends upon the level and nature of the stimulus they receive in the classroom. Rich challenges, novelty of experience, and encouragement provide fertile ground for budding mathematicians. We know a lot more about children’s learning of mathematics than at any time in the past. For teachers who are attentive to new ways of teaching and intentional in their commitment to mathematics, learning can successfully shepherd children through the first abstract challenges of mathematics.

At the same time, there is concern that the nature of mathematical literacy changed dramatically in the past century. The level of mathematical understanding required to read the newspaper, make thoughtful democratic decisions and cope with everyday life grew exponentially (Paulos, 1989). Recent reform initiatives also promote a more challenging curriculum requiring higher-level thinking and reasoning strategies at all levels of the school system (National Association for the Education of Young Children,
There is also concern about the rising gap between achievement in mathematics of children from different socio-cultural backgrounds (Ontario Ministry of Education, 2003a). These children especially require quality experiences during their primary years, also called the “years of promise” by the Carnegie Corporation (1994). Often low-income minority children, beginning around the third grade, have difficulty with school mathematics (Seo & Ginsburg, 2004). There is evidence that improved instruction in the primary grades can mediate socio-cultural effects (Fuson, 2004; Griffin, Case & Siegler, 1994; McCain & Mustard, 1999; NAEYC, 2002; NCTM, 2000).

Research internationally supports the promise of a "brain gain” through an investment in the mathematics education in the primary grades (Bowman, Donovan, & Burns, 2001; Fosnot & Dolk, 2001; Greenes, 1999; McCain & Mustard, 1999). Critical to such investment being effective is the professional development of teachers. Teachers who teach primary mathematics, therefore, have a rewarding but challenging task ahead of them and they need professional learning opportunities to accomplish that.

Effective professional development involves providing teachers with both the pedagogical knowledge about the teaching of mathematics and an understanding of the underlying concepts within the mathematics itself. This understanding of how young children learn mathematics has grown considerably in the recent past. There is now a rich reservoir of research and resources available for primary teachers. With this comes the opportunity for children to engage in and learn mathematics more fully than in the past.

However, there are challenges in providing teachers with professional development
that adequately accesses this reservoir in ways that nurture teaching and learning in the classroom. Contemporary professional development does not often provide opportunities for mutual practice of new ideas together with personal reflection and collaboration among colleagues, even though these are the core tenets of good professional learning.

As a long time participant and presenter of mathematical professional development, I have witnessed the rise and fall of many professional development initiatives. As a participant, I keenly attended every opportunity for ongoing professional growth in mathematics. As a consultant, faculty instructor, and later Ontario Ministry of Education representative, I led many professional development programs in mathematics. Though there are some successes along the way, there is always the problem of the large-scale adoption of the superficial accoutrements of change and, when it fails, a return to the practices of the past.

Critical to effective long-term change is professional development that allows teachers to work in self-sustaining, supportive, and intellectually stimulating communities. In such communities, practical knowledge of the participants is connected to the “expert” knowledge of researchers, and then discussed and developed into a comfortable combination of theory and practice. Professional learning communities provide a conceptual context for bridging the breach between theory and practice in the teaching and learning of mathematics.

Also connected to this is the opportunity to focus on specific content relevant to the grade level that the participants teach. Enthusiasm of presenters and participants for new pedagogical strategies during workshops cannot overcome the complexity of individual teachers trying to translate theory into practice in the context of their own classrooms.
while using the specific content related to their grade level. Confronted by the conditions of the normal messiness of student learning against which teachers have to contend, unsupported in the school milieu, in isolation from their colleagues, and against a backdrop of public policy that often complicates, rather than advances professional development (i.e., withdrawal of professional development days), teachers often return to the comfort zone of their previous practice while professional resources languish on classroom shelves; the chasm of cynicism growing wider in response to the lack of true learning opportunities.

As well, I believe that professional development should not be separated from student learning, especially students’ mathematical learning. The choice of mathematics as the context for looking at professional learning communities was intentional. The area of greatest need for professional development is in the area of mathematics as will be seen in the literature review, which indicates that teachers' understanding of mathematics is not robust enough for the needs of today. At the same time, we know that mathematical success is something of an academic sieve, rewarding those who understand it with many academic and career choices. The evidence is clear that improving mathematics learning at an early age reaps many benefits (Bredekamp, Bailey & Sadler, 2000) including future academic success throughout the elementary grades into high school and college. Without success in mathematics at the earliest ages, children, particularly low-income children, are at increased risk of school failure (Bowman, Donovan & Burns, 2001; Griffin, Case & Siegler, 1994; McCain & Mustard, 1999; Natriello, McDill & Pallas, 1990). Lack of equity in these early stages of education has long-term impact on the quality of life and careers for such children.
Research Context

In 2003, a major large-scale initiative was undertaken by the Ontario Ministry of Education in both primary mathematics and literacy. The impetus for this project was the recommendations of the Ontario Ministry of Education's Expert Panel on Early Math in Ontario (2003a) that primary teachers receive more professional development in instruction. In particular, it recommended that instruction focus on developing conceptual understanding of mathematics, problem solving, reasoning, and communication.

I was seconded to the Ministry at that time as a mathematics lead on the primary mathematics part of the initiative. A description of this initiative is important to this thesis. The participants in my study all participated in the in-servicing described below. As one of the two leaders developing the materials and training protocols for this initiative, I had a vested interest in its implementation and particularly in its success. A description of the initiative from my viewpoint at that time will articulate the mindset with which I entered into my own research project as well as provide some insight into the impact of the training on the group of participants in my study. It is interesting that at the moment of developing the Ontario Ministry initiative's materials and protocols, all of the parties involved, including myself, made assumptions about the level of understanding of mathematics. In particular, we miscalculated the level of mathematics pedagogy that the teachers already had and, most egregiously, the amount of knowledge and understanding they could be expected to learn and integrate into their practice after a three-day workshop.

The objectives of the planners were well intended. The research background for the initiative was well developed. The only impediment was that research indicated that
short-term training sessions of this ilk were generally unsuccessful, and that although they often generated excitement and interest around new learning theories, the transference of the theory into practice in the classroom was very limited (Ball & Cohen, 1999; Joyce & Showers, 2002). As anyone who has ever been involved in a large-scale venture of this nature knows, the final decisions are impacted by time and money constraints. A project that would provide teachers with more in-depth professional development, including working time together to support one another in integrating new practices into their classroom, was more costly than the Ontario Ministry of Education could afford to bear. Therefore, the initiative was constrained by the cost of releasing teachers to work in-depth on issues of teaching and learning, and a modified version that limited the training to three days with no follow-up was developed.

The initiative included two parts: the development of a resource on primary mathematics based on research and best practices; and the second part of the initiative was the training of a provincial team to provide training to the boards using the traditional “train the trainer” model. The training focused on general areas of good pedagogy, research on teaching and learning, as well as specific training on the teaching and learning of Number Sense and Numeration from Kindergarten to Grade 3.

**What was Envisioned for the Professional Development?**

The intention was to provide teachers with both the pedagogical knowledge about the teaching of mathematics and an understanding of the underlying concepts within the mathematics itself. The philosophy of the training was that there are fundamental understandings that are important for children to acquire if they are to have a solid foundation on which to build future mathematical knowledge. It also included a
commitment to ensuring instruction takes place in an environment promoting problem-solving, communication, and reasoning skills.

The challenge that was recognized was that teachers often did not have a full understanding of the concepts inherent in the mathematics they taught, or how such concepts relate to the prior knowledge that children bring to the classroom, or to the future mathematics that children will encounter in later grades. Children come to pre-school and school with some beginning sense of number (especially quantity: two toys are better than one) and pre-reasoning skills (if there are two toys and we each get one, it is fair, but if one person gets two and the other person gets none, it is not). However, that prior learning is not always readily valued by or sometimes discernible to the untrained. What does a complex skill such as problem solving look like when manifested in the words and actions of a young child? It takes a thoughtful and knowledgeable teacher to sift out the beginning kernels of problem solving and mathematical understanding in the young child’s behaviour. The training for the Early Math Strategy was designed to give teachers this knowledge and skill.

Another challenge in early mathematics teaching was the added pressure on teachers, from parents and sometimes from the children themselves, to concentrate mainly on one skill, namely counting, to the detriment of the other concepts that build number sense. Some children come to school able to count to high numbers, and they and their parents are very proud of this fact. Or, students might be able to rhyme off basic number facts. However, in neither case is there always a complete understanding of the underlying concepts of numbers and it is this understanding that underlies all successful future mathematical learning. Teachers often need much more expertise than they have to
withstand such pressure and educate parents that while, yes, counting and reciting are valuable skills, it is equally, or more important, that they develop understanding. Of particular importance are those concepts that involve developing a clear awareness of the composition of and relationships between small numbers such as five and ten so that such understanding can be extrapolated to future understanding of larger numbers and work with the operations. Part of the Early Math Strategy training involved providing teachers with access to the knowledge and skills that would help them recognize the importance of the foundational early mathematics concepts.

**What was Enacted in the Training?**

The training for this stage of the initiative was on general mathematical pedagogy with a focus on Number Sense and Numeration. The in-service sessions focused on creating a mathematically rich environment through the use of problem solving, communication, and the big ideas in mathematics instruction.

Several fundamental understandings are important prerequisites to developing good number sense. These fundamental understandings were divided under five categories (called big ideas), namely, counting, quantity, relationships, representation, and operational sense. Within these five categories was an exploration of how particular concepts developed from Pre-Kindergarten to Grade Three. The Ontario Ministry of Education Guide to Effective Instruction in Mathematics, Kindergarten to Grade Three, (2003a), provided some guidelines for the underlying concepts of Number Sense and Numeration. Below is a diagram of the five big ideas, (Figure 1) which comprised a significant component of the training (Ontario Ministry of Education, 2003a).
Another important component of the training was determining how the concepts developed over time. What does the kindergarten teacher do to influence a child’s performance in Grade One and what does the Grade Two teacher do to link back to the prior learning from Kindergarten. A summary of the concepts that are embedded in the primary mathematics curriculum were also addressed in the training. The concepts included:

- an understanding of part-whole-relationships (all numbers can be separated into parts; all parts can be joined into wholes);
- an understanding that numerals represent quantities, and these quantities increase as you move along the number line or hundreds chart;
- an understanding of counting-all (“If one part is made up of two counters and the other part is made up of three counters, I can put them into a whole that can be counted and the whole is the total of those two parts) and counting-on (for instance 5 counters are given to a child and she counts them, then she is given 3 more and she is able to add on from the 5 by counting on 6, 7, 8.
• an understanding of the importance of the numbers 5 and 10 and the relationship of other numbers to these two important numbers (for instance knowing all the combinations of numbers that make 5 and all the combinations that make ten);
• an understanding of place value and how important it is for children to understand how numbers increase by a rate of 10 as they move in place to the left on a number and decrease by a rate of 10 as they move to the right (for instance when a child is asked to show the number of counters representing the 1 digit in 16 they show 10 counters rather than 1);
• confidence in addition and subtraction of numbers to 20. Again, many experiences working in this range of numbers are very important.
• knowing how to decompose and compose a higher level unit. For instance knowing that 56 decomposes into 5 tens and 6 ones, or 4 tens, 16 ones, etc. (Ontario Ministry of Education, 2005b)

Teachers were encouraged to develop these concepts through problem-solving activities that provided a balance of small group, whole group, and independent experiences depending on the developmental level of the students.

To help children learn these concepts, it was recommended that teachers use manipulatives, especially counters and linking cubes, hundreds charts and carpets, number lines, calculators, picture books that present math ideas in interesting and engaging ways, and simple games.

This Ontario Ministry of Education initiative had bold expectations for affecting changes in mathematics teaching in primary classrooms. It was the most intensive initiative that had been implemented in early year’s mathematics professional development in the Ministry's history. The rationale for the initiative was based on the positive research from other large scale ventures to improve student achievement such as the work of Hill and Crevola (1999) in Australia, Superintendent Tony Alvarado's success in New York District 2 (Elmore & Burney, 1997) and England's National Literacy and Numeracy strategy (Fullan & Earl, 2002).

Yet, the Ministry initiative had a few significant drawbacks highlighted by the
experience of the teachers in my project. The training did not go far enough in providing teachers with the time and support to learn how to implement the recommended changes in their classroom. It also tried to cover too much in too short a time. The three days of training was insufficient. As discussed later in this thesis, the Ministry initiative period and framework was not sufficient to allow teachers to integrate the new learning into their practice.

Only with the additional time for collaborative learning, as set out through this project, were they able to begin to explore alternatives to their present teaching practices. But of equal or more importance is the fact that the Ministry initiative did not connect with teachers' prior learning; it was not sensitive to their zone of proximal development and was unmindful of the context of the mathematical realities of teachers and students in their classrooms. So, although I think it is important to recognize that the Ministry initiative forms an important backdrop to the project described in this thesis, it also confirms the insufficiency of reform movements that do not provide for engagement at the level of professional collaboration with colleagues and opportunities to work together in each other's classrooms.

Below is a conceptual map, which situates my project in relation to the Ministry initiative. It was not a part of the Ministry initiative, but all of the participants in this study had received the Ministry training just prior to the beginning of my study.

As indicated in the conceptual map, the professional learning community, which is the topic of this thesis, was an offshoot of the Ministry project, informed by it but not formally integrated into the initiative itself. It was an attempt to further the goals of the Ministry training to develop high levels of mathematical literacy in teachers and students.
Intended professional learning goals at provincial Ontario Ministry of Education level
- Develop understanding of development levels of children’s acquisition of mathematics.
- Expand repertoire of teaching strategies.
- Improved understanding of concepts in Number Sense and Numeration.
- Develop awareness of importance of problem-solving, communication and, planning in mathematics instruction

Development of the Training Modules at the Ontario Ministry of Education Level
- 7 teachers seconded to the Ministry.

Developers from the Ontario Ministry of Education level
- Train 60 trainers from across the province.

Provincial trainers
- Train one or two teachers from each board across the province (200 in total).

Board trainers
- Train 4000 teachers from across the province (one primary teacher per school trained to become primary lead teacher).

Primary lead teachers
- Share their training with the other primary teachers in their schools.

Mathematics Project – Professional Learning Community (PLC)
- Separate from Ministry initiative.
- 8 primary lead teachers from 8 schools in one board.

PLC's professional learning goals
- Identify mathematical area of greatest need in Grade 2 curriculum.
- Observe student learning in that area.
- Identify strategies for improving student learning.

Figure 2: Conceptual Map
Research Questions

This is a case study of a mathematics professional learning community. It illustrates the experience of eight Grade 2 teachers as they collaborate to improve their students' understanding of mathematics. The case study describes the experiences of the teachers as they develop their knowledge of the mathematical learning of young children and secondly, the teachers' growth as a professional learning community committed to improving the mathematical understanding of their students and of themselves.

The specific questions to be addressed are:

1. How does participation in a professional learning community affect teachers’ pedagogical content knowledge and their understanding of students’ learning of mathematics?

2. How do primary teachers develop an effective mathematics professional learning community?

These questions explore the relationship between teachers’ self-efficacy and their participation in a professional learning community focused on improving their knowledge of mathematics teaching and learning.

Background of the Researcher

Everyone has personal and professional roles but it is only the very lucky who are able to integrate them in ways that are fulfilling and transforming. I watch my young granddaughter as she maneuvers the playroom, putting geometric shapes into boxes, fitting together puzzles, yelling loudly as she counts to three (she is only a year and a half) and then clapping out patterns in the air. Playing and learning are indistinguishable in her wake. I envy her ‘flow’ (Csikszentmihalyi, 1990, p. 1). I learn from her about the
plasticity of the human mind and its exponential power for learning. Her antics fill me with delight and remind me why I became a teacher. It is the lure of learning, watching it, and doing it. For at least twenty years, that allure has remained constant drawing me to the mathematical learning of young children. – I like to kidwatch (Goodman, 1985, p. 1). This fascination with kidwatching and with mathematics learning was the reason I wanted to do research in this area.

At different points in my career, I have had the opportunity to do that research in small doses. As a teacher in the classroom, I conducted many informal little action research projects. Later as a consultant, I had the opportunity to work with other teachers as they conducted informal research in their classrooms. For three years, I was seconded to York University as a faculty member and in that position I was again able to work with pre-service teachers as they did their own kidwatching. For four years, in a secondment to the Ontario Ministry of Education, I delved into research on early mathematics in children and developing workshops and training protocols for elementary teachers in the primary and junior divisions. In my present role, with the Ontario English Catholic Teachers Association, I lead professional development opportunities for members. These multiple professional opportunities have cultivated a deep interest in the combination of kidwatching, mathematics learning, and professional development.

On the personal front, my beliefs about mathematics learning and professional development were groomed by a different experience. Many years ago, I used to jog with a group of teacher friends on a regular basis. As we ran, we talked about our personal lives, and also our professional lives, about our students, our most recent readings, and the newest strategies we tried in the classroom. It was not always about mathematics, but
many times, it was, simply because as a group, we were quite interested in the topic. The conversation fulfilled two purposes: a distraction from sore limbs and a sounding board for new teaching ideas. Those were probably the richest professional conversations in my career. They opened up vital connections for intellectual renewal, both pragmatically and viscerally. The most powerful impetus for change was the relationship with other educators. It changed my practice more dramatically than subsequent opportunities for in-depth professional development. The relationships opened the channels for discourse while sustaining the trust needed for safety in exposing professional and personal vulnerability about complex issues of teaching practice.

Those conversations crystallized into a belief in the potential of professional learning to enrich and energize my career-long love of teaching children mathematics. The experience continues to motivate my search for parallel professional learning opportunities. Gladwell (2008) proposes that we need 10,000 hours of intense interest and interaction with a subject to become a specialist in it. I do not think being a specialist means you know everything, but it does help you to know what really does not work and what has the possibility for success and growth. I think I have done my 10,000 plus hours of investigation of children’s learning of mathematics and professional development. I hope I have fulfilled “the deep interest that makes one an educator” (van Manen, 1990, p. 2) and that this thesis will contribute to the learning of other people who have pursued an interest in professional development and children’s learning of mathematics. Underlying this thesis is the strong conviction that good teaching is like good art, when you see the best, it brings shivers down your spine. I was able to not only kidwatch but also teacherwatch and many times, it did bring shivers down my spine.
Format of Thesis

This thesis is organized into five chapters. In Chapter One, an introduction is given that informs the reader about the context of this research, its significance, and the main questions that drive the research.

Chapter Two contains the literature review. This literature is reviewed from two perspectives: mathematics learning and professional learning. The mathematics learning component contains a section on philosophical roots, why mathematical literacy, theories of learning mathematics, children’s learning of mathematics, and elementary teachers understanding of mathematics. The professional learning component reviews literature on linking mathematical knowledge and professional development, and professional learning communities.

Chapter Three describes the rationale for the methods design, a description of the participants, their board, and their classrooms. It also includes information about the videotaping and audiotaping and the format of the in-classroom and out of classroom observations. The issue of access to the participants and the ethical considerations involving the teacher participants are also considered.

Chapter Four provides the account of the findings. It is divided into nine sections: deciding on a topic, stages of mathematics development, using research, cases, professional learning community norms, moving at different speeds, misconceptions, assessment, and learning communities. The findings emerge from the participants’ experiences teaching mathematics, looking at research about mathematical learning, and collaborating in a professional learning community.

Chapter Five discusses the findings in terms of the research questions and the
literature review. The information gathered from the professional learning sessions is integrated into the findings, a discussion presented on the implications of the findings, and suggestions for further study are recommended.
Chapter Two: Literature Review

Introduction

As will be more fully described in the methods chapter, the framework for this inquiry deviates in some ways from the traditional professional learning community that is commonly supported in large scale initiatives such as those proposed by Dufour (2004), Crevola and Fullan (2006), and supported by and the Ontario government’s Literacy and Numeracy Secretariat and the Managing Information for Student Achievement Branch (MISA). The professional learning community in this thesis differs from the provincial model because of its emphasis on self-direction, self-motivation, and autonomic decision-making. In contrast, the Ontario Ministry of Education model is based on improving Education Quality and Assessment (EQAO) achievement levels at Grade 3 and Grade 6 based on school-wide and board-wide educational prerogatives. This type of large-scale initiative, which can serve a purpose, is top-down and based on a deficit model of teacher capacity for change.

There is a philosophical shift between these two models. Often the literature on the mathematical knowledge of teachers is based on a deficit model, and certainly, the literature review in the next sections of this chapter will confirm that there are gaps in elementary teachers' understanding of mathematics, as well as mathematics teaching and learning. However, it is important to recognize teachers' facility for change and growth, as well as the centrality of their role in the building of teaching capacity. Therefore, I have chosen to begin this chapter with a short overview of some of the critical authors who together embody the practical and philosophical sensitivities that underlie the philosophical framework of this thesis.
In this section, I present a set of ideas that have influenced the nature of this inquiry. The next sections will look at the main literature reviews, which form the basis of this thesis. The following concept map (Figure 3) identifies how these sections interrelate:

**Figure 3: Concept Map of Literature Review**

**Philosophical Roots**

The collective characteristics of Dewey, Schwab, and Greene put forward the common conviction that teachers are at the heart of the educational process. They are the pioneers for deep and thoughtful consideration of teaching issues and learning, and they operate within a moral dimension centred on student learning. Teaching is a craft that takes hard work and careful consideration of the social context of the classroom environment, the child's cultural milieu, and the child's capacity for learning in particular ways. Although their influence is not central to mathematics or professional learning specifically, this thesis draws inspiration from their substantial commitment to theories of...
teaching and learning.

**Dewey**

Almost one hundred years ago, Dewey (1916) acknowledged the importance of mindfulness in the teaching profession. He saw this fostered by a rich personal and social understanding of students, both by honouring their educational contexts and by recognizing the explicit and implicit curriculum. The explicit curriculum was the required teaching. The implicit curriculum includes the effects of the culture of the classroom and the relationships between its members. The heart of the educational process is to create thinking, creative human beings, not to reproduce mass imitation and insipidity disguised as teaching and learning. He championed the power of "teachers adequately moved by their own intelligences and ideas" (Dewey, 1916, p. 160) and "the fruitfulness or value of the experience" (1916, p. 163). He also stated, "When the natural and the cultivated blend in one, acts of social intercourse become works of art" (Dewey, 1934, p. 63). He saw thoughtful and reasoned discussion about teaching and learning as fundamental components of teachers' growth. Although the coining of the term "professional learning communities" was not yet conceived, Dewey was the progenitor of its core values and beliefs.

**Schwab**

Schwab (1983) promoted the idea of teachers as researchers in the classroom. Schwab (1973) believed that all learning situations could be understood in terms of subject matter, learners, milieus, and teachers. He deemed educational decisions that did not consider those four areas facile and ineffective. Schwab (1971) was especially cynical about the over reliance on what we would call “hard data” today as the most important
determinant for making decisions. Ameliorating educational dilemmas required local initiatives that took into account diverse contexts, students, and teachers, "with each one throwing … useful light on the subject treated" (Schwab, 1971, p. 494). Rich inquiry was seen as an important source for fresh understandings and as crucial for "ready(ing) theory for practical use" (Schwab, 1971, p. 495). Schwab (1971) recognized that teaching and learning are complex issues irresolvable by didactic solutions disconnected from the realities of educational content and contexts. He talked of the evolution of expertise. Experts learn complex tasks by organizing and linking core concepts that become a framework applicable to multiple situations (Schwab, 1971). The needs of individual students and situations must hold primacy in all educational endeavours. In other words, theory must be modified and adjusted to the needs of students rather than the other way around (Schwab, 1971).

Greene

Greene (1978) speaks to the moral dimension that underlies all education. All worthwhile education is a moral pursuit. All teachers should be the pursuers. She calls this moral search “wide-awakeness” (p. 151). She states:

I believe this can only be done [wide-awakeness] if teachers can identify themselves as moral beings, concerned with defining their own life purposes in a way that arouses others to do the same. I believe, you see, that the young are most likely to be stirred to learn when they are challenged by teachers who themselves are learning, who are breaking with what they have too easily taken for granted, who are creating their own part in the process of liberating and arousing, in helping people pose questions with regard to what is oppressive, mindless, and wrong. (p. 151)

The moral dimension of any kind of teaching and learning, mathematics or otherwise, needs to always be present, and this presence is enhanced by teachers taking the lead on their learning. "Whatever efforts can be made to enable teachers-to-be to speak
for themselves and confront the concreteness of their lives ought to play into the critique that challenges mystification" (1978, p. 70). Thus, teaching becomes a vocation of the heart. The larger issues of equity and fairness have to be addressed through the rigour of intellectual scrutiny, and social advocacy. Although she did not use the term, her writing convinces that education is a matter of social justice.

**Summary**

Doyle (1997) captures the essence of teacher empowerment embodied by the foregoing thinkers. He states that modern views of teaching often tend "to squeeze the life out of teaching and to silence the voices of those who know most about teaching phenomena, namely teachers themselves" (Doyle, 1997, p. 94). Teachers need to be both theory builders as well as theory users (Cochran-Smith & Lytle, 1993). Keeping teachers at the heart of the educational process, especially one that is focused on mathematics is a challenge. Those of us who have worked with elementary teachers for many years have to withstand the urge to jump ahead, to dictate change, or to sabotage teachers' sense of self-efficacy. Schwab, Dewey, and Greene speak out of the historical past to remind us that political or social change will come and go, but at its core, the education system rises or falls on the backs or hearts and minds of its teachers.

**Why Mathematical Literacy**

Of important consideration to this thesis is a discussion of “why we need to be numerate” in our modern era of calculators and high-speed computers. Despite the call for significant improvements in international and provincial educational reform in the past few years, the dialogue skews in favour of literacy advocates. Mathematics has become a distant second to its favoured sibling, literacy, in the amount of funding and attention it
receives (Literacy and Numeracy Secretariat, 2008). There appears to be an imbalance in the intensity of the focus on literacy as compared to numeracy.

The importance of mathematical literacy has grown exponentially in the past century. The level of mathematical understanding required to read the newspaper, make thoughtful democratic decisions, and cope with everyday life is far greater than any time in the past (Paulos, 1989). Jon Paulos shares in his book Innumeracy the many areas in which the public is duped by their own mathematical misconceptions. In one anecdote, he recalls that often despite conflicting math facts on different pages of the New York Times, no one writes in to complain about the inaccuracy of the reports. These inaccurate reports influence important policies on the environment, poverty, and international conflicts. However, literacy type errors such as spelling or grammar mistakes conjure up thousands of letters of rebuke.

We now live in a culture saturated with mathematical decisions that need resolving about the economy, the environment, public policy, and advanced technology. In a democracy, it is crucial that citizens are able to cope with a level of mathematics needed to make thoughtful decisions at the personal, public, and national level. The National Research Council's Report (2001) states: "Citizens who cannot reason mathematically are cut off from whole realms of human endeavor. Innumeracy deprives them not only of opportunity but also of competence in everyday tasks" (Kilpatrick et al., 2001, p. 1). Gutstein (2006) argues even further that students need to be mathematically literate to address issues of social, economic, and political inequities.

Recent provincial and international reform initiatives have sought a more challenging curriculum allowing for more complex thinking and reasoning strategies in
mathematics at all levels of the school system (National Council of Teachers of Mathematics, 2000; Ontario Ministry of Education, 2003, 2004, 2005). As far back as 1996, The Ontario Royal Commission on Learning called for “a clearer focus on understanding, rather than memorization... and more value placed on reasoning” (p. 138).

Publicly funded education is judged by the level of mathematical achievement of its students. There has been recent increased political pressure on student achievement and much of the dialogue that surrounds this pressure is driven by the fear of the economic juggernaut of China and India. The competition is not only economic. Both countries have a focus on education and their sheer numbers (25% of population of China with the highest IQ is greater than the number of all North American students) are expected to have an impact on technological and economic world leadership in the near future (Fisch, 2008). Their high mathematical literacy rates are often touted as the tipping point that will leverage their economic expansion at the expense of our own. Whether one is susceptible or not to the fear mongering that often visits this theory, it does speak to the very real need for our students to become better at mathematics so they can compete on a level international playing field.

In the last twenty years, we have moved forward in our understanding of equity issues. An important equity issue is the access to equal learning opportunities. Both in the social and educational realm, the adoption of elitist views that proscribed mathematical literacy as the purview of a select few with unique intellectual powers are being questioned. It used to be a common belief that only some people could excel at mathematics. Often, people still often find no shame in laughingly sharing that “they
were never any good at math,” while at the same time, few people would consider being illiterate a joke worthy of public proclamation.

In the past, many students just accepted that they could not pass their high school or junior university mathematics classes and simply acceded to their teachers' or professors' suggestion that they give up. There is now plentiful research on some of the root causes of student failure in becoming mathematically literate, such as an over-reliance on memorization, instead of conceptual understanding; a cultural acceptance of genetic predestination, rather than hard work as the predictor of mathematical success; and the embrace of shallow, unsustained reforms in teacher education improvement that never make it to the classroom (National Research Council, 2001).

The opportunity for high levels of numeracy should be available to all. There is evidence that becoming numerate is attached to socio-economic status with high status in one related to high achievement in the other. A study by Wright (1994) described the three-year difference in children's early number knowledge, indicating that some four-year-olds enter school with a level that others will not attain until they reach seven years old. Children who are low-attaining in the early years continue as such through the grades with the gap widening so that by grade eight there is a seven year gap between the highest and lowest achieving students (Cockcroft, 1982; Steen, 1990). The evidence is that this lag influences negative attitudes toward mathematics, which continue throughout the child's education.

Overcoming this socio-economic gap involves catching children young and ensuring early intervention for those who are struggling. Evidence from brain-based learning theories (Jensen, 1998; McCain, Mustard, & Shanker, 2007) suggests that a
strong conceptual understanding of numeracy by the age of seven is a strong indicator of future success in mathematics and that a lack of early remediation in this area is very difficult to compensate for later on. The learning curves of those “who get it” and those “who don’t” at an early age is exponentially impacted by the time they reach the higher grades. This leaves primary teachers with the imperative to learn all they can about how children learn and how to support that learning. Every child deserves the opportunity to become capable and competent mathematicians at the highest level of their ability.

**Pioneers of Mathematics Teaching and Learning**

Mathematical teaching and learning is the focus of the professional learning community in this study. The teachers had been recipients of recent training in mathematics framed in a constructivist approach to learning. Constructivism is a belief that the individual through his or her actions and experiences constructs all knowledge (Confrey, 1992). Deep and thoughtful consideration of the issues that surround teachers’ teaching and learning of mathematics requires an understanding of the work of the theoretical pioneers who cut the path to our current understanding of constructivism.

Although the underpinning of the training was a belief in the value of constructivism, just as other large-scale initiatives have also found, constructivism endorsed in training is not necessarily constructivism enacted in the classroom (Wilson, 2003). Of particular importance to the data analysis section of this thesis is consideration of how teachers respond to constructivist ideas of teaching and learning.

The next section of this literature review will look at constructivism and some of the theorists who influence our understanding of constructivism, namely, Piaget (1955), Vygotsky (1978), von Glasersfeld (1995), Skemp (1987), and Fosnot and Dolk (2001).
Piaget's (1955) cognitive-development focus was a major contributor to this concept (Smith, 2001). He proposed that children construct their understanding using what they already know through an ecological law of learning in which children learn by recreating mathematical concepts through assimilation and accommodation, the primary vehicle for which is investigation (Smith, 2001). Learning comes from a state of cognitive dissonance, which propels children's learning forward as they seek new knowledge to fill the gap in understanding and cure the dissonance. When a child measures the length of his body with mini-cubes and he is 100 cubes long, and then later is measured by someone using the maxi-cubes and he is 50 cubes long, he will probably be in a state of dissonance. The child knows he did not shrink in size so something else is creating this gap between the high and low numbers. From this dissonance, the child might identify that measurement numbers only matter when the size of the measure is known, meaning 100 mini-cubes is the same as 50 maxi-cubes.

Of particular importance was Piaget's contribution to the movement away from an unrealistic belief in teaching by telling and rote learning that had tended to dominate educational practice. In Conversations with Jean Piaget, he stated,

Education, for most people, means trying to lead the child to resemble the typical adult of his society... but for me and no one else, education means making creators...You have to make inventors, innovators—not conformists. (Bringuier, 1980, p. 132).

Some criticism levied at his work included the limitations he imposed by using his own children in the research (Smith, 2001). He also promulgated an almost evangelical belief in the developmental levels of children's understanding of mathematics. Although immensely valuable, others criticized his work, especially Lev Vygotsky, because it
marginalized large swathes of the population, in particular those of non-European or non-middle-class backgrounds (Smith, 2001). Vygotsky pointed out that different cultures stress different social interactions. He also challenged Piaget's theory that learning development followed a trajectory that had to develop in succession (Smith, 2001). Piaget was the leader in a movement that embraced mathematics as a doing, talking, investigating endeavour, and his work was the impetus for much more research in the field of how children learn mathematics.

**Vygotsky**

Vygotsky's (1978) contextualist view expands on Piaget's work. His theory of the social construction of knowledge work deviates from, but also complements, the Piagetian viewpoint. He believed knowledge was not just "in the head" (Sophian, 1999, p. 13), but was also influenced by social experiences and instructional activities. He believed that learning mathematics is about connecting personal knowledge of concepts with the social knowledge of the wider community (Daniels, Wertsch, & Cole, 2007). In Vygotsky's view of learning, the activities that teachers introduce have significant influence on students' learning. He viewed children's thinking and problem solving as directly linked to the instructional activities in which they participate.

Vygotsky (1986) also introduced the concept of a “zone of proximal development” in which the mathematics is not too easy and not too hard, but just uncomfortable enough to propel students into a new conceptual range (Daniels et al., 2007). The teacher's job in facilitating learning is to pose problems in that zone and provide assistance by scaffolding through probing, questioning and modelling (Vygotsky, 1986). As the learning is scaffolded, students make more connections to prior learning and new ideas become better
understood. He stated, "Therefore the only good kind of instruction is that which marches ahead of development and leads it" and “Intelligent, conscious imitation comes instantly in the form of insight, not requiring repetition" (Vygotsky, 1986, p. 188).

Insight in a primary child is demonstrated by the measurement scenario in the previous section. The child overcomes their cognitive dissonance in an “ah ha” moment. At some point, the child's innate reasoning needs to make sense of the discrepancy in measurements and the conclusion that the attribute of the measure itself alters the number that is attached to the measure but does not alter the overall size. Such understanding will usually eventually be understood by all children. However, the teacher who provides the stimulus, namely two different sets of blocks to measure with and then uses probing questions to have the child think about the discrepancy in the two numbers, scaffolds the understanding ensuring its achievement. In contrast, a true Piagetian might have disagreed that the child was in the correct developmental level for such insight.

**von Glasersfeld**

von Glasersfeld (1995) added to the Piagetian view that all people, all of the time, construct meanings through actions with objects and ideas and from this interaction they develop a schema from which all new learning is viewed (von Glasersfeld, 1995). He believed that the perception is personal and unique to each person and needs to be recognized in the learning/teaching process. Teachers and students, even while focused on the same curriculum and activities, are dependent on their experiences. This creates a schema through which all learning, including learning about teaching, assimilates. There is always a tension and gap between what the teacher thinks they are teaching and what the learner is learning. Knowledge is in the mind of the learner, not out there in the
textbook or curriculum. He stated, "This changed assessment of cognitive activity entails an irrevocable break with the generally accepted epistemological tradition of Western civilization, according to which the knower must strive to attain a picture of the real world" (von Glasersfeld, 1995, pg. 3). Instead, the teacher's role is to try to help the learner make sense of their schema in an active process of expansion of thinking, rather than the accumulation of facts. He stated:

Understanding can therefore never be demonstrated by the presentation of results that may have been acquired by rote learning …. mathematics teachers often insist (to the immense boredom of the students) on the exact documentation of the algorithm by means of which the result was obtained. The flaw in this procedure is that any documentation of an algorithm is again a sequence of symbols which in themselves do not demonstrate the speaker’s or writer’s understanding of the symbolized operations. (von Glasersfeld, 2008, p. 1)

An important concept in this theory is the recognition by teachers that students perceive the curriculum, textbooks, and the instruction in very different ways than might have been intended. The role of teachers is to improve communication and focus on understanding, rather than overemphasis on procedural knowledge. In the primary grades, a child already has a schema for how new knowledge is perceived. This is often reflected by fitting a schema from one concept on top of another incompatible concept.

Children learn about numbers and about counting. They know they can count many things, no matter what the size, and the total means there are x number of things. In measurement, the counted items used to measure something all need to be the same size in order to have meaning. So a child who uses a combination of different sized blocks to measure the length of something and then says it is 7 blocks long is incorrect in a measurement activity but correct for a counting activity that requires knowing the number of things. The counting schema, which was very useful in one context, does not work in
another.

**Skemp**

In the past, mathematics teaching has often adhered to an instrumental, mechanistic approach to learning, and in the case of those who are already mathematically astute, such learning, arguably, might suffice. But Skemp (1987) theorized that most learners learn best when they can find meaningful relationships between ideas and concepts. He introduced the concept of relational versus instrumental understanding of mathematics. These two terms are also sometimes referred to as conceptual versus procedural knowledge (National Research Council, 2001). Skemp's (1987) theory was that mathematical knowledge is based on relationships between mathematical concepts and ideas, but often the mathematics learner receives only instruction in the instrumental components of mathematics (such as memorization of an algorithm). Instead of building a foundation through a conceptual understanding of mathematics as students move through the elementary system, such teaching techniques tend to promulgate the belief that mathematics is mysterious and unknowable. Students provided with instruction that allows them to find relationships in their mathematical learning have a distinct advantage over those who do not.

In the primary years, children are often prompted to learn their basic facts by memorization and practice. But children who are provided with the opportunity to look at a variety of relationships between numbers are able to develop a relational sense of number facts. For instance, knowing how numbers decompose into smaller numbers, such as that ten can be decomposed into 1 and 9, 2 and 8, 3 and 7, 4 and 6, 5 and 5, builds up a relational sense. When a child is confronted with a fact they don't know such as 7 +
8, they can use their knowledge of decomposition to decompose the 8 into smaller, easier to work with numbers. 7 + 8 becomes an easier to calculate expression of 7 + 3 + 5 (7 + 3 makes ten and the additional 5 makes 15). This understanding of how a number can be decomposed is not just useful in this one instance. It also extends throughout the number system so that 27 + 8 can be viewed in the same way by thinking of it as 27 + 3 makes 30 plus 5 more makes 35.

Fosnot

Fosnot (Fosnot & Dolk, 2001) has done research since the late eighties, in the United States and earlier with the Freudenthal Institute in the Netherlands, expanding the theory of constructivism. In her work with Dolk (Fosnot & Dolk, 2001), she has been investigating what she calls children's "mathematizing" (p. xix). The child that comes to an understanding of the concept of unitizing, or making tens and representing it by a single digit to the left of the one’s place, has made a giant conceptual leap similar to the leap mathematicians made with the same concept centuries ago (Fosnot & Dolk, 2001). This understanding then becomes integrated within an expanding network of interconnected concepts and skills. Together these can be effectively scaffolded by teachers who understand the "landscape of the strategies, big ideas, and models children construct of the landmarks they pass as they journey towards numeracy" (2001, p. xix).

As humans act on and attempt to interpret their surroundings (assimilation), they construct new representations and models of reality (accommodation) with culturally developed tools and symbols. Then they further negotiate such meaning through cooperative social activity, discourse, and debate in communities of practice. Her particular contribution to the field has been her emphasis on the use of models that
children construct (Fosnot & Dolk, 2001). The construction of the models is scaffolded by the teacher through tasks that encourage higher-level thinking, often with the use of pictures that are chosen specifically because they might cause cognitive dissonance. For instance, a picture of a tiled kitchen floor that is 8 tiles by 6 tiles might have the central area of the floor covered by a table. Children who like to count each of the tiles to find the answer are not able to do so in this case. They need to find other ways to determine the answer, one of which would be recognizing that each row has to have the same number in it and counting each row as eight then adding all the eights together for the total (Fosnot & Dolk, 2001). It is a task that encourages grouping numbers rather than counting all. It is a task that children can struggle with, and then when they get the “ah ha” moment, the learning is forever theirs.

**Summary**

Substantial to any understanding of contemporary thinking about constructivism is an understanding of the influence of these thinkers. Their writings share a common faith in two principles: 1) the importance of students’ construction of their own understanding of mathematics; and 2) the importance of conceptual understanding as opposed to reliance on rote procedures. Piaget identified developmental levels of mathematics learning and considered them as absolute and static with no possibility of moving a child forward until they themselves evolved to the next level. Vygotsky added to the field by determining that the developmental levels were not immutable to change and that the teacher could add immense value to the learning through social interaction. Skemp reconfigured the field by identifying that both developmental levels and the intervention of teachers could be divided into realms of learning – relational or instrumental understanding. von
Glasersfeld radicalized the idea of constructing one’s understanding by adding the notion that there is no objective reality to any subject, including mathematics. This radicalization is softened somewhat by the work of Catherine Fosnot. She shows how even young children can come to complex understandings of concepts such as multiplication using their own devices when a savvy teacher is available to set-up thinking tasks and then be able to scaffold the learning as the students move through stages of understanding.

Each one of these theorists has reconfigured the field, and any renewal in how mathematics is taught and learned is dependent on an understanding of their contributions to the field. Although constructivism is not a theory of teaching, it suggests taking a significantly different approach to instruction from that which was historically used in most schools.

Teachers who base their practice on constructivism reject the notion that meaning can be passed on to learners via symbols and transmission, that learners can incorporate exact copies of teachers’ understanding for their own use, that whole concepts can be broken into discrete sub-skills, and that concepts can be taught out of context. In contrast, a constructivist view of learning suggests a developmentally appropriate, student-centered, active workshop approach to teaching that gives learners the opportunity for concrete, contextually meaningful experience through which they can search for patterns; raise questions; and model, interpret, and defend their strategies and ideas. The classroom in this model is a mini-society, a community of learners engaged in activity, discourse, interpretation, justification, and reflection (Fosnot & Dolk, 2001).

In developing the framework for the professional learning community, I had to think about the role of constructivism. The training that the participants had received through
the Ontario Ministry of Education initiative, described earlier, emphasized constructivism as the foundation for mathematics learning. I know this because I developed the training package and did the training at the first level, which involved the 60 provincial trainers (most of whom were consultants in their boards) who subsequently went out to the districts to do the training at the next level. But as stated earlier, the training was only for three days which, is a short time to try to shift paradigms. Even at the provincial level of training, there were sharp deviations in beliefs about mathematical learning. The idea of allowing students to develop their own personal algorithms for such concepts as multiplication was treated as revolutionary by the majority of the provincial participants.

The training itself could be called anti-constructivist since it did not allow teachers to construct new knowledge for themselves, it did not take into account their own particular schemas, and it did not allow enough time for social collaboration.

**Children’s Learning of Mathematics**

The central message of the research on children’s learning is that it flourishes through “doing, talking, reflecting, discussing, observing, investigating, listening, and reasoning” (Copley, 2000, p. 29). Constructivism provides a foundation for thinking about children's learning of mathematics. The major components of constructivist instruction are meaning making through understanding, active and engaged interactions with other students and the teacher within a culture of mutual support and respect. The research evidence is clear that given effective instruction, many more students than at present, or ever in the past, can learn complex mathematics (Ball, 1991; Fosnot & Dolk, 2001; Fuson, 2003; Griffin, Case, & Siegler, 1994; Hiebert et al. 2003; Kilpatrick, 2001; Ma, 1999;). As stated in the 2001 National Research Council report, “Mathematics is a
realm no longer restricted to a select few” (p. 1). All students need to learn to think mathematically and “they must think mathematically to learn” (National Research Council, 2001, p. 1).

Constructivism is a component of what is often referred to as reform mathematics. Reform mathematics places value on students’ deep understanding of mathematics through active meaning making, discourse, and reflection within a community of learners. The movement has generated substantial evidence in its support and has widespread acceptance and calls for implementation (Ontario Ministry of Education, 2003, NCTM, 2000).

The following section will outline some of the research findings on attributes of the reform agenda, which are important to improving student learning of mathematics. This connects to the later chapters in which the analysis of the data reflects the interest of the teachers’ in this study to reform their practice and growth in the understanding of students' learning. The teachers in this study revised some of their thinking on mathematics teaching and learning based on the books and articles that they read on their own and in their groups. These revisions were influenced by constructivism as described above, but also other factors to consider when contemplating mathematical success in young children.

The first section of this chapter refers to the “Strands of Mathematical Proficiency” outlined by the National Research Council in 2001. The second section looks at “Mathematical Influences”, which are applicable to all learners in some ways but are specifically applicable to young learners.
Strands of Mathematical Proficiency

In 2001, the National Research Council redefined mathematical proficiency to take into account more current research in cognitive psychology and mathematics education. In their report, they list five interdependent strands:

![Diagram of Strands of Mathematical Proficiency]

Figure 4: Strands of Mathematical Proficiency (National Research Council, 2001)

Conceptual Understanding

Students learn best that which they understand and can connect to other learning ((Baroody, 1998; Carpenter & Fenema, 1999; Hiebert and Carpenter, 1992; Piaget, 1972; Wright, Martland, Stafford & Stanger, 2002). Conceptual understanding occurs when students recognize the relationships within and between numbers and can actively construct a representation of the concepts.

To understand number relationships, students need the opportunity to do the mathematics of their mathematical predecessors who first noticed that ten fingers made a useful tool for basing our number system (Fosnot & Dolk, 2001). The purpose of the “doing” of mathematics is to attain conceptual understanding of the mathematics extending beyond simple procedural fluency. According to Hiebert and Carpenter (1992), conceptual knowledge is knowledge that is understood as opposed to procedural...
knowledge, which is acquisition of the rules and symbols of mathematics.

Such functional understanding arises out of the student's own construction of knowledge aided by good instruction, but not induced by it. As Schifter and Fosnot (1993) state:

If the creation of the conceptual networks that constitute each individual’s map of reality – including her mathematical understanding – is the product of constructive and interpretive activity, then it follows that no matter how lucidly and patiently teachers explain to their students, they cannot understand for their students. (Schifter & Fosnot 1993, p. 9)

Many adults may be able to do division of fractions, if they remember the rules for the algorithm, but very few, including teachers, are able to explain ‘invert and multiply’ works or what to do if you happen to forget the rule (Ma, 1999). Being able to explain it in their own words would constitute conceptual understanding.

**Procedural Fluency**

Procedural fluency has unquestionably received the most attention throughout the history of mathematics education (National Research Council, 2001). It involves skill in accurately, flexibly and efficiently using algorithms to solve problems. Algorithms understood conceptually avoid rote procedural processes that rely on extensive practice and memorization. Conceptual and procedural learning need to reside side by side, “Students need to see that procedures can be developed that will solve entire classes of problems, not just individual problems. By studying algorithms as ‘general procedures’, students can gain insight into the fact that mathematics is well-structured (highly organized, filled with patterns, predictable), and that a carefully developed procedure can be a powerful tool for completing routine tasks” (National Research Council, 2001, p. 121). An example of procedural fluency without conceptual understanding is cited in the
National Research Council Report (2001), "although 90% of U.S. 13-year olds could add and subtract multidigit numbers, only 60% of them could construct a number given its digits and their place values (e.g., in the number 57, the digit 5 should represent five tens" (p. 136). The students knew the procedure, but did not have a conceptual understanding of number or, the operations on numbers.

**Strategic Competence**

Strategic competence is similar to what is generally called problem solving. It requires being able to generate mathematical representations (physical or mental) to help solve problems. The representations help students to see connections within and between problem situations. There is a reciprocal relationship between conceptual understanding and strategic competence. Before an idea can be represented, there needs to be some understanding, but sometimes the representation itself can bring a student to a higher level of understanding.

Students with strategic competence have a range of strategies that they can use when solving a novel problem. They may draw a picture, verbalize aloud, or use manipulatives. As students begin to carry out operations on numbers, their strategies may at first be inefficient and cumbersome, but accurate and embedded in an understanding of the problem. As students become more mathematically mature, their strategies become more effective in both speed and accuracy. For instance, counting all the counters to determine the sum of five counters and six counters is time consuming and prone to mistakes. Whereas, counting on from the six counters for five more counts is less likely to create mistakes and is faster to compute. Being able to calculate the sum by using a known fact such as $5 + 5 = 10$ so $5 + 6$ is one more than ten, therefore, it is 11, is even
more efficient and reflects a student’s growth in strategic competence.

**Adaptive Reasoning**

Reasoning is central to children's ability to mathematize their experiences (Fosnot & Dolk, 2001). In the National Research Council Report (2001), reference is made to adaptive reasoning as one of the strands of mathematical proficiency. They describe adaptive reasoning as the ability to make connections across mathematical ideas and to be able to justify their answers. “In mathematics, adaptive reasoning is the glue that holds everything together, the lodestar that guides learning” (National Research Council, 2001, p. 129). Teachers who use problem solving as the centrepiece of their instruction help children develop and extend their problem-solving skills (Baroody, 1998; Clements, Sarama & DiBiase, 2004; Carpenter & Fennema, 1999; Fuson; 2003; Gelman & Gallistel 1978; Kamii 1985). Sometimes children's natural problem-solving and reasoning skills are circumvented by dogmatic adherence to formulaic ways of doing mathematics without a foundation of conceptual understanding. In children’s everyday experiences, they are intuitively solving problems. The difficulty they have is attaching the mathematical formulas of school mathematics to their own reasoning strategies. For instance, children may quite successfully be able to share twenty-four cookies and treats among twelve friends, an experience that provides ample opportunity for learning about multiplication and division. Once the algorithm is introduced, if done so without focusing on linking concepts and procedures, the child may resort to over-reliance on the procedure at the expense of understanding.

Cobb (Yackel, 2001) conducted mathematical interviews with Grade 1 and 2 children. He asked them, “Do you have a way to figure out how much 16 + 9 is?” The
children tried various methods, including counting, with almost all of them finding the answer of 25. But when the same problem was given from within a typical page from a school text with a vertical format as in the standard North American addition algorithm with carrying, they were not as successful. This time many of them attempted to use the standard “carrying” school algorithm. Some who had originally given correct answers now had errors. The errors they made ranged illogically from 15 to 115. When Cobb discussed the answer of 15 with one child and asked her whether her original answer of 25 as well as her latter answer of 15 could both be right, she said that, if you were counting cookies 25 would be right, but in school 15 would be the right answer (Lawson, 2002).

**Productive Disposition**

Attitude towards mathematics is of paramount importance. Students who are most successful in mathematics:

…think of themselves as capable of engaging in independent thinking and of exercising control over their learning process… The term disposition should not be taken to imply a biological or inherited trait. As used here, it is more akin to a habit of thought, one that can be learned and, therefore, taught. (Resnick, 1987, p. 41)

Students who are most successful in mathematics are most likely to see themselves as mathematically capable and mathematics as sense-making (National Research Council, 2001). However, sustaining positive attitudes has its challenges. Attitudes toward mathematics tend to decline as children go through the school system. “Their view of mathematics shifts gradually from enthusiasm to apprehension, from confidence to fear” (National Research Council, 1989, p. 44). The eagerness to learn mathematics as children enter school diminishes as children are rushed to deal with complex concepts without a strong conceptual base (National Research Council, 2001). “One important factor in attaining a productive disposition toward mathematics and maintaining the motivation
required to learn it is the extent to which children perceive achievement as the product of effort as opposed to fixed ability” (Kilpatrick, 2001, p. 171). It is important to encourage the belief that everyone can do mathematics (Baroody, 1998). The five strands of mathematical proficiency are interrelated. No one strand can stand alone as the precursor to proficiency (National Research Council, 2001).

Given traditional curricula and methods of instruction, students develop proficiency among the five strands in a very uneven way. They are most proficient in aspects of procedural fluency and less proficient in conceptual understanding, strategic competence, adaptive reasoning, and productive disposition. “Many students show few connections among these strands” (National Research Council, 2001, p. 136).

**Mathematical Influences**

The second section looks at Mathematical Influences, as shown below:

![Figure 5: Mathematical Influences](image-url)
These are applicable to all learners in some ways, but are specifically applicable to young learners.

**Developmental Sensitivity**

Piaget’s strictly developmental premise that children cannot think logically about the characteristics of number until the concrete operational stage from about 7 to 11 years is no longer widely supported. But there is some consensus (at least at the earliest stages of mathematical learning) that learning is developmentally sensitive and instruction needs to be responsive to the needs of the student at that stage of development (Clements et al. 2004; Gelman & Gallistel, 1978; Griffin, Case & Siegler, 1994; Copley, 1999; Clarke & Clarke 2002).

Ginsburg et al. (1999) cite research that indicates that the order of general developmental concepts is consistent across cultures and social status. Performance at any particular age is usually lower in groups with lower status, but the course that the developmental trajectory takes remains consistent. Students generally enter school with some innate understanding of quantity and often some counting skill. There is a consistent progression of numeracy acquisition. Children recognize “more than” and “less than” when there is a large discrepancy in the numbers (e.g., a child recognizes that many candies are more than one or two and given a choice will pick many rather than the one or two). They can also instantly recognize and name small quantities (i.e., subitizing).

Once students know how to count and how to directly model quantities (e.g., two counters for the quantity of two, three counters for a quantity of three, etc.) they can operate on the numbers, combining counters and then counting all the counters in the total. There is a developmental leap that occurs when children recognize that the last
number counted actually pertains to the total quantity (cardinality).

Gradually students recognize the efficiency of counting-on from one, number rather than counting all the counters in an addition problem. This is a rather sophisticated stage of development and some researchers (Fuson, 2004; Steffe, 2004) argue that it cannot be taught, but has to come from the interior knowledge building of the child. With experience, students move to using other strategies such as derived facts (e.g., if 4 + 5 = 9 then 4 + 6 = 10). Although not a strictly linear process, there is progress from least abstract concepts to most abstract concepts that follows a regular pathway (Baroody, 2004; Clements et al., 2004; Fuson, 2004; Van de Walle, 2001).

Developmentally sensitive means that the differentiated needs of students are identified and met through reasonably challenging but attainable tasks (Clements et al. 2004). It does not mean that children should be constrained by a label of one phase of development or another, which could limit a child's opportunities. As Clements et al. (2004) has stated, it is the opportunity to learn that is more important than defining a specific developmental level of a child's learning. However, at the same time there needs to be a recognition that developmental levels matter. A child who manifests attributes of Piaget's pre-operational stage, such as difficulty with conservation of number, may not be ready for the hurdle of addition and subtraction.

**Learning through talk**

Children also learn mathematics by talking. Mathematics is a type of language that relies on symbols and representations. Children who learn the language benefit in their ability to understand the mathematics. They need to talk mathematics, both with the teacher and with their classmates. Research indicates that the order of general
developmental concepts is consistent across cultures and social status (Ginsburg et al., 1999). By talking to others about their mathematical understandings, children are compelled to explain their reasoning and revisit their strategies. Children, who work together to solve problems, learn from one another as they demonstrate and communicate their mathematical understanding.

Primary children are dependent on their understanding of language in their early development. The language of our number system actually makes children's understanding of number and place value more difficult than it needs to be. There is a difference in the use of English words for numbers compared to numbers in other languages, particularly Asian languages. The language of mathematics has an effect on children's early understanding of the concepts in numbers.

The link between the spoken word and the value of a number is much more evident in the Asian numeration system than in the English one (Table 1). Each power of ten in the Asian numeration system is explicitly indicated by the name of the numeral (Fuson & Kwon, 1992). The word for two-digit numbers in the Asian languages is the equivalent of saying “one ten and one one” for eleven; one ten and two ones for 12. A sample of the first twelve numbers is:

Table 1: Arabic, English and Korean Numbers

<table>
<thead>
<tr>
<th>Arabic</th>
<th>English</th>
<th>Korean</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>One</td>
<td>Eel</td>
</tr>
<tr>
<td>2</td>
<td>Two</td>
<td>Ee</td>
</tr>
<tr>
<td>3</td>
<td>Three</td>
<td>Sahm</td>
</tr>
<tr>
<td>4</td>
<td>Four</td>
<td>Sah</td>
</tr>
<tr>
<td>5</td>
<td>Five</td>
<td>Oh</td>
</tr>
<tr>
<td>6</td>
<td>Six</td>
<td>Yook</td>
</tr>
<tr>
<td>7</td>
<td>Seven</td>
<td>Chil</td>
</tr>
<tr>
<td>8</td>
<td>Eight</td>
<td>Pal</td>
</tr>
<tr>
<td>9</td>
<td>Nine</td>
<td>Goo</td>
</tr>
<tr>
<td>10</td>
<td>Ten</td>
<td>Sip</td>
</tr>
<tr>
<td>11</td>
<td>Eleven</td>
<td>Sipeel</td>
</tr>
<tr>
<td>12</td>
<td>Twelve</td>
<td>Sip-ee</td>
</tr>
</tbody>
</table>
The names of the numerals dispel any confusion children have about the place values represented by digits to the left or right of a given number. Asian children demonstrated understanding of the base ten structure of two and three digit written numbers earlier than American first graders and before being introduced to tens and ones in school. When asked to represent two-digit numbers using base-ten blocks, Chinese, Japanese, and Korean children were more likely than children in France, Sweden, and the United States to create representations using such things as base ten blocks (Guberman, 1999, p. 33).

**Use of Representations**

Concepts in mathematics are often hard to explain and hard to think about for young children, but difficult concepts can often be seen through representations, either concrete or pictorial. Representations provide children with a concrete model of their thinking (Fosnot & Dolk, 2001). Van de Walle (2001) says:

Models can be thought of as thinker toys, tester toys, and talker toys. It is difficult for students (of all ages) to talk about and test out abstract relationships using words alone. Models give learners something to think about, explore with, talk about and reason with… Although on its surface school mathematics may seem to be about facts and procedures, much of the real intellectual work in mathematics concerns the interpretation and use of representations of mathematical ideas. (p. 34)

Being able to build representations of their thinking makes it easier for young children to also talk about their understanding. In the act of working with concrete materials and watching others working with concrete materials, children can come to a common understanding of abstract concepts.

**Active Engagement**

Children who are allowed to use their preferred learning styles to access difficult concepts (pictures, concrete representations, music, movement) appreciate mathematics
more in their lives (Baroody, 1998). The importance of doing mathematics rather than passively mimicking procedures put forward by the teacher is also essential to good learning. "Children learn mathematics primarily through…doing, talking, reflecting, discussing, observing, investigating, listening and reasoning” (Copley, 2000, p. 29).

Children's learning also depends on their attention and engagement in the learning process. Teachers need to:

- Be the architects of the classroom environment ensuring that children’s curiosity is provoked and their pursuit of learning is well supported. They must investigate with the children and monitor their performances. And they must set the example for oral communication and for the investigation process. (Greenes, 1999, p. 47)

**Real-world situations**

Clements et al. (2004) recommend that mathematical experiences for young children should be integrated as much as possible within their daily activities and interests. This does not mean random and unplanned lessons. However, he found that everyday activities such as play, building, and stories could be used to support and enhance conceptual understanding of important mathematical concepts. It is up to the perceptive teacher to ensure the staging of such activities. The environment needs to be designed so that “young children bump into interesting mathematics at every turn” (Carole Greenes, 1999, p. 46).

Clements et al. (2004) further state that:

- Teachers need to consistently integrate real-world situations problem solving and mathematical content, and that this integration is more than a pedagogical nicety; it is necessary to achieve both sense making and the development of skills such as computational fluency. It supports transfer to future learning and out-of-school contexts. (p. 59)

Mathematics is an interwoven web of connections among concepts and topics and programs from preschool to Grade 2 need to help students see the connections between
the real-world, problem-solving and mathematical concepts.

**Problem solving**

The Ontario Curriculum: Mathematics (2005) states that “students learn mathematics most effectively when they are given opportunities to investigate ideas and concepts through problem solving” (Ontario Ministry of Education, 2005, p. 4). It also says that problem solving should be the central focus of all mathematics learning.

By learning to solve problems and by learning through problem solving, students are given numerous opportunities to connect mathematical ideas and to develop conceptual understanding. Problem solving forms the basis of effective mathematics programs and should be the mainstay of mathematical instruction (Ontario Ministry of Education, 2005, p. 11).

The National Council of Teachers of Mathematics (1989, 2000) has long called for an enhanced emphasis on problem solving as the central focus of the mathematics curriculum. It needs to be the primary goal of all mathematics instruction and an integral part of all mathematical activity. “Problem solving is not a distinct topic but a process that should permeate the entire program and provide the context in which concepts and skills can be learned” (NCTM, 1998, p. 23).

**Summary**

We now have a robust understanding of the factors that enhance student learning in mathematics, but there is often inadequate knowledge of how to embed these factors into everyday teaching and learning. Often, success in mathematics is built on a wobbly foundation of short-term memorization at the expense of meaning. Gardner (1991) contends that, even those students who “exhibit the overt signs of success” typically do
not display an adequate understanding of the concepts crucial to the discipline within which they have been working (p. 3). Katz (1985) and Gardner (1991) describe this discrepancy between perceived and actual success as the difference between learning and performance. They stress that emphasis on performance to the detriment of an emphasis on true understanding, usually results in little internalization of concepts over time. When asked several weeks or months later to apply what they had supposedly learned, most students cannot do it. The ramifications of this pseudo-learning are far-reaching for students; they miss out on the genuine learning, which generates long-term understanding.

There is now significant research on the best practices for enabling more students to become more competent and confident in mathematics. It becomes an equity issue for students if we allow the gap between those with mathematical acumen and those without to grow wider when we have so much knowledge at our fingertips. But it also becomes an equity issue for educators if we continue to also allow the gap between the teachers who are given the opportunity to indulge in mathematics knowledge building, and those who are not, to also widen.

Theories of mathematical learning for students are also applicable to the teaching of teachers. Teachers also need to have the time and opportunity to construct their own learning over sustained periods of time within a community of learners. They also need to do mathematics and to engage in social interaction around mathematical concepts. Providing teachers with opportunities for knowledge building and understanding, both pedagogical and content based, are the keys to opening the doors for student knowledge.

We have known for at least forty years that a focus on meaning is crucial to students' long-term success in mathematics (Brownell, 1947). For the last twenty years,
there has also been large scale consensus about other attributes of a successful
mathematical learning experience (NAEYC, 2002; NCTM, 1989; NCTM, 2000; NRC,
2000), such as social interactions with others, student talk, use of models and
representations, conceptual understanding, focus on reasoning and problem solving, and a
positive disposition towards mathematics. Even though such knowledge has had a
significant lifespan, its influence has had only recent prominence in educational reform
movements. In major research studies of large-scale initiatives to reform mathematics
there is evidence that enactment of these components in the classroom is often non-
existent or only superficially indicated (Kilpatrick, 2001; Wilson, 2003).

Elementary Teachers’ Mathematics Knowledge

The goal of improving the mathematical instruction of teachers has been
recommended by many recent policy recommendations and research reports, such as, the
Ontario Ministry of Education’s new mathematics curriculum from Kindergarten to Grade
12; recent initiatives in numeracy training; the expert panel reports of the Expert Panel on
Early Math in Ontario (2003), Teaching and Learning Mathematics (2004), Leading Math
documents consistently propose a newer and more rigorous level of instructional
strategies, particularly in problem solving, communication, reasoning, and conceptual
understanding. Some of these ideas are new for teachers and are often inconsistent with
their current teaching practices and personal understanding of mathematics.

The concern with teacher knowledge of mathematics is that, in many cases,
 elemental teachers, and particularly primary teachers, have very little prior academic
experience in mathematics in secondary or post-secondary courses (Fields Institute, 2005)
and few opportunities to expand their limited knowledge when they enter the education system as teachers. "Learning mathematics is threatening to most teachers, especially elementary teachers whose limited experiences with mathematics have often been anxiety-provoking and uninspiring" (Peterson & Barnes, 1996, p. 485).

**Pre-service at Faculties**

The opportunity to ameliorate this condition through pre-service professional development at faculties is also limited. Although many elementary teachers may have been exposed to reform methods of teaching mathematics in their pre-service training, the maximum amount of pre-service instruction in mathematics would have been 36 hours (Fields Institute, 2005).

This is not an adequate foundation for building substantial mathematical knowledge. Once in the classroom, the educational realities of diverse learners and accelerating responsibilities is not conducive to serious further investigation into the mathematical learning of children, at least not in the first year or so. Consequently, the initial instructional aspirations a new teacher may have had about ensuring his or her teaching was research and evidence based and has been slowly eroded by the realities of classroom life. The spark he or she may have acquired from pre-service training in mathematics learning becomes burned out by the reality that support in mathematics is often not available at the board level, and opportunities to dialogue over mathematical issues is further dampened by the overwhelming deluge of educational initiatives. In the face of such obstacles, teachers revert to the traditional images they see in their schools and remember from their own elementary education.

Ball, Lubienski and Mewborn (2001) confirm how difficult it is for new teachers to
conquer their reliance on the traditional models of teaching from their own school experience, "this specialized apprenticeship of observation which not only has instilled traditional images of teaching and learning but has also shaped their understanding of mathematics" (Ball et al., 2001, p. 437). Watson (1995) also found that "teachers are much more likely to teach as they have been taught throughout their schooling than as they have been taught in teacher-education programs" (p. 2).

**In-Service Support**

Lack of confidence and on site in-service support for teachers as they tackle the complex task of undertaking new curriculum and instructional expectations curtails reform predilections teachers might have carried to their teaching roles. Teachers in this predicament do what over-stressed learners often do. They revert to what they feel most comfortable doing, namely what they have had the most exposure to, and this, of course, is the teaching that they received themselves.

According to the TIMSS Video Study, mathematics teaching has changed little in North America since 1900 (Stigler & Hiebert, 1999). Typically, teachers divide a lesson into two parts. In the first part, the teacher demonstrates while students passively observe. In the second part, students work independently on seatwork that is generally finished as homework that night. Despite the recognition that such prior instruction may have been faulty and phobia instilling, the tendency to teach as one was taught is deeply engrained in our educational culture (Ma, 1999; Stigler & Hiebert, 1999; Wilson, 2003).

To add to this is dearth of professional development in mathematics provided to elementary teachers, Weiss, Banilower, McMahon, and Smith, (2001) found that 68% of teachers in Grades K-4 spent fewer than 16 hours in mathematics-related professional
development over the last three years despite a recognized need by both the teachers and administration. My own survey of ten boards from across Ontario indicated that even less hours have been provided in the past year and there is little anticipation that more will be provided next year.

**International Comparisons of Elementary Teachers of Mathematics**

The mathematical knowledge of North American elementary teachers is limited compared to high achieving countries such as the Netherlands, Japan and China (Ball 1990; Fosnot & Dolk, 2001; Ma, 1999; Stigler & Hiebert, 1999). This knowledge is particularly weak when it comes to understanding how the ideas or concepts of mathematics connect to procedures (Hill & Ball, 2004; Kilpatrick et al., 2001; Ma, 1999; Wilson, 2003). Ma (1999) did a study of teachers in the United States that compared to teachers in China. She found that the Chinese teachers had a better conceptual understanding of the mathematics they taught and had many strategies for helping students whose mathematical learning was weak. In the case of the North American teachers, she found little conceptual understanding in the teachers and even less in their teaching. The North American teachers also did not have a repertoire of strategies for helping students learn complex mathematics other than through repetition of instruction and much practice by students. She found that many of the teachers in China had a “profound understanding of fundamental mathematics” (Ma, 1999, p. 136). In their instruction, teachers promoted multiple approaches to solving a problem, were able to provide explanations for those approaches, present connections among mathematical concepts and procedures, and provide overall coherence from concept to concept.

In another international comparison study, eighth-grade mathematics lessons in
seven countries (Australia, Czech Republic, Hong Kong, Japan, the Netherlands, Switzerland, and the United States) were taped during regularly scheduled class periods over the course of a single school term (TIMSS Video Study, 1999). Stigler and Hiebert, (1999) and Hiebert et al., (2003) found that each had distinct patterns of teaching and understanding mathematics. The North American teachers did not have the same facility and flexibility in using numbers. They were tied to explicating specific features of algorithms in a step-by-step manner. They were not able, or simply did not open up, the mathematics instruction to high levels of reasoning through number sense and problem solving. Hiebert et al. (2003) argue that this culturally shared teaching practice explains why it is so hard for instructional practices to change.

Teachers do not change because they do not have a high level of flexibility in their understanding of number concepts and they repeat the same instructional methods they witnessed as students themselves. From kindergarten onward, through their pre-service induction, teachers are likely to have seen the same instructional practices many times. Along the way, they receive little opportunity to re-learn the mathematics so that they have Ma's “profound understanding” of mathematical concepts. These are difficult patterns to break in a similar way that parenting techniques are modeled on familiar experience, teaching techniques are culturally engrained and often impervious to policy-mandated changes despite billions of dollars spent on persuading teachers to do otherwise.

**Teachers’ Understanding of Mathematics**

A study by Adams (1998) also found that teachers of mathematics are often limited in their own understanding of mathematics. Even in the case where teachers had been introduced to such reform oriented practices as having their students make connections to
solve problems, Stein and Lane (1996) found that teachers often lost sight of the principle of “making connections” and instead converted it into a "using procedures" problem as they worked it through with the class. The teachers were not strong enough on the concepts themselves to allow for divergent thinking that took them too far away from the protective cover of procedural knowledge. Hiebert et al., (2003) also found that teachers typically broke “making connections” types of problems into procedures that they took their students through systematically.

In a large scale initiative in California in the 1990s (touted as the largest and most expensive mathematics initiative in the world), the premise was that extraordinary measures that included many layers of professional intervention in teaching would be influential in improving the instruction of teachers and the learning of students (Wilson, 2003). It followed a top-down professional development model that began with experts in the field developing the in-service, then proceeded to a train the trainer model that eventually ended at the level of the classroom (Wilson, 2003).

Real understanding of mathematics and mathematical learning did not permeate to the level of the classroom teacher. Teachers did not have Ma's profound understanding of mathematical concepts and the training did not address this need in any real depth. The strategies that teachers did take from the training tended to be facile and superficial, such as the use of manipulatives and cooperative learning without adoption of the complex mathematical modeling and discussion that needed to go with it. The missing link was the profound understanding of mathematics (Ma, 1999) that is crucial if teachers are to make sense of recent initiatives to improve curriculum materials and open mathematical learning to a wider participation by students (Ball, Hill, Bass, & Hyman, 2005; Kilpatrick
et al., 2001; Ma, 1999; Sherin, 1996; NCTM, 2000; Stigler & Hiebert, 1999).

**Need to Re-Learn Mathematical Concepts**

For reformation of mathematics teaching to occur, teachers often have to re-learn the mathematical concepts and especially re-think their beliefs about mathematics learning (Ball & Forzani, 2007; Darling-Hammond & McLaughlin, 1996; Fosnot & Dolk, 2001; Hill & Ball, 2004; Kilpatrick, 2001). There is a need for sweeping changes in elementary teachers understanding of mathematics. Reform movements compelling elementary teachers to close the gap and raise the bar on student learning in mathematics have missed a crucial point – the mathematical capacity of teachers is constrained by their own education in elementary school and as teachers in pre-service and in-service education at the faculties and in their boards. There is a need for transformation in teachers‘ own understanding of the elementary mathematics they teach (Ball, 1988; Kilpatrick et al., 2001; Hill et al., 2004; Ontario Ministry of Education, 2003)

**Pedagogical Content Knowledge**

The transformation needed in teachers' mathematical knowledge has another dimension. It is not enough to know the mathematics well, it is also important to know how to teach it well. Compelling research for new directions in this area have been developed over the past 20 years. Shulman (1986) introduced the concept of pedagogical content knowledge. He considered pedagogical content knowledge as a convergence of knowledge of subject content with knowledge of how best to teach that content. He stated:

Knowledge that includes…regularly taught topics in one’s subject area, the most useful forms of representation of those ideas, the most powerful analogies, illustrations, examples, explanations and demonstrations – in a word, the ways of
representing and formulating the subject that make it comprehensible to others. (p. 9)

In a subsequent article, Shulman (1987) defined pedagogical content knowledge as "that special amalgam of content and pedagogy that is uniquely the province of teachers, their own special form of professional understanding" (p. 8).

Boaler and Greeno (2000) devised a framework to use as an interpretive scheme to describe “the different ways of knowing that students [and teachers] are required to accept, negotiate, or oppose in mathematics classrooms” (p. 174). From this framework, they identified pedagogical content knowledge as flowing along a continuum from considering mathematics as a static body of knowledge with inviolable facts, rules, and skills to considering mathematics as a regenerative process of coming to know through inquiry, reflection, and shared interactions with other people.

This pedagogical content knowledge (PCK) is also connected to other forms of knowledge expressed in the research, such as "knowing-in-practice" (Schon, 1983); "language of practice" (Zeichner, Tabachnick, & Densmore, 1987); "practical knowledge" (Calderhead, 1987; Elbaz, 1991); "personal practical knowledge" (Clandinin, 1986); and "knowledge for practice" (Cochran-Smith & Lytle, 1999). It also fits with Dewey’s notion (1916) that the best instruction flows from the teacher's learning to learn from the learner's perspective or schema by thinking about what it takes to understand a mathematical idea for someone seeing it for the first time.

Since Shulman’s (1986) introduction, other researchers have contributed to the literature on pedagogical content knowledge. Ball et al. (2005) have spent the last 10 years further developing this concept, tying issues of pedagogical content knowledge and student achievement. Ball and her colleagues, Hill, Bass, and others have particularly
focused on just what is pedagogical content knowledge for teachers of elementary
mathematics on the one hand, and on the other hand, the effect of a teacher's pedagogical
content knowledge on students. Ball, Hill, & Hyman (2005) make the following
statement:

Although the typical methods of improving U.S. instructional quality have been to
develop curriculum, and —especially in the last decade—to articulate standards for
what students should learn, little improvement is possible without direct attention to
the practice of teaching. Strong standards and quality curriculum are important.
But no curriculum teaches itself, and standards do not operate independently of
professional's use of them. (p. 14)

They further make the connection that the quality of mathematics teaching depends
on the sound knowledge of content and that many American teachers lack this element:

This is to be expected because most teachers —like most other adults in this
country— are graduates of the very system that we seek to improve and… their own
opportunities to learn mathematics have been uneven and often inadequate, just like
those of their non-teaching peers. (Ball et al., 2005, p. 14)

**Pedagogical content knowledge and student achievement**

Rowan, Chiang, and Miller (1997) found that the mathematical content knowledge
of teachers can be a powerful predictor of student achievement. Teachers with a solid
understanding of the mathematics they teach feel more confident in their adoption of
reform methods of teaching in which students explore mathematical ideas without the
safety net of worksheets and procedural knowledge.

Ball et al. (2005), building on the work of Shulman (1986) to delineate specific
attributes of what they called mathematical knowledge for teaching, state that it is "a kind
of professional knowledge of mathematics different from that demanded by other
mathematically intensive occupations, such as engineering, physics, accounting, or
carpentry" (p. 17). They found that expert personal knowledge of mathematics (such as
that from post-secondary mathematics content courses) was inadequate for teaching. Instead, teachers need the capacity to deconstruct one’s own knowledge into a less sophisticated final form where critical concepts are accessible and transparent. “Teachers have to work backward from their mature understanding of mathematical content” (p. 245) and make mathematical ideas accessible to others. They give the example of a teacher understanding why a 6-year-old might write “1005” for “one hundred five,” and not reading it as a mistaken count, “one thousand five.” Instead, the teacher would recognize the underlying logic of the number. Roman numerals follow the same structure of each element having its own notation such as CV for “one hundred five” because there is no inherent place value in Roman numerals. Ball states:

Being able to see and hear from someone else’s perspective, to make sense of a student’s apparent error or appreciate a student’s non-conventionally expressed insight requires this special capacity to unpack one’s own highly compressed understandings that are the hallmark of expert knowledge. (Ball, 2000, p. 245)

They developed a tool to measure these PCK attributes and then conducted a study of 700 first- and second-grade teachers (and almost 3,000 students) to determine if teachers' high performance on their teacher assessment tool linked to high achievement in students. Their findings were that high levels of mathematical knowledge produced higher gains in student achievement. In their report, they stated that they found that:

Teachers' performance on the knowledge for teaching questions – including both common and specialized content knowledge – significantly predicted the size of student gain scores, even though we controlled for things such as student SES, student absence rate, teacher credentials, teacher experience, and average length of mathematics lessons. (Hill, Rowan & Ball, 2005, p. 4)

The students of teachers who answered more items gained more over the course of a year of instruction (p. 4). They also found that the measures of teachers’ mathematical knowledge for teaching overcame any effect of socioeconomic status on student
achievement. This has important implications for Ontario. In a study by Tremblay, Ross, & Berthelot (2001), it was found that Ontario’s Education Quality and Accountability Office (EQAO) test results were consistently higher for children who had parents with higher incomes. In effect, teachers' knowledge is a way to "stall the widening of the achievement gap" of poor children (Hill, Rowan, & Ball, 2005, p. 44).

Ball's research and the use of the assessment tool are gaining wide acceptance and utilization. She has made several presentations to the Ontario Ministry of Education through their professional development sessions for teachers and for principals. The Ministry also provides a webcast of Deborah Ball outlining her beliefs about teachers' content knowledge. The effect of her research on the Ontario context is, therefore, significant. I think her findings are important. She and her colleagues have made significant contributions to the field by linking pedagogical content knowledge, student achievement, and effective professional development.

Some of their work, however, has been controversial because of its reliance on a standardized form of testing that is creating consternation amongst some teacher organizations. The best way to cure the math phobia that often debilitates the public, including teachers, is probably not to formally introduce a standardized test on their performance but informal use of the test allows teachers to measure their progress as they study reform mathematics methods.

**Summary**

Elementary teachers’ prior knowledge of the subject matter of mathematics appears to put them at a distinct disadvantage for improving the mathematics achievement of the next generation of students. However, the research on pedagogical content knowledge
provides great promise for overcoming that disadvantage. If teachers can find the opportunity to re-learn elementary mathematics, but with a focus on real understanding and meaning making, they will be able to deconstruct the concepts they teach to make them accessible to students.

Ball’s premise and that of other researchers concerned about pedagogical content knowledge is not new. Over one hundred years ago, Dewey (1904) envisioned the integration of content and pedagogy. As Ball (2000) has stated, there are three problems that need to be solved in mathematics education: “what teachers need to know, how they have to know it, and helping them learn to use it, by grounding the problem of teachers’ content preparation in practice—could help to close the gaps that have plagued progress in teacher education” (p. 246).

**Professional Development**

Many times, we act as if learning happens as a direct result of exposure to new information; as if at the moment of hearing new information, we 'learn' it. “Learning is much more complex than that, especially when the goal of learning is to build the capacity of the individual or the system” (Wald & Castleberry, 2000, p. 8). Good professional development is the key to providing teachers with the pedagogical content knowledge and the understanding of mathematics itself. However, there has been significant evidence that the affects of professional development rarely turn into professional learning for teachers (Garet, Porter, & Desimone, 2001; Joyce & Showers, 2002; Lieberman, 1995; Wilson, 2003). The criticism of professional development models is that they are concentrated on transmission of knowledge through top-down, hierarchical structures (Loucks-Horsley, Love, Styles, Mundry, & Hewson, 2003) with little opportunity for
sustained collaboration and moderate to no change in practice (Dalgarno & Colgan, 2007; Loucks-Horsley, Love, Styles, Mundry, & Hewson, 2003). It is also often based on outside expert opinions of what teachers' need, which is usually tied tightly to political agendas and does not provide the content, nor the opportunities teachers view as essential for their personal professional growth (Lieberman, 1995; Loucks-Horsley et al., 2003).

Alexander, Murphy, and Woods (1996) contend that the “revolving door” (p. 31) of educational innovations deflects progress in the implementation of innovative practices. They attribute this to two factors. The first is that professional development focuses mainly on a superficial level of practice, rather than undertaking solid implementation of innovative practices. A second explanation is that implementers do not have “an extensive knowledge of the literatures or research that underlie these innovations, resulting in the reinvention or recycling of old movements under new labels” (p. 31).

The criticism of professional development models specific to mathematics is that they do not address the fact that teachers do not have a profound understanding of mathematics (Ma, 1999), do not acknowledge the need to boost teachers' pedagogical content knowledge (Ball, Thames, & Phelps, 2008), do not provide opportunity for teachers to look at their own practices (Stigler & Hiebert, 1999), and do not provide opportunity for thoughtful reflection or dialogue (Lieberman, personal communication, May, 2008). Teachers themselves request professional development that is (a) current research-based; (b) addresses pedagogy and content knowledge within the context of the teachers' learning experiences; and (c) provides opportunities for sharing (Ball & Wilson, 1996; Lieberman, personal communication, 2008; Loucks-Horsley et al., 2003; Sykes & Darling-Hammond, 1999).
Characteristics of Good Professional Development

The literature indicates that the best characteristics of effective professional development are (1) long-term sustainability; (2) focus on content; (3) classroom embedded; active participation; teachers treated as professional learners; (4) consistent with teachers “zone of enactment”; (5) teacher ownership of the professional learning; (6) a focus on student learning; and (7) consistent with standards-based prerogatives. There are several studies in professional development initiatives that support the importance of these characteristics.

Long-Term Sustainability

A study by Garet, Desimone, Birman, & Yoon (2001) used a national probability sample of 1,027 mathematics and science teachers to provide empirical effects of different characteristics of professional development on teachers' learning. The data was collected from teachers' self-reported view of their increase in knowledge and skills, and changes in classroom practice. The core features of professional development that had the most significant, positive effects on teachers' self-reported increases in knowledge and skills, and changes in classroom practice were: (a) “focus on content knowledge; (b) opportunities for active learning; and (c) coherence with other learning activities…and duration of the activity” (p. 916). Sustained professional development, over time, with more contact hours and the opportunity for all teachers of a school, subject or grade to interact and work together, was most likely to catalyze changes in teaching practice. They concluded that professional development needs to conform to the reality of teachers' professional lives. Strategies, presented through in-service that are not tied directly to the content teachers teach, are rarely integrated into practice. Even when it is connected, if it
is of short duration with little opportunity for follow-up, the new learning is unlikely to link with old practices.

The contentions of the Garet et al. (2001) research have been supported by other research. Studies also found that sustained professional development could significantly improve teaching practice (Borko & Putnam., 1996; Parsad, Lewis, & Farris, 2001). They stated that the time crunch of teachers' work lives means that it is difficult to implement change in instruction without support over a long period of time. Teachers cannot afford to experiment on their students based on information they receive from one workshop. They need sustained time with support to try new methods in thoughtful and effective ways.

A multi-year study of the effects of the Kentucky Education Reform Act professional development initiative found that many teachers soon returned to more traditional instruction because there was no ongoing sustainability to the initiative (Kannapel, Aagaard, Coe, & Reeves 2001). The researchers also stated that this was caused in part by lack of ongoing monitoring of the implementation process. On the teachers' side, they had concerns that the suggested changes in instruction would take away from the opportunity to cover all the content required for the state tests. Sustained professional development might have been able to address and alleviate some of these types of daily concerns that tend to infringe upon teachers' time.

Another large-scale study that also confirmed the need for long-term sustainability of professional development included the National Science Foundation's Statewide Systemic Initiatives (SSI) Program in the States. This initiative involved 200 hours of professional development. Heck, Banilower, Weiss, and Rosenberg (2008), in their
investigation of this initiative, found that professional development that focused on content, had long-term duration, and was connected to practice had a positive impact on teachers’ attitudes and perceptions of preparedness for teaching reform-centred mathematics in the classroom. The actual quantity of professional development seemed to matter: the greater the extent of professional development, the greater the impact. They also confirmed that professional development that allows for depth of learning opportunities has an important influence on the enhancement of teachers' mathematical knowledge for teaching and for how this knowledge transforms their teaching from instruction that is procedural to teaching focused on conceptual understanding.

**Focus on Content**

Kennedy (1998) conducted a review of the differences between professional development focused on content and professional development aimed toward more general topics. He found that professional development that focuses on specific content and how students learn that content has larger positive effects on student achievement outcomes than professional development focused on general topics such as the processes of learning. This was especially important in the area of conceptual understanding of mathematics.

**Classroom-Embedded, Active Participation, Teachers as Professional Learners**

Putnam and Borko (1997) conducted an analysis of their and others’ professional development research and found other common characteristics identified as important to effective professional development, namely:

- embedding teacher education in classroom practice;
- active participation by teachers; and
- treating teachers as professionals.
A similar list from other researchers also confirms the importance of embeddedness, active participation, and respect (Elmore, 2002; Leiberman, 2008; Loucks-Horsley et al., 2003; Putnam & Borko, 1997). Darling-Hammond's (1999) list of characteristics of good professional development is similar. She found that professional development should be:

- interactive, allowing teachers to participate in real tasks of teaching and learning with colleagues;
- include observation of students with a focus on student improvement and the use of data;
- based on research;
- sustained over time; and
- include collaboration with colleagues.

The Learning First Alliance in the United States, a consortium of educational organizations conducting research on professional development strategies that promote long-term sustainable improvements in student learning, also did research. Hargreaves (2003, p. 172), one of the members of this group, shares their choice of characteristics:

- continuous, shared, job-embedded, and closely connected to teaching and learning;
- intensive training, mentoring, and coaching for school leaders;
- evidence-informed decision making;
- shared commitment and responsibility for student improvement;
- local creativity and flexibility;
- high scope at school level for deciding the best way to achieve improvement.

**Zone of Enactment**

A long-term large-scale initiative that added another dimension to the concept of long-term sustainability in professional development was the National Numeracy Strategy (1999/2000), implemented in all primary schools in England during 1999 and 2000. Millet, Brown, and Askew (2004), in their research of this initiative, developed the concept of “zone of enactment” (the levels at which teachers were able to implement change based on their own cognitive readiness). Teachers only implement change that is within a realistic range of their capability based on their experiences to date. Just as all
learners need to have their prior learning recognized, teachers need professional development that extends what they already know, but not by so great a leap that they cannot integrate it into their existing repertoire of knowledge and skills. Once the connection to prior learning is made, teachers need long-term opportunities to continue to develop that learning into a “zone” that has direct applicability to their work in the classroom. They also confirmed the work of Spillane (1999) and confirmed his focus on the importance of teachers having "rich deliberations, grounded in practice and supported by resources" (p. 4).

**Teacher Ownership**

The question of why some teachers modify their instruction in response to professional development and some do not has often stymied policymakers and administrators. Millet et al. (2004) found that a partial solution to this was to give teachers ownership as researchers, curriculum developers, and learners of mathematics. It is within the rich discussions in these roles that teachers are able to give input into change so that it is a better fit with the realities of the classroom environment.

**Focus on Student Learning**

Carpenter, Fennema, Peterson, Chiang, and Loef (1989) have done considerable work with designing professional development around students’ mathematical work. They found that a focus on student learning is the most powerful motivator for changes in practice (Carpenter et al., 1989; Fennema, Carpenter, Franke, Levi, Jacobs, & Empson, 1996; Franke, Carpenter, Levi, & Fennema, 2001) “Furthermore teachers who were given opportunities to learn from the thinking of the students in their classrooms were able to continue learning and improve their practice even after the formal professional
development support ended” (Franke et al., 2001). In their most recent study they also speak to the need to “reconceptualize” our understanding of the knowledge, skills, and dispositions teachers require for effective practice (Fennema, Franke, & Carpenter, 2008). Their conclusion is that the centre of all teacher learning should be the development of increased understanding of how children learn mathematics and the tools that teachers need in order to support that learning.

Self-reporting by teachers in a recent dissertation by Pace (2009) indicates that teachers who participated in professional development focused on a specific area of students’ mathematical understanding were more likely to evaluate students’ learning gaps than non-participating teachers. The research also indicated a possible relationship between an intense focus on student learning and teachers’ confidence in teaching mathematics.

The need to focus on the lesson is the conclusion of research done by Stigler and Hiebert (1999). In the Third International Mathematics and Science Study (TIMSS), Hiebert and Stigler (2000) analyzed videotapes from hundreds of classrooms worldwide. They found that Japanese students were among the highest achievers in the world, at least partly, because of the effective models of professional development deployed there. Unlike the United States (which is very similar to the Canadian model), less time is spent on development of curriculum and individual lesson planning, and more time is spent on planning lessons collaboratively and then refining such lessons based on observation of the level of success they have in the classroom (Lewis, 2002).

Jugyou kenkyuu, or lesson study as it commonly known here, is a model in which teachers examine their own practices by working with colleagues to plan, teach, observe,
and critique lessons (Fernandez, Cannon, & Chokshi, 2003; Ma, 1999). It is now a common model used throughout North America (Lewis, 2002). It includes a collaborative process in which a group of teachers set goals for student learning (which include both content type goals as well as affective goals, such as behaving respectfully to peers), plan a research lesson to meet these goals, observe the lesson, and then reflect on the lesson. The cycle is then repeated for new goals.

Lewis and Tsuchida (1997) describe the most important components of lesson study as the focus on planning and reflection on a lesson with peers. This brings to the surface the underlying structures of a lesson, making its strengths and weaknesses explicit and malleable for change and improvement.

**Standards-Based**

A study by Tarr, Reyes, Reyes, Chaves, Shih, and Osterland (2008) contains a caveat that is important to consider when evaluating professional development models. Even where the characteristics of good professional development may be apparent, it may still not necessarily achieve the desired goals. It can often be a case of fitting a square peg into a round hole. They found it just didn't “take” in classrooms that were not already standards-based classrooms. Though, significant improvements were found in classrooms where there was a standards-based learning environment already in place. Tarr et al. (2008) found that when reform curriculum and pedagogy were coupled together, achievement was “significantly impacted” (p. 275). The literature is fairly consistent in its call for professional development that has long-term sustainability for long-term sustenance, collaborative structures for ongoing discourse with peers, and active engagement through real-life experiences (NSDC 2009; Wilson 2003). Even the studies
of exemplary professional development initiatives report that it is difficult for teachers to maintain change without the support of peers through ongoing discourse and sharing of strategies (Fennema et al., 1996; Romberg, 1997).

Because studies continuously show that traditional methods of professional development are not meeting the needs of teachers (Ball & Cohen, 1999), there has been a shift in professional learning. Newer models that focus on a "socially and culturally situated process of knowledge construction" (Jenlink & Kinnucan-Welsch, 1999, p. 377) and on discourse reflection, inquiry, and direct application to the classroom (Loucks-Horsley et al., 2003; Jenlink & Kinnucan-Welsch, 1999; NCTM, 2000; NSDC, 2009, Stigler & Hiebert, 2003) have gained respect.

**Summary**

Contrary to the recommendations of the literature in the field, most of the professional development in Ontario still follows a reductionist model (Little, 1993) lacking sustained, in-depth, and active engagement in issues of teaching and learning. This model contradicts not only what we know about teaching and learning, but also the very model of instruction that we are encouraging teachers to adapt in their own classrooms, namely, a model that connects to deep learning, reflection, and discourse over a sustained period of time. Ontario teachers need new approaches to professional development in order to build their capacity for making decisions around complex instructional issues, especially in the area of mathematics, the weakest link in teachers' repertoire of instructional strategies.

Back in 1993, Huberman (1993) criticized professional development models for indulging in more of a tinkering around the edges than a profoundly thoughtful, or
comprehensive reaction to the specific needs of classroom instruction. Fifteen years later, this still holds true. It seems to be assumed that based on the evidence of the multiple levels of professional development provided by the Ministry and by boards of education over the past 10 years, elementary teachers can take the new strategies, techniques, and models, and reconceptualize them to the specific needs of their classrooms. In mathematics, especially, this is an ineffective stance. We know from the research that mathematics is usually an elementary teacher’s weakest subject and they deserve more than a rudimentary introduction to new ways of teaching and learning mathematics.

**Professional Learning Communities**

**Introduction**

The literature indicates that teachers need the opportunity for long-term, job-embedded, supportive, and intellectually stimulating communities in which knowledge for practice is discussed, new practices are deliberated in light of new knowledge, and new strategies are developed based on research, evidence and the practical knowledge of the participants (Cochran-Smith & Lytle, 1999). Within the normal structures of traditional professional development, it is hard to ensure long-term commitment and coherence of purpose (e.g., student achievement). Professional learning communities provide a learning context for bridging the gap between the ideal attributes of professional learning and the limitations of traditional professional development initiatives. The need for intense focus on the learning of students, sustained over a long term, in-depth, and specific to teachers’ needs requires new models of professional development. One model that has gained prominence is professional learning communities.

The professional development research in mathematics teaching is also consistent in
confirming the need for elementary teachers to be given the opportunity to relearn mathematics in a more meaningful manner (Ball, Lubienski, & Mewborn, 2001) and to be provided with strategies for improving their own pedagogical content knowledge (Shulman, 1986). There are also consistent impediments to opportunities for in-depth attention to those two professional learning needs. One reason is that professional development initiatives are often of short duration with little opportunity for ongoing support. Also, professional development is usually generic so that it can reach a wide audience, but the needs of teachers in their own practice are often specific to the content they teach and the context in which they teach.

A solution to some of the impediments to teachers' successful implementation of new strategies is evident in the significant research about the value of classroom or school embedded professional development through professional learning communities (Berry, Johnson, & Montgomery, 2005; Bolam, McMahon, Stolt, Thomas, & Wallace, 2005; Bryk & Holland, 1993; Buysse, Sparkman, & Wesley, 2003; Cochran-Smith & Lytle, 1999; Darling-Hammond & McLaughlin, 1995; Engler & Tarrant, 1995; Hord, 1997; Louis & Marks, 1998; Little, Gearhart, Curry, & Kafka, 2003; Newmann et al., 1996; Supovitz, 2002; Supovitz & Christman, 2003).

Professional learning communities are groups of teachers meeting and collaborating with a goal towards improving some aspect of their teaching and the learning of their students (McLaughlin & Talbert, 1993). Although there is no certainty that organizing professional learning communities will eliminate all problems, there is the potential for professional dialogue around new practices, collegial support as the practices are implemented, and the intellectual stimulus of many heads pursuing the same problem.
Professional learning communities' models have a robust research base that extends back at least 18 years. Astuto et al. (1993) gave the first definition of professional learning communities. They defined a professional community of learners as an educational entity in which teachers continuously share learning and act on what they learn. The ultimate goal of such actions is to enhance instructional effectiveness as professionals so that students' learning benefits.

**Definition of Professional Learning Communities**

Hord (1997) defined a professional learning community as a group in which the teachers continuously seek and share learning in order to increase their effectiveness for students, and act on what they learn. Importance lies in the emphasis on learning and a high value on teachers’ inquiry and reflection (Darling-Hammond, 1990; Toole, 2001). Louis and Marks (1995) also add to this the need for a group that is based on communitarian principles and personally connected by common goals and beliefs. At the heart of all the definitions of professional learning communities is a deep responsibility for teachers' lifelong learning.

This literature review of professional development communities looks at the component parts of effective professional learning communities. Although not all the research provided here is mathematics based, it still has significant implications for professional learning communities focused on mathematics.

In 1990, Senge wrote an influential management text entitled The Fifth Discipline. The text outlines the importance of learning communities in a knowledge-based economy. In the complexity and fast pace of today's technological and information explosion, he saw the collaboration of groups of people focusing on a common problem as the pathway
to innovation and creativity. Without the people processes that ensured collaborative problem solving and decision-making, systems become stagnant, incapable of responding to the challenges of today’s world (Senge, 1990). He also stated that learning organizations can increase organizational capacity and creativity when “people continually expand their capacity to create the results they truly desire, where new and expansive patterns of thinking are nurtured, where collective aspiration is set free, and where people are continually learning how to learn together” (p. 3). Our world, particularly the world of education, has become even more knowledge based in the eighteen years since the writing of his book. Creative solutions to complex questions require a fundamental shift to the types of expansive thinking that Senge proposes. Professional learning communities provide a foundation for such expansion.

Wenger (1998), in his work with communities of practice, found that people who work together come to know a lot of information from their community. This inner space of social knowledge shapes what they do, who they are, and what they become; thus, it shapes ideas and worldviews. When people participate in groups, they learn about themselves, their identity and come to think differently about themselves as thinkers, learners, and leaders. This social participation is important professional learning. It situates personal knowledge within the larger social sphere and vice versa, creating a community of knowledge seekers more potent because of both their wholeness and their discrete parts.

Pertinent to a discussion about professional learning communities is the work of Schon (1983). Schon writes about reflective practice and makes the statement that real expansion of knowledge for what you do comes from what you are doing. He says that
people do not know what they are doing until they reflect about it. He captured the important idea that we need to make what is private public in our teaching; make what is implicit in what we do explicit. Working in communities of practice is one step towards shifting the implicit to the explicit.

**Changing Beliefs**

For "expansive patterns of thinking…and collective aspiration" (Senge, 1990, p. 3) and the unveiling of implicit knowledge (Schon, 1983) to permeate educational thought, there is often a need for a change in values and beliefs. Professional learning communities hold the potential for changing belief structures in ways that support instructional improvement. Changing beliefs about student learning is the first step to improving mathematics instruction (Ma, 1999; Stigler et al., 2000; Ball & Cohen, 1999).

Wideman (1991) found in his research that "teachers have to change their practices before they will change their beliefs," and "these breakthroughs in teachers' belief systems make them more receptive to further professional learning" (as cited in Hargreaves, 2003, p. 177). Gladwell (2000) found that to change people's beliefs and behaviour, "you need to create a community around them, where these new beliefs could be practiced, expressed, and nurtured" (p. 173).

A change in beliefs is a mind shift. This mindshift requires opportunities for reflection and thoughtful discourse "centred in the critical activities of the profession – that is, in and about the practices of teaching and learning" (Ball & Cohen 1999, p. 13). It "should include opportunities for deepening understanding of mathematical content... discussing current research and educational literature" (NCTM, 2000, p. 48). Professional learning communities provide a practical and comfortable context for both experimenting
with changes in practice, and for thoughtful and critical contemplation of belief systems within a venue receptive to both professional expression and communal nurturing.

**Changing Practice and Student Achievement**

Effective professional learning communities put change in the hands of teachers. Hall and Hord (1987) emphasize that organizations do not change; instead, it is the individual’s personal conviction that creates change. Fullan (2001) reiterates that it is the individual who provides the most effective route for accomplishing systemic change.

This potential for change in practice and improvement in student learning is supported by large-scale evidence. A study of 11,000 students in 820 secondary schools found that in those schools with professional learning communities, the staff worked together, changed their classroom pedagogy, and engaged students in highly intellectual learning tasks (Lee, Smith, & Croninger, 1995). In addition, the students achieved greater academic gains than students in traditionally organized schools did. In addition, the achievement gaps between students from different backgrounds were smaller and students learned more. There was also less staff absenteeism and higher morale.

In a three-year longitudinal project, results showed that a redesign of schools, including professional learning communities, improved student learning (Newmann & Wehlage, 1995). The areas of greatest improvement were the development of intellectually challenging learning tasks, the use of pedagogy that met the needs of diverse student populations, and a collective responsibility for student learning.

Darling-Hammond (1995) found that schools that concentrated on looking into teaching and learning, and discussing how practices were effective for students showed academic improvement. She insists that teachers need to have opportunities to share what
they know, to consult with peers, and to observe peers teaching. Darling-Hammond noted
that such activities in professional learning communities deepen teachers’ professional
understanding. Darling-Hammond and McLaughlin (1995) write:

The vision of practice that underlies the nation’s reform agenda requires most
teachers to rethink their own practice, to construct new classroom roles and
expectations about student outcomes, and to teach in ways they have never taught
before. (paragraph 1).

In other words, it requires a cultural shift in educational norms for professional
learning. Research also found that student achievement was significantly higher in
schools with the most committed professional learning communities (Louis & Marks,
1998). More specifically, Supovitz (2002) and Supovitz and Christman (2003) found that:

There was evidence to suggest that those communities that did engage in structured,
sustained, and supported instructional discussions and that investigated the
relationships between instructional practices and student work produce significant
gains in student learning. (p. 5)

Dunne, Nave and Lewis (2000) studied the findings of a two-year study on
professional learning groups commissioned by the Annenberg Institute for School
Reform. They found that teachers involved in such groups became more student-focused
over time than groups not involved in professional learning communities. They became
more inclined to change their practices, and they became more adept at accommodating
for varying levels of student understanding. Some of the gains in student achievement as
a result of professional learning communities have been demonstrated in quantitative
terms. Berry et al. (2005), in a study of an elementary school over a four-year period,
found that students moved from a level of low performance (50% performing at or above
grade level) to a high of 80% meeting grade level standards. In a three-year study,
students ratings on standardized tests improved from a level of 50% of students passing
subject area testing in reading, writing, mathematics, science and social studies to a success rate of over 90% of students passing each subject area (Phillips (2003)).

In three studies, similar results were found. Stranhan's (2003) three-year study of three low performing schools who implemented professional learning communities improved student achievement from a level of 50% proficiency to more than 75% on state achievement tests. Hollins, McIntyre, DeBose, Hollins, and Towner (2004) researched the results of struggling second graders and found that their achievement went from 45% of second graders at the 25th percentile to 73% in a two-year period, found similar results. Bolam et al. (2005), in a large-scale study in England, found that there was a statistically significant improvement in student achievement when correlated to professional learning communities' participation by their teachers.

A large-scale, 10-year Australian study found large, significant improvement in student learning when a sustained commitment to professional learning communities was incorporated into district wide plans as part of an overall strategy of student achievement (Hill & Crevola, 1999). The professional communities comprised the dominant model of professional development for the teachers in these districts. The trial schools were able to improve grade one achievement rates by 25%. Although this is a literacy large-scale intervention, it has implications that can be generalized to professional learning communities focused on mathematics. The same attributes that are important to literacy professional development are important to numeracy; namely, a focus on the specific learning needs of children, collaborative planning, and problem solving, support and particularly, time to thoroughly and thoughtfully discuss learning and teaching.

A graphic of the cyclical nature of the PLC structure is shown below (Figure 6). A
significant focus was allocated to looking at data to determine student needs, and using teacher moderation of student work to determine student and teacher growth. It was also a tightly monitored model where an expert in literacy led the PLC and evaluated changes in practice.

**Teaching and Learning Cycle**

![Teaching and Learning Cycle Diagram]

*Figure 6: Graphic Representation of the Hill and Crevola (1999) PLC Structure*

Louis and Marks (1998) conducted research on eight elementary schools, eight middle schools, and eight high schools. They looked at both pedagogical changes in instruction and the social environment of the classroom to determine changes in teaching practices. They used the term ‘authentic pedagogy’ to determine practices that focused on higher order thinking, construction of meaning, and depth of knowledge. They found that teachers who were engaged in professional community contributed to higher levels of authentic pedagogy and student achievement. The model they established to quantify the difference in authentic pedagogy from classroom to classroom indicated a 36% variance
in the quality of professional learning communities on classroom practice.

Jacobs, Franke, Carpenter, Levi, and Battey (2007) conducted a study of 89 teachers from an urban, low-performing school district engaged in professional development focused on algebraic reasoning. They found that professional learning communities that included teachers’ discussion and analysis of work samples from their own classrooms were most effective. They provided teachers with fodder for enhancing discussions and focusing on practice as well as evidence to support their development of understanding of students' thinking. Their project emphasized the need for teachers to have flexibility in the tasks they provided to their students rather than following a lock-step model of task generation just for having common work samples to discuss. The point was for teachers to attend to "students' thinking and types of conversations that arose" (p. 269). They "also engaged teachers in telling stories about the mathematics their students could do rather than what they could not do” (p. 267). Opportunities for deep reflection on students' work and focused professional dialogue considerably strengthened the professional learning of the teachers.

**Characteristics of Professional Learning Communities**

Professional learning communities have common characteristics with good professional development in general, namely, opportunities for long-term sustainability, a focus on students and content, and a safe and supportive environment. They thrive on collective conversation and collaborative action.

Newmann et al. (1996) describe the five most essential characteristics of professional learning communities as: (1) shared values and norms around "views about children and children's ability to learn, school priorities for the use of time and space, and
the proper roles of parents, teachers, and administrators; (2) a focus on student achievement; (3) reflective dialogue between teachers on curriculum, instruction and student development; (4) making teaching a public rather than a private venture; and (5) collaboration among colleagues (p. 182). Similarly, Louis and Marks (1998) found that the effectiveness of a professional learning community could be categorized under two main indices: collaborative activity and making teaching practices public.

In a large scale Ontario project on professional learning communities, Rolheiser, Fullan, and Edge (2003) found that the important components of effective professional learning communities was supporting school goals, collecting, and examining student data and using data to set improvement learning targets. During interviews with 60 participants at the beginning and end of one school year, teachers said working together with colleagues was a powerful support that helped them build a collaborative culture and make a difference for students. They advised that it was important to establish a safe, caring environment; choose a meaningful focus; and model collaborative work.

**Capacity Building**

In a large British study by Bolam et al. (2005) that included 393 schools, teachers reported that their participation in professional learning communities had a positive impact on their teaching practices. They became more collaborative and open about their teaching practices.

Sparks (2003) found that there was a reciprocal relationship between high quality teaching and professional learning communities. Capacity building attributes of professional learning communities were a reduction in staff isolation, a caring and productive environment, and an improvement in school programs (Boyd & Hord, 1994).
These attributes were built through five dimensions: shared leadership, shared vision, collective learning, application of learning, supportive conditions, and shared personal practice (Hord, 1997).

Teachers who felt supported in their own ongoing learning and classroom practice were more committed and effective in their professional learning communities than those who did not (Rosenholtz, 1989). Teachers found support through teacher networks, cooperation among colleagues, and expanded professional roles. This same sense of efficacy meant a greater commitment in the profession (an unexpected benefit of this was that more teachers stayed in the profession).

Bryk and Schneider (2002) determined that capacity building is influenced by the trust that the members of a professional community have for each other and for process itself. Relational trust sustained group commitment and efficacy. Relational trust required four attributes: respect, competence, personal regard for others, and integrity (Bryk & Schneider, 2002). Together, these four nurtured and solidified a strong collaborative culture in a school.

**Sustained Teacher-to-Teacher Communication**

Sustained teacher-to-teacher communication about teaching and learning is one of the most powerful and underused sources of professional learning and instruction improvement (Hord, 1997). The importance of embedding activities that include discussion and reflection of teachers' everyday work was found to be important for changing and improving practice by many researchers (Ball et al., 2001; Fullan, 2005; Lieberman & Miller, 1990; Lieberman & Wood, 2002; McLaughlin & Talbert, 1993; Secada & Adajian, 1997; Tharp & Gallimore, 1988).
Concern for Students and Achievement

McLaughlin and Talbert (2001) conducted detailed case studies of sixteen high schools. They found that strong learning communities "centred their work on students and shared responsibility for students' mastery of content and progress in the curriculum. They developed innovative methods of instruction that achieved a better fit of course work to students without compromising expectations for students' conceptual learning" (p. 129). Unfortunately, they were disappointed to find that only three of sixteen schools had a strong focus on student achievement. In those schools, without such a focus, the professional learning communities were found to be weak and ineffectual.

Newmann and Wehlage (1995) found that the most effective professional learning communities focused on student achievement. Their focus also led to improvement in student achievement that was sustainable over time. They maintained that the concern of adults in the school for the “intellectual quality of student learning, in contrast to concern for the techniques, such as whether to have portfolios or whether to eliminate all ability grouping” makes the difference in the values and visions that the staff bring to teaching and learning (p. 73). Newmann and Wehlage (1995) explained that the degree to which the staff develops into a professional community that engages the commitment and talents of all individuals into a group effort that “pushes for learning of high intellectual quality” is the key to success (p. 73).

Stoll and Seashore (2007) concur with this finding, stating that focus on student achievement improves the professional skill and capacity of individual teachers in the school, which accelerates long-term momentum for further improvement. The effectiveness of professional learning communities that focus on student learning and
achievement is also supported by the research on effective professional learning communities by Phillips (2003); Englert and Tarrant (1995); Supovitz (2002); Supovitz and Christman (2003).

**Flexible and Voluntary**

Ann Lieberman has done more than 10 years of research on the National Writing Project in the States. This project brings together huge numbers of teachers who share their practices, successes, and challenges. She found that the collaborative communities were most successful when members begin small and grow with the changing needs and goals of their members. They flourish when there is an environment that:

- promotes voluntary participation;
- contains a commitment to the vision and purpose of the community;
- collaborates in rethinking ways of engaging students in authentic learning activities;
- provides a safe support network which promotes risk-taking.

(Lieberman & Miller, 2000)

Dalgarno and Colgan (2007) refer to the necessity of addressing the view of learning that takes place in a community of practice. It is both an individual and social construction of knowledge within a safe sphere of collegial relationships. This safety aspect is often crucial for the success of a collegial endeavour. Lieberman (1995) had also previously found that it is important for teachers to be able to voluntarily form their own community rather than submit to prescriptive participation.

**School Factors**

Several researchers find that the overall school climate is important to the development of positive professional learning community (Sarason, 1990). “Our view is, by the way, that if you can’t make a school a great professional place for its staff, it’s never going to be a great place for kids” (Brandt, 1992, p. 21, quoting Hank Levin).
Sergiovanni (1996) supports this view, “if our aim is to help students become lifelong learners by cultivating a spirit of inquiry and the capacity for inquiry, then we must provide the same conditions for teachers” (p. 52).

School factors such as time to meet and talk, small size of the school, physical proximity of the staff to one another, teaching roles that are interdependent, effective communication structures, and school autonomy were also found to be important for the encouragement of professional learning (Louis & Kruse, 1995). Often such actions require structural re-organization since most schools do not presently have the institutional capability to allow teachers to be released as cohort groups to work on issues of mutual concern (Leithwood, 2002). Darling-Hammond (1996) found that it was clear that teachers’ responsibilities and roles need to be restructured to provide time to work together in professional learning communities, and without such restructuring, the possibility for success was diminished. Boyd (1992) found some additional school features that affect community development such as the availability of resources, schedules, and structures that reduce isolation and policies that provide autonomy.

**Norms Established**

Professional learning communities are not necessarily effective simply by the force of their being. There are attributes that need to be fostered. Fullan (2001) makes the point that strong teacher communities need positive goals. He states that “weak collaboration is always ineffective, but strong communities can make matters worse if, in their collaboration, teachers (however unwittingly) reinforce each other’s bad or ineffective practice” (p. 68). Thus, benefits of a professional learning community are contingent upon factors related to the beliefs and purposes that underlie how effectively a
professional learning community is developed. Hargreaves (2003) states that teachers need "grown-up norms of professional communities in which spirited disagreement and debate about the best ways to improve teaching and learning is accepted as a productive output of intellectual discourse" (p. 175). They need to become "as comfortable and assertive in a vigorous and rigorous culture of sometimes argumentative adults as they are with a class of subordinate children" (Hargreaves, 2003, p. 175).

Problems with Professional Learning Communities

There are also documented cases of problematic instances of professional learning communities. Bryk, Camburn, and Louis (1999) found that externally mandated professional learning communities insensitive to the professional needs of teachers as learners have disappointing outcomes both in teachers' capacity building and in the achievement of students. As Wenger (1998) found, communities of practice without a solid foundation of inquiry and openness could become "a cage for the soul", rather than a "cradle for the self" (p. 83). In this case, the professional learning communities constrain the learning needs of the teachers by colonizing the goals, methods, and results of the process. Sometimes this occurs through political or public pressure focused on aspirations that conflict with the learning needs of the teachers such as a focus on raising test scores at the expense of improving students’ attitudes towards learning in general.

Hargreaves (1999) warns also that the congenial culture of a community can also mask its congenital dysfunction. A true learning community needs to tackle complex issues of teaching and learning that can take participants out of their zone of comfort. In an effort to avoid even friendly confrontation, participants can become charmed into "groupthink." Another aspect of dysfunction is a reliance on local, practical knowledge
without reference to what is happening in research or in other areas of the education world. At its worst, a professional learning community becomes insular and inbred (Fenwick, 2001). In this instance, professional learning communities open the possibility for inappropriate or ineffective teaching practices to gain dominance. This can happen from the hesitancy of dissenting teachers to disagree with more powerful members of a professional learning group, such as, in some cases, PLC members with more seniority who may have a jaded approach to new ideas that challenge the way they have always done things. At its worst, such ineffective practices can promulgate beliefs that support inequities in opportunities for student learning, such as assumptions about the capabilities of marginalized groups to acquire postsecondary education.

Hargreaves (2003) also criticizes the excessive formalizing of the processes for participation in a professional learning community. He states that importing “systems thinking” into a micro system, such as a professional learning community, interferes with the natural evolution of relationship building, which is crucial to the success of good professional learning. He warns against "contrived congeniality" where top-down imposition of rules of engagement for professional learning communities create a "prison of micromanagement that constrains it" (Hargreaves, 2003, p. 165). Furthermore, "contrived collegiality neglects, crowds out or actively undermines opportunities for teachers to initiate their own joint projects shared learning, and collective inquiry in such areas as action research, team-teaching, and curriculum planning….inhibit[ing] bottom up professional initiative (Hargreaves, 2003, p. 165).

Little (2003) analyzed transcripts of teachers' dialogues in one professional learning community. From her findings, she warns that professional learning communities can be
limited by staying within their own "horizons of observations" (p. 917). If teachers only confront the problems in their own practices without questioning their own values and beliefs, and seeking understanding from outside sources, they limit the opportunity for growth and improvement for themselves and for their students.

Grossman, Wineburg, and Woolworth (2000) did a three-year study of a professional learning community of high school English and History teachers. They found that at the beginning of the foundation of a community, there is an innate tendency to play at being a community, and they adopt Peck’s term of pseudocommunity (p. 17) to explain this paradox. “The imperative of pseudocommunity is to behave as if we all agree. An interactional congeniality is maintained by a surface friendliness, vigilant never to intrude on issues of personal space” (Grossman et al., 2000, p. 17). Therefore, an artificial esprit de corps leads to the “illusion of consensus” (p. 17) that may have the consequence of disrupting the intellectual quality of discussion and mitigating against thoughtful changes in practice.

Although significant research has been done on professional learning communities in general, there is still a need to expand the literature on how professional learning communities enhance the mathematical knowledge of teachers, both as pedagogical content knowledge (Shulman, 1986; Ball, 2002) and the complementary knowledge of developmental levels of mathematics learning in the primary grades (Clements et al, 2004; Wright et al., 2002).

There are certain aspects of this model of professional learning that overlaps with some of the components of Japanese Lesson Study (Lewis, 2002; Stigler & Hiebert, 1999). The Japanese lesson study model has some similarities to the professional learning
communities' model in that a lesson is presented and then jointly reflected upon during and after the lesson. However, the Japanese Lesson Study Model does not incorporate all of the practices found in the professional learning communities' literature. It also makes assumptions about the comfort level and expertise of elementary teachers for conducting model lessons in the company of large groups of their peers. The teachers in this study needed a model that allowed for relationship building, trust, self-directed learning, and non-judgmental support. The other difference in the lesson study model is that it does not incorporate opportunities for teachers to interact with students in small groups. Being able to observe and interact with students in one's own classroom and in other classrooms provides teachers with a wealth of pedagogical content knowledge that can inform their instructional and assessment practices – helping them improve their expertise in the mathematics and on children's ways of knowing mathematics.

A significant amount of the learning in the primary grades is affected by the developmental level of the children's knowledge. Sometimes this is because children enter school with a wide range of mathematical experiences. Sometimes it is because children are maturing at different rates and the preliminary understanding needed to grasp a new concept has simply not been accessed yet. This is an important component of the learning of mathematics in the primary grades. Teachers need to be able to identify a child's prior knowledge and at the same time know how to scaffold new concepts within a zone that produces optimal learning. The teachers' focus was on growth in knowledge of the developmental aspects of mathematical learning and lesson study, in its traditional form, does not allow for that level of observation and analysis of individual children.

Underlying these two models (i.e., lesson study versus learning communities) are
fundamental cultural differences, particularly in how teachers develop professional knowledge and how teachers perceive their role as arbiters of their own knowledge building. Professional learning communities' research (Dufour & Eaker, 1998; Dufour, 2004) is more holistic and flexible than the Japanese model in its approach to teachers’ professional development, especially in its acknowledgement of the different socio-cultural contexts for teaching in our culture. In my experience, teachers are often reluctant to use the lesson study model because they feel their performance is being judged. Professional learning communities have the advantage of providing opportunities for teachers to build trust and rapport with one another. In the model used in this project, the teachers stayed focused on the learning of the students, usually sitting in groups with the students and working with them, rather than in a pseudo-evaluative role of observing the teacher teaching. This research project will incorporate practices from the professional learning communities' literature while remaining informed by the literature on lesson study.

**Summary**

In Ontario, professional learning community research has been given some acclaim from provincial leaders who propose to close the gap and raise the bar for student achievement through educational change (Fullan, 2005; Levin, 2005). This admiration is not misplaced as the literature on professional learning communities paints a positive portrait of the effectiveness of professional learning communities to propel forward change in teaching practices. The advantages of the professional learning communities' model for professional development over traditional professional development models is significant as long as there is a commitment to academic success for students (Berry et al.,
Teachers gain an increased understanding of how students learn and how teaching strategies can be adapted to meet student needs (Berry et al., 2005; Darling-Hammond 1996; Hill et al., 1999; Jacobs et al., 2007; Lee, Smith, & Croninger, 1995; Lieberman & Miller, 2000; McLaughlin & Talbert, 2001; Newman & Wehlage, 1995; Rolheiser et al., 2003). Student achievement is accelerated particularly in the area of diverse populations of students, including minority students and students with special needs (Englert & Tarrant, 1995; Hollins et al., 2004). Students reap the benefits of this model of professional learning on the part of their teachers and this is reflected in a positive school climate including increased achievement and less dropout and absentee rates (McLaughlin & Talbert, 2001).

The teachers in my study were under intense board pressure to improve their educational practices and student learning. They had already received a traditional form of professional development through the Ontario Ministry of Education's Early Math (2003) strategy. They were the mathematics leaders for their schools and wanted to become change agents for the improvement of mathematics instruction in their schools. Professional learning communities’ literature held great promise for allowing these teachers the time, support, and motivation to improve their practice. As the literature indicates, central to the success of this premise is the conviction that student learning, rather than just teaching instruction, is at the heart of the educational process. The teachers in this project held a conviction as well as a commitment to communal action and reciprocal responsibility for improving student learning. Working in teams also lightens the load and strengthens the spirit of co-operation towards a common purpose.
The literature on professional learning communities provides evidence that pedagogical and practical change is well facilitated by professional learning communities of teachers. The literature also provides a road map for navigating this terrain and opens the gates for further exploration of professional learning communities as an alternative destination for those seeking professional development that is meaningful, student-focused, and amenable to long-term, sustainable change.

From the literature, it was apparent that professional learning communities needed to be voluntary and long-term, based on common norms of behaviour, knowledge building, open to new ideas, flexible in format, and concerned with improving practice and student learning. The literature indicated that a professional learning community model would be the best foundation for building a knowledge base of best practices for teaching grade two students about mathematics.
Chapter 3: Methods

Research studies are needed to determine the efficacy of various types of professional development activities including pre-service and in-service seminars, workshops, and summer institutes. Studies should include professional development activities that are extended over time and across broad teacher learning communities in order to identify the processes and mechanisms that contribute to the development of teachers' learning communities. (Bransford, Brown, & Cocking, 1999, p. 240)

There is great potential for professional learning communities enhancing mathematical reform in the classroom. This thesis is an interpretative case study (Stake, 1995) that aims to deepen understanding of the complexity and challenges of professional learning communities in a very specific and personalized instance of eight grade two teachers working together to improve their teaching practices. It is designed to examine how a professional learning community that is self-directed and self-sustaining affects teachers' mathematics knowledge and skills, and classroom teaching practices. The methods were focused around the research questions that guided this thesis:

3. How does participation in a professional learning community affect teachers’ pedagogical content knowledge and their understanding of students’ learning of mathematics?

4. How do primary teachers develop an effective mathematics professional learning community?

This chapter will provide the rationale for the methods, a description of participants, and the research design.

Rationale for Methods Design

Presently, there is a gap in the amount of qualitative data being considered
about teacher practice, particularly as it relates to the large-scale mathematics initiatives that arose out of the Ontario Early Math Strategy: The Report of the Expert Panel on Early Math in Ontario (2003) and that have continued over the past five years. This research design will describe the qualitative aspects of teachers' learning about mathematics as they interact in professional learning communities that arose out of their original participation in the Ontario Ministry of Education's mathematics initiative.

These qualitative aspects consist of the narratives of teachers as they struggle with new concepts in their teaching and learning. It also includes instances of personal inquiry and self-reflection shared within a community of others who are grappling with the same issues of teaching and learning. These instances become a generative force for improving practice, but do not lend themselves to numerical delineation of success or failure. Instead, the use of qualitative data in this thesis is a means to articulate the more intimate processes of teaching and learning that underlie any large-scale venture to push reform in mathematics.

The collection of quantitative data and high pressure of recent Ontario reforms have a purpose in large-scale educational reform. But in the realities of teacher’s day to day work lives, articulation of the smaller details and practicalities of reform are more beneficial. This thesis addresses the particular stories of these eight participant teachers as they chart their own way through the complexities and challenges of changing mathematical practices.

This thesis documents and analyzes the experiences of the teachers as they attempted to improve their mathematical knowledge of concepts and their
pedagogical content knowledge with the sole intent of improving their students' understanding. The participant teachers were conducting a personal inquiry within a communal context of their students' and their own mathematical learning. The theoretical context of this inquiry, as outlined in the beginning of this thesis, is primarily socio-cultural and constructivist. Therefore, a qualitative method (Teppo, 1998; Glesne, 1998) favouring social construction of knowledge, and in the moment observation of learning, was the most logical choice for this subject. It incorporates a variety of "empirical materials…case study, personal experience, interview, observations…that describe problematic moments and meanings in individuals' lives“ which allows for richer and more realistic observations and analysis (Denzin & Lincoln, 1994, p. 2).

The design of this research also needed to take into consideration some of the research on the teacher as researcher, which comes from a number of traditions including professional development, professional learning communities, school reform, and practical inquiry (Clark & Clark, 2002; Cochran-Smith & Lytle, 1999; Cochran-Smith & Lytle, 2001; Elmore & Burney, 1999; McLaughlin & Mitra 2000; Wenger, 1998). The teachers were researchers in this professional learning community. They were researching their students' and their own understanding of mathematics.

Although I designed this study with two overarching questions in mind (see above), the teachers also had their questions, which generally focused on the more minute details of values, beliefs, and practices. These questions formed a framework embedded within the larger structure of the research design. Greene
(2000) stated that, “Once granted the ability to reflect upon their practice within a complex context, teachers can be expected to make their own choices out of their own situations” (p. 12). The teachers made the decision to look at the areas of most difficulty for their grade two students and attempt to improve their practice in that area.

The teachers researched information about mathematics, particularly as it pertained to problematic areas in students' understanding. The design of the research had to provide time for the teachers to do this research and to share their knowledge with each other. Each meeting with the participants began with a question about the students' learning and the next steps to be taken in order to improve or identify that learning.

The research was also dependent on narrative inquiry and the methods design had to include the opportunity for "retrospective meaning-making" (Chase, 2005, p. 656). Narrative inquiry encompasses a way of knowing and a pedagogical tool for analyzing that knowing (Clandinin & Connelly, 2000). It is an "intentional, reflective activity" that is "socially and contextually situated" that also interrogates "aspects of teaching and learning by storying experience" (Lyons & LaBoskey, 2002, p. 21). Clandinin and Connelly (2000) state that the focus is on composing field texts. Field texts may take the form of autobiography, biography, field notes, conversations, interviews, documentation, etc. The theoretical context of this inquiry, as outlined in the beginning of this thesis, is primarily socio-cultural and constructivist. In this research, I collected field notes, conducted interviews, and video and audio taped conversations and actions in the classroom and in the post-
classroom meetings. The design of a narrative inquiry included attention to the patterns and themes that related to both the teachers' learning and the teachers' learning about their own students.

Participants

Most of the research on professional learning communities is concerned with participants who work in the same school (Grossman et al., 2000). There are benefits to same school combinations, particularly the focus on improving school capacity and establishing and attaining shared goals (DuFour, 2004; Grossman et al., 2000; Little, 1999). The professional learning community for this thesis consisted of grade two teachers from eight different schools. The diversity of including teachers from across the board allows for more learning for teachers. There is evidence to support the benefits of "distributed learning communities" (Lave & Wenger, 1991; Lieberman & Miller, 2000; Rogoff, 1994) such as this one. Participation in this professional learning community was through invitation. An invitation went out to all grade two teachers who were mathematical leads in the primary division of their schools, from within one central Ontario school board, which covered a wide geographic area. The participants represented both rural and urban demographics and the far north, central, and far south areas of the board.

The teachers divided into two different groups: a northern group and a southern group, based on the geographical proximity of the participants. Each group consisted of four teachers. They all taught grade two, although some of the teachers had combined grades that included either grade one students or grade three students. Table 1 (below) describes the background information of the group.
Table 2: Teacher Background Information

<table>
<thead>
<tr>
<th>Teachers</th>
<th>Location</th>
<th>Years Teaching</th>
<th>Grade(s)</th>
<th>No. of Students</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Jane</td>
<td>Northern group</td>
<td>10</td>
<td>Grade 2/3</td>
<td>23</td>
</tr>
<tr>
<td>2. Ruth</td>
<td>Northern group</td>
<td>11</td>
<td>Grade 2</td>
<td>24</td>
</tr>
<tr>
<td>3. Kelly</td>
<td>Northern group</td>
<td>17</td>
<td>Grade 2</td>
<td>23</td>
</tr>
<tr>
<td>4. Sheila</td>
<td>Southern group</td>
<td>5</td>
<td>Grade 1/2</td>
<td>24</td>
</tr>
<tr>
<td>5. Melanie</td>
<td>Northern group</td>
<td>13</td>
<td>Grade 2</td>
<td>22</td>
</tr>
<tr>
<td>6. Mary</td>
<td>Southern group</td>
<td>20</td>
<td>Grade 1/2</td>
<td>19</td>
</tr>
<tr>
<td>7. Sara</td>
<td>Southern group</td>
<td>21</td>
<td>Grade 2</td>
<td>23</td>
</tr>
<tr>
<td>8. Carol</td>
<td>Southern group</td>
<td>6</td>
<td>Grade 1/2</td>
<td>24</td>
</tr>
<tr>
<td>TOTAL</td>
<td></td>
<td></td>
<td></td>
<td>182</td>
</tr>
</tbody>
</table>

The participants in this thesis were all primary school mathematics leads. They had just finished participating in the Ontario Ministry of Education's Early Math Strategy (Suurtamm, Graves, & Vezina, 2004), which had provided each of them with three days of in-servicing on Number Sense and Numeration and one day of observation in other teachers' classrooms. Jane had also received previous training on the Ontario Ministry of Education Mathematics Curriculum (1998).

None had received any additional training in mathematics other than their pre-service training and from their own professional reading. This made them a typical group of elementary teachers. Sinclair (2005) also found that most elementary teachers have received less than Grade 13, and for younger teachers, less than Grade 12 mathematical education. In the past ten years, the teachers had not received much professional development in mathematics. A few after school-learning opportunities had been implemented by the board, and the teachers had participated to varying degrees. Table 3 outlines the teachers' mathematical experience.
Table 3: Mathematics Experience

<table>
<thead>
<tr>
<th>Teachers</th>
<th>Primary Math Lead 3 day inservice</th>
<th>University Level Math Courses</th>
<th>Additional Qualifications in Math</th>
<th>No. of Hours of Ministry In-Service of Mathematics in Last 10 years</th>
<th>No. of Hours in Other Math Workshops in Last 10 Years</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Jane</td>
<td>yes</td>
<td>nil</td>
<td>no</td>
<td>21</td>
<td>6</td>
</tr>
<tr>
<td>2. Ruth</td>
<td>yes</td>
<td>nil</td>
<td>no</td>
<td>18</td>
<td>2</td>
</tr>
<tr>
<td>3. Kelly</td>
<td>yes</td>
<td>nil</td>
<td>no</td>
<td>18</td>
<td>2</td>
</tr>
<tr>
<td>4. Sheila</td>
<td>yes</td>
<td>nil</td>
<td>no</td>
<td>18</td>
<td>2</td>
</tr>
<tr>
<td>5. Melanie</td>
<td>yes</td>
<td>nil</td>
<td>no</td>
<td>18</td>
<td>2</td>
</tr>
<tr>
<td>6. Mary</td>
<td>yes</td>
<td>nil</td>
<td>no</td>
<td>18</td>
<td>2</td>
</tr>
<tr>
<td>7. Sara</td>
<td>yes</td>
<td>nil</td>
<td>no</td>
<td>18</td>
<td>2</td>
</tr>
<tr>
<td>8. Carol</td>
<td>yes</td>
<td>nil</td>
<td>no</td>
<td>18</td>
<td>2</td>
</tr>
</tbody>
</table>

Schools

The schools were typical of schools from this board. They were relatively small (around 300 students) except for one school, which had over 600 students. Each school had a full-time principal except for the smallest school, which only had a half-time principal. The two largest schools had vice-principals. Each school included three divisions: primary, junior, and intermediate in one building. Five of the classrooms contained students who were supported by a part-time educational assistant. A special education teacher worked in one of the classrooms during the mathematics period. She worked exclusively with one child.

The schools were mostly racially, linguistically, and socio-economically homogeneous, with few examples of exceptionally low or high ranges of socio-economic status (as reported by the teachers). The EQAO data from 2004-2005 also confirms that the board had low numbers of ESL/ELD learners (ranging from 1% to less than 1%), few students were born outside of Canada (ranging from 2% to
4%), and few had a first language other than English (4% to 8%).

**Board**

There are 42 schools in the board and approximately 1500 Grade 2 students. This research was only concerned with eight of those schools, but I think that it is helpful to have a sense of the profile of the whole board. EQAO data from the 2004-2005 school year indicates that 67% of Grade 3 students achieved at the provincial standard of Level 3 in mathematics (EQAO, 2008). The results from previous years showed that there had been little improvement. The scores varied by one or two points over the previous three years. There was increasing pressure from the board to improve EQAO scores in numeracy. To that end, funding from the Ontario Ministry of Education was used to supply each primary classroom with manipulatives and other mathematics materials such as new textbooks.

**Research Design**

The goal of the research was the development of an effective professional learning community dedicated to the improvement of students’ learning in a mathematics area to be determined by the participant Grade 2 teachers. The research questions were:

1. How does participation in a professional learning community affect teachers’ pedagogical content knowledge and their understanding of students’ learning of mathematics?
2. How do primary teachers develop an effective mathematics professional learning community?

In Table 4, there is an overview of the general aspects of the professional
learning community meetings, which provides a sense of the structure of the PLC meetings.

*Table 4: Overview of Professional Learning Community Meetings*

<table>
<thead>
<tr>
<th>Dates of Meetings</th>
<th>Research Design</th>
<th>Data Collection by Researcher</th>
</tr>
</thead>
<tbody>
<tr>
<td>December 15 Whole group meeting.</td>
<td>Establish prior knowledge of teachers. Teachers set goals. Begin a narrative of teachers' beliefs and understandings. Share research and resources. Set pragmatics for meetings.</td>
<td>Interview of teachers, field notes, Video and audiotapes of discussions, field notes, identification of themes, and issues.</td>
</tr>
<tr>
<td>Jan. 10, 13, 18, 20, 25, 27 Feb. 3, 9, 11, 15, 17, 22, 24 Mar. 1, 3, 8, 24 April 5, 7, 12, 14 (separate groups)</td>
<td>Observe students and teachers in the classroom. Observe teachers in PLC. Provide time for reflection, looking at research, establishing new questions, and planning next steps.</td>
<td>Videotape and audiotape students and teachers in the classroom and PLC discussions, emails, field notes, transcription of videotape, themes, and issues in the data.</td>
</tr>
<tr>
<td>Feb. 1 Whole group meeting.</td>
<td>Share new learning from the experiences of both groups. Share research and other resources. Share the narratives of their experiences in the classroom and in their PLC. Determine if modifications needed to the format, timetabling or the focus of the PLCs.</td>
<td>Interview with teachers, field notes, video and audiotapes of discussions, field notes, identification of themes, and issues.</td>
</tr>
</tbody>
</table>

**Format of Meetings**

Teachers met together in two different formats. The first meeting and two later ones (one midway and one at the end) were held for a half day as a whole group, with no observations in the classrooms. In these meetings, the teachers
shared research, reviewed research, and discussed their students and their teaching practices.

The other meetings were held separately with the two different groups (a northern group and a southern group) meeting weekly for a half day. In the first hour of the half-day meeting, one of the teachers conducted a lesson, while the other teachers observed the beginning of the lesson and then worked with groups of students to both observe and interact with the students as they worked on the concepts introduced by the lesson. The second half of the half-day meeting was used for the professional learning community discussions. Their board of education supported the project and provided substitute teachers for the PLC meetings. In Table 5, there is a timetable for the meetings as follows:

Table 5: Schedule of Meetings

<table>
<thead>
<tr>
<th>Date</th>
<th>Group</th>
</tr>
</thead>
<tbody>
<tr>
<td>December 15th, 2004</td>
<td>Whole group</td>
</tr>
<tr>
<td>January 10th, 2005</td>
<td>Southern group</td>
</tr>
<tr>
<td>January 18th</td>
<td>Southern group</td>
</tr>
<tr>
<td>January 25th</td>
<td>Southern group</td>
</tr>
<tr>
<td>February 1st</td>
<td>Whole group</td>
</tr>
<tr>
<td>February 15th</td>
<td>Southern group</td>
</tr>
<tr>
<td>February 22nd</td>
<td>Southern group</td>
</tr>
<tr>
<td>March 1st</td>
<td>Southern group</td>
</tr>
<tr>
<td>March 8th</td>
<td>Southern group</td>
</tr>
<tr>
<td>April 5th</td>
<td>Southern group</td>
</tr>
<tr>
<td>April 12th</td>
<td>Southern group</td>
</tr>
<tr>
<td>May 10th</td>
<td>Whole group</td>
</tr>
</tbody>
</table>

Meeting pragmatics were decided at the first whole-group session. A
timetable was established for the meetings (Table 5). For each group, the meetings would occur on ten separate occasions at least one week apart, as well as three whole-group meetings. The schedule for the meetings took into consideration the weeks that it would be inconvenient for teachers to meet because of report card writing or meetings with parents, education week, etc.

The eight teachers were from eight different schools. They each took turns hosting the group at their school. The teachers developed their own goals for the professional learning community based on the area of mathematics that they wished to work on with their students.

Collaboratively, they designed general outlines for lessons focusing on difficult concepts although they modified the lessons or the themes of the lessons to meet the particular interests or needs of their individual classrooms. At each session, they attended the host classroom to observe the students, to work with small groups of students, and then met to share their observations with each other after the class. Then they reviewed video and audio tapes of the lesson and reflected on how the students came to know mathematics. The researcher observed the ways in which teachers’ understanding of how children learn mathematics is affected by observation, reflection and collaborative planning for student learning within a professional learning community model.

At the beginning of the project, it was important to set up a safe space for discussion (Dalgarno & Colgan, 2007; Lieberman & Wood, 2002). There is an emotional underpinning to teachers' professional autonomy even in those who are exemplary teachers, confident in their teaching practice. Being observed by your
peers whose main purpose is to observe and formatively assess the learning of your students creates tension. The possibility that teachers would feel vulnerable was discussed. The professional norms for the project were established and they are outlined below:

- the autonomy of each teacher in their classroom would be respected;
- the discussion at the end of each observation period would focus on student learning, not the teachers' delivery of the lesson;
- the usual rules of respectful interaction would be used;
- there would be a chairperson for each meeting [the original intention was a rotation of this position, but unfortunately, I was put in this position for all of the meetings due to the reluctance of the participants to take on the role. This put me in a position that required more discussion participation on my part than I had intended].

The explicit discussion of these norms for interaction released some of the tension that the teachers felt about their role in the project.

Zeichner and Noffke (2001) also talk about research that is "up close and personal" (p. 307). This research had to be cognizant of the intimate nature of this type of close interaction between participants in a PLC, and the research design had to ensure the opportunity for the development of rapport and communal spirit among the participants. Although there has been much denigration of the aspect of "congeniality" of teachers as a blockade to true inquiry (Fullan, 2001), it was an important personality trait of this professional learning community. These participants did not know each other well prior to the professional learning community, so the common courtesies of getting to know one another, to share family stories, and professional histories was important to the beginning stages of the research and was a continual thread through the meetings as the participants continued to make respectful and caring inquiries of each other. Although the original design of the research was meant to include a straight-to-business practicality, it was later
remodeled to include opportunities to indulge in the niceties of human interaction.

**My Role and Protocols for Facilitation of the PLC**

As a participant in the group, I had a dual role as researcher, documenting the progress of the project; and as co-participant, reading books, discussing curriculum, sharing my own ideas, and learning with the group. I also facilitated discussions and ran the cameras and audio equipment. But throughout the research, I had to remain conscious of the fact that even though I was the researcher, I was also "in the parade" that I "presumed to study" and as such, was never a "disembodied" recorder of "someone else's experience" (Clandinin & Connelly, 2000, p. 81).

In this role, I had to tread the fine line between facilitating the group, helping them find appropriate research, and at the same time not interfering with the natural flow of their learning by falling into the trap of becoming their ‘trainer’. I wanted the teachers to pursue their own mathematical learning needs.

Warshauer (2001) found that “the opportunity to learn seems to be central to sustaining teachers’ interest” (p. 89). I wanted to sustain the teachers’ interest by allowing them to pursue their own questions, not simply comply with the dictates of provincial or board imperatives and I did not want to become a proxy for either of those organizations. Of course, this would not be ethically tenable if the teachers were not also focused on the issue of student learning. Their priority was student learning. The research design allowed ongoing opportunities to learn. These included access to research articles, books, and videotapes. The teachers designed their professional development with these resources and used them as a stimulus for discussion and reflection.
In the initial design of the professional learning community, I started with the premise that since they had received three days of in-service professional development from the board this would be their opportunity to expand on some area of their and their students’ mathematical learning. My role in this would be to provide them with the resources and research that they required to pursue such learning. Although I joined in their discussions and observed in their classrooms, I tried not to unduly intervene in their learning. I did ask them questions about the choices they made in how they designed a lesson, used manipulatives, and the strategies they used. This helped me understand the context of their decision-making. Asking questions may have influenced the teachers’ and may have modified their thinking.

There was also the concern of how to answer the participants’ questions directly related to the research. The parameters I established around their questioning was to answer the questions as fully as I could but also to direct them back to the research or other research. In this way, I did have some influence. Where I curtailed my influence was in avoiding making judgements or intervening when the teachers conducted a lesson or used a strategy in a way that was contradictory to my understanding of the literature. By not intervening, I was able to observe the evolution of the teachers’ understanding and use of research literature.

For the first session of the PLC, the teachers were encouraged to bring research and resources to share. I also brought research and resources, all of which were listed in the Ontario Ministry of Education’s Guide to Effective Instruction
(2005). They were given the opportunity to borrow the resources and in subsequent meetings, the readings were shared and discussed.

The professional learning community began with what teachers already knew. They had participated in some board and provincial level training. They had received a certain amount of mathematical training from those experiences. Beginning with what teachers know, rather than transmitting knowledge to teachers, shifts the emphasis toward practitioners (Clandinen & Connelly, 1999). By allowing teachers to socially construct their knowledge, they, like all learners, link their prior knowledge to new understandings. Beginning with teacher knowledge means that the teachers‘ prior knowledge is respected and used as leverage for new learning. The first stage of the professional learning communities was to revisit what the teachers felt they had learned from their participation in the Ministry in-servicing.

Data Collection

Multiple data sets were collected. This collection included interviews, emails, field notes from the meetings, and transcripts from the videotaping and audiotaping. Figure 7 below is a diagram of the data that was collected from the PLC:

![Figure 7: Case Study Data](image-url)
Videotaping and audio taping were used to capture the nuances of the lesson and the students’ responses to it as they engaged in interactions with each other and with the teachers. Videotaping also took place at the teachers’ pre- and post-lesson discussions as a whole group and in personal interviews with the teachers at the beginning, middle, and end of the project. The videotapes and audiotapes were transcribed.

The classroom videotapes and/or audiotapes were often referred to during the professional learning community meetings to generate discussion about a particular finding that one of the teachers may have seen in his or her group.

Several decisions were made about the mode of data collection. I had to decide whether the professional learning community needed the added component of in-classroom observations by each of the teachers, whether to videotape, or just rely on field notes, and what the observations would look like. A discussion of these decisions is outlined below:

**Classroom Interactions**

The dynamics of classroom interactions between teacher to students and students to students enforces a particular mathematics culture. This culture provides the context for teaching and learning mathematics, and the context is important if children’s learning is to be observed and reflected upon within any kind of meaningful dialogue (Clarke, 1998). Teachers understand classroom contexts so it provides an effective venue for their own learning as they observed students learning mathematics. It is important to use the classroom as the site of research because this is where theory and practice are melded (or not) into the teachers’
perspective on how children learn and how teachers teach (Glesne, 1999; Pirie, 1998).

**Observation**

The major purpose of this research is to analyze how teachers learn about children's mathematical knowledge through observation and interaction with children in their own classrooms and in the classrooms of their colleagues. Observation data through videotaping and audio taping as well as anecdotal notes provide rich, thick, description for analysis and interpretation. It also provides a window into the teaching and learning of mathematics from multiple perspectives – from the classroom teacher, from colleagues, from students, and from me. It also makes it possible to look at the more complex features of mathematics teaching and learning that are not discernible through more empirical methods of data analysis (Steffe, 1996).

In this project, there are two levels of qualitative research being conducted. On one level, it is the teachers observing the students’ mathematics learning and using this research to inform their own practice. On the other level, it is a case study of the teachers as they conduct their research on their students’ learning of mathematics. I was searching for the salient, recurring features of the teachers’ personal journeys as they sought to make sense of how children learn and how teaching practices impact on such learning.

**Videotaping and Audiotaping of Teachers and Students**

The videotaping of the classroom during the lessons was shared with teachers during the post lesson discussions. These helped teachers reflect more deeply on
what happened during the lesson. A careful analysis of videotapes of groups of students in the classroom working through problematic situations alerts teachers to students’ abilities to develop powerful mathematical ways of thinking (Maher & Martino, 1996). It also alerts them to the impediments children sometimes encounter as they struggle with new concepts. Once the impediment is identified, teachers can determine strategies or tools to scaffold children’s learning. It also gives teachers the power and voice to act as researchers themselves in pursuing lines of inquiry directly applicable to what is happening in their classrooms (Kennedy, 1997).

Qualitative research of this kind helps to narrow the gap between research and practice (Pirie, 1996). It also raises the bar on the possibilities for compounding teacher knowledge while concomitantly improving student learning. Freire has observed that videos "help us understand better our own practice and to perceive the gulf that almost always exists between what we say and what we do" (Freire, 1993, p. 121).

In the classroom, I performed the videotaping. I spent some time videotaping each teacher as she worked with a small group of students. In some cases, one of the teachers would signal me if there was something that the students were doing that she really wanted captured on film. Each group of students also had a tape recorder with an external mike that was taped to the desks, which were generally arranged in groups of four. Each teacher worked with one or two groups. The video recorder also had an external mike, but with the noise of the classroom, it was often hard to pick up every conversation on the videotape. In that case, the
Audiotapes became very useful for later transcription.

In the professional learning community, conversation that took place after the classroom work, the stationary camera was made use of, including an external mike so that no one was responsible for doing the videotaping. Audiotaping was also done at this time.

Jot notes were taken during the professional learning community and then elaborated more fully into field notes after the sessions. The videotapes and audiotapes were transcribed at a later date. The field notes were cross-referenced with the transcriptions to provide a fuller picture of each session. At three points over the course of this research, the respondents were interviewed. In the initial interview, the teachers were interviewed about the following:

- educational background;
- mathematical training;
- years of teaching;
- grade levels;
- description of their class;
- reason for volunteering.

The subsequent interviews provided an ongoing critical reflection through dialogue with the teachers about their perspectives on the learning of students as well as their own learning. The interviews were loosely structured and based on the following questions:

- What changes were they making in their practice in the classroom?
- What new understandings of mathematics were they finding?
- Were changes being made in their group efficacy as they operated as a professional learning community?
- And what were those changes?

The researcher attempted to follow the teachers’ paths of thinking as they answered these questions by probing more deeply into the individual responses of
the teachers as they shared anecdotes or information related to the questions. This helped provide a “credibility” check (Steffe & Wiegel, 1996) that ensured the observations were relevant. Gitlin (1990) states that it is important for those involved in research processes to critically assess one's own "assumptions about the teaching and schooling that underlie those events" (p. 460).

**Data Analysis**

A case study approach was used for obtaining data (Glesne, 1999). Qualitative data from the transcripts, field notes, and interviews were analyzed. The transcripts and the field notes were coded to indicate instances of growth in mathematical understanding, growth in pedagogical content knowledge, and growth in the group as an effective professional learning community. Four phases were employed for the analysis: (1) searching for patterns; (2) categorizing and ordering observations; (3) revising and refining patterns; and (4) explicating themes (McMillan & Schumacher, 2001). The data was triangulated by the use of interviews, video and audio transcripts, and field notes (Denzin, 1978). The videotapes and audiotapes were reviewed twice at the end of each session. In the first instance, transcription took place and specific instances were linked to the field notes. In the second review, general themes were identified and links were made between the field notes, learning community observations, classroom observations, and the interview notes.

Two major categories of observations were made, namely, experiences with teaching and learning mathematics (pedagogical content knowledge growth), and experiences working with others in a professional learning community (communal...
professional growth). It was my intention to preserve an open response to the emerging themes that might evolve under the two categories above. To provide a framework for distinguishing the different types of themes, the data from the audio and videotapes, and interviews were transcribed and divided into one of the two categories or into a combined category:

- professional learning community;
- mathematical pedagogy;
- a combined category of professional learning community and pedagogy when there was an overlap.

Within each of these categories, themes were identified. After the first meeting, three themes had their genesis. In the area of teaching and learning mathematics was the challenge of learning new ways of teaching mathematics and the diversity of the needs of the children in their classrooms. The area of professional learning community included the professional self-consciousness of working with strangers. Over the course of the research, each new set of observations was used to confirm existing themes or to suggest new ones. In the area of teaching and learning mathematics was added the following themes:
- importance of teachers’ prior learning and need for a research based pedagogical content knowledge. The area of professional learning community was expanded to include goal setting, values and beliefs, negotiating norms, misconceptions, importance of assessment and growth in understanding of mathematical teaching and learning, and becoming a community.

**Internal Validity**

Observing the teachers in the PLC and in their classrooms in as open a manner as possible provided the opportunity for both breadth and depth of
observation that increased the complexity of the analysis and provided rich fodder for exploring the relationships between professional learning communities and the teachers’ growth in mathematical pedagogy. The qualitative nature of this approach meant that the internal validity rests with the researcher. In order to reduce the impact of the researcher on the research, a number of steps were taken, including:

- A group of five colleagues who were part of a weekly writing group at the Ontario Institute for Studies in Education, served as a focus group, provided feedback on the interviews and my observations from the transcripts.
- The teachers were asked to review information provided by them through interviews.

According to Lincoln and Guba (1985), it is important to ask friends and colleagues to look at your data, to turn a critical eye to the coding and the findings to help justify the trustworthiness of the data (as cited in Glesne, 1999). Glesne (1999) also states that you can “share the interpretative process with research respondents as a form of member checking” (p. 152).

Using triangulation as described previously, also reinforces the internal validity of an investigation (Denzin & Lincoln, 1994). Data from one method of collection can be compared with another to support the findings.

**External Validity**

This thesis focuses on very specific instances of the professional learning community of eight grade two teachers from the same board in Ontario. Despite its narrow base, the findings and implications of this study will extend beyond the participants. The use of “thick description” unveils sufficient details, processes, and information that readers can make comparisons to their own experiences, thus, allowing for generalizations to other teachers and other professional learning
communities (Biklen, 1992, p. 39). It will add to the literature in the field and enhance other collections of quantitative and qualitative data on professional learning communities and teachers’ growth in mathematics instruction. Detailing the nature of the learning of this group of participants as they search for a new model of professional learning will highlight the challenges and realities that quantitative data might not have revealed. This case study provides a story map of one group’s particular journey.

**Ethical Considerations**

Approval for this research was provided by the Research Ethics Board of the University of Toronto by expedited review, prior to the collection of data. Raw data were collected solely by the researcher and remained, at all times, confidential. The right of the participants and their employers to confidentiality was honoured. Pseudonyms were used. Access to data was made available to participants, respective only to their personal contribution to the research. Raw data were not made available to school and/or board administration. All data, including observation notes, audio and video recordings, and any transcripts were secured in a locked facility. Electronic files were stored in files protected by passwords. Access to hardware containing any information regarding the study, as well as printed information was kept in a secure facility. Only the researcher and research advisor had access to primary data. Within five years of completion of the study, paperwork will be shredded and all files deleted. Participants were made aware that they may request a summary of findings and have access to the final research paper.

Participants were informed that there was no obligation to participate in this
study and that they could withdraw from participation at any time. Participants were further informed that if they decided to withdraw from participation in this research study that all data pertaining to them would be destroyed immediately and not be used as part of this undertaking. There were no apparent risks or inconvenience to participants in this study.

The participants benefited from the opportunity through opportunities to collaborate and reflect with colleagues. This research served to inform the participants of a new model of professional learning and provided them with the opportunity to share their experiences and reflections with other colleagues. It is anticipated that this research will serve to inform future professional learning decisions by providing insight into the benefits and challenges of professional learning communities and elementary teachers learning and teaching of mathematics.
Chapter 4: Findings

Introduction

This is a case study of teachers engaged in a professional learning community (PLC) focused on students' learning of mathematics. The two questions it seeks to answer are:

1. How does participation in a professional learning community affect teachers’ pedagogical content knowledge and their understanding of students’ learning of mathematics?

2. How do primary teachers develop an effective mathematics professional learning community?

Answering these questions required an exploration of the essential elements of this professional learning community, which contributed to, or deferred its growth as a learning entity. Secondly, because of its mathematics focus, the connections between the learning community, the growth in content and pedagogical matter, and the improvement of strategies for student learning needed to be addressed. Pedagogical content knowledge is the common term for the combination of teachers’ growth in subject matter and improvement in teaching strategies. The analysis of the data highlights the continuing intellectual development of the PLC participants as teachers and learners of mathematics, as well as their social formation as a community of learners supporting one another. The pedagogical content knowledge focuses on the teaching of multi-digit computations. So while the data on the professional learning community expands the broader dialogue on professional development models, the data on the pedagogical content knowledge is narrowly bounded by a specific area of teaching and learning, namely, Grade 2.
There is a developmental pathway of the teachers' growth as they move from the “birth pangs of teacher community” (Grossman, Wineburg, & Woolworth, 2000, p. 7) to a more communal intellectual endeavour concentrated on students' learning of mathematics and teachers' pedagogical content knowledge. This intellectual endeavour has many challenges. The teachers struggle with their own learning, the learning of their students, and the social context of working with disparate individuals. These challenges have their genesis in several different fields of academic research which are more fully and formally articulated in the literature research section, and which are addressed more informally as they are encountered in the vignettes discussed in this chapter.

The chapter is divided into nine sections. The first two sections: deciding on a topic and stages of mathematical development describe the participants as they made their initial decisions about their preferred focus for the PLC and their stages of mathematical development over the course of the PLC. The third section, using research, outlines the significant time they spent together sharing their readings and discussing its implications. It also provides some background for the actions that are taken during the fourth section, which is the description of five cases: Melanie, Mary, Sheila, Sara, and Jane. Following that section are the findings regarding professional learning community norms and their importance to the PLC. The next three sections discuss some of the challenges the PLC had to overcome or accommodate on the journey to becoming a professional learning community such as moving at different speeds, assessment, and developing learning communities in the classroom. The final section provides a summary of the chapter.
Deciding on a Topic

At the first session, the teachers agreed that the goal of this professional learning community (PLC) would be to address the area of most difficulty for their Grade 2 students. The initial discussion focused on several strands: Number Sense and Numeration, Geometry, and Measurement. As they narrowed the focus, they reached a consensus that the greatest degree of difficulty was teaching two-digit computations of addition and subtraction to Grade 2 students. As in other research (Lieberman, 2008; McLaughlin & Talbert, 1993), the teachers in this group saw the importance of meeting and collaborating with a goal towards improving some aspect of their teaching and the learning of their students.

The rationale for the goals was unanimous agreement that students had only a tenuous hold on concepts related to multi-digit computations when they graduated from Grade 2. The following dialogue reveals some of the rationale for their decisions:

Jane: The Grade 3 curriculum is so packed with new concepts. They have to learn multiplication and division when they still do not have addition and subtraction down pat. Grade 3 is also a shorter year. They have to write the EQAO test in May. It's just so cramped. Some of the kids who aren't coming out of Grade 2 strong really miss out.
Sara reiterated this concern: I told Mike [her student teacher] that this is one area of the curriculum I really don't feel I do justice to even though we seem to spend an inordinate amount of time on it. At the end of the year, the students are not solid in this area. They make random, unreasonable mistakes.
Mary: The other thing with addition and subtraction is that they don't know which one to use when they are given a problem. They just make a guess and then go ahead and use whatever.
Jane: Yes. When I taught addition, they were okay with the problems but then after doing subtraction and I mixed the problems up, they were all over the place when it came to which to use: addition or subtraction even though they could actually do the computations correctly on paper.
Kelly: I also find that they just don't know their basic facts so when they have to work on two-digit computations; they have a lot of difficulty. Yet, two-digit computations are the expectations for Grade 2.
Their opening discussions illustrated their natural strength as a group in defining a common purpose and a vision for where they wanted to go. As Ernest Boyer (1995) stated, "Community begins with a shared vision. It's sustained by teachers, who as school leaders, bring inspiration and direction to the institution….Teachers are without question, the heartbeat of a successful school" (p. 31).

The teachers' reasons for choosing two-digit computations varied, but their main reason was a common disturbing element in the learning of the students in their classrooms, namely, the challenge of learning two-digit computations. Professional learning communities are often faulted for their lack of common purpose, or more specifically, a lack of commitment to a common purpose (Little, Loucks-Horsley, Hewson Love, & Stiles, 2008). This is often the case when purposes are externally and generically imposed, with only a nod to the actual realities with which the teacher is contending. In this instance, the imposition was intrinsic and collegial.

The teachers' professional knowledge formed the basis for the setting of their goals. It was specific to their needs so it provided motivational impetus. Self-direction is a key motivator for adult learning (Tough, 1979). Knowles (1980) states: “Adults have a self-concept of being responsible for their own lives…they develop a deep psychological need to be seen and treated by others as being capable of self-direction” (p. 83).

The teachers personally connected through a common goal that had professional relevancy to their teaching. It was an authentic problem. When a problem is authentic, it no longer becomes an add-on to the school day, but instead an invigorating possibility of action towards a solution. As a PLC, they had captured one of the key elements of successful professional development – an authentic problem that once solved, could
improve student learning (Bolam, 2005; Louis & Marks, 1995; Hannay, Wideman, & Seller, 2006).

**Stages of Mathematical Development**

A significant shift in the teachers’ understanding of teaching and learning mathematics occurred over the course of the PLC. In the beginning, their curriculum strength was in literacy, an area of high concentration in their board’s professional development projects. Ruth's comment in their initial discussions revealed the tension that elementary teachers often feel. She said:

> We have come so far with what we do in literacy. We have so many strategies that we can introduce for students who are having difficulty with reading and we are usually successful these days. But in mathematics, we don't have strategies except more practice. Some of the students get it that way, but even after a short period of not doing facts, half the class will seem to have lost them.

Many elementary teachers are confident in their strategies for teaching literacy, but not for numeracy. In the continuing dialogue in the PLC, the teachers also brought to the surface issues of concern about their confidence in their past training. The teachers themselves did not feel they had a repertoire of strategies to offer to students. This is important when the amount of expertise and experience is considered. All of these teachers were interested in mathematics teaching and learning, as witnessed by their volunteering for a project focused specifically on this topic. They had just recently been participants in the Ontario Ministry of Education's training sessions on Number Sense and Numeration in which they had been designated the primary division mathematics leaders for their schools. Despite this, they stated that their professional learning from both their pre-service and in-service experiences had been inadequate.

Their concerns about the adequacy of pre- and in-service professional learning have
been corroborated by many elementary teachers both in Ontario and internationally (NSDC, 2009; Sinclair, 2005; Suurtamm, Graves, & Koch, 2005; Wilson, 2003). They also discussed the number of hours of pre-service training they had received. Their pre-service training in mathematics ranged from a low of 20 hours to a high of 36 hours. In their undergraduate work, none of them had taken any mathematics courses. Their mathematical experiences are reflective of primary teachers as a whole, as indicated by the Ontario Ministry of Education Expert Panel Report on Mathematics: K-3 (2003).

In addition, a broader political context constrained their professional development in mathematics. Literacy training has been the dominant force for professional development provincially and locally. Significant funds at the board and provincial level were allocated to professional development in literacy. Anecdotally, teachers and consultants at boards reported that the intense pressure on literacy initiatives was reducing time and money for mathematics reform. In my experience at the Ontario Ministry of Education, I was able to view the board level plans for most of the province, literacy was the predominant, and in most cases only, professional development initiative for elementary.

The teachers’ discussions at the beginning of the PLC illustrated some common misconceptions about mathematics learning, particularly about the learning of computations, which was the focus they had chosen for their PLC. Their conversations indicated that addition and subtraction should be taught separately from one another; that basic facts needed to be memorized, that lack of fluency with “basic facts” was the cause of multi-digit computational errors, and that problem solving with addition and subtraction should be introduced only after computational fluency.

Research literature does not support these initial beliefs about mathematical
Current research indicates that students can learn 'basic facts' best when integrated within a problem-solving context with emphasis on conceptual understanding (Carpenter & Fennema, 1999; Fosnot & Dolk, 2001; Kilpatrick, Swafford, & Findell, 2001; Ma, 1999). Research has also shown that when students only know how to solve problems through memorization, they may not develop effective strategies such as “making tens” or using derived facts that will not only help them with the basic facts, but also with multi-digit computations (Carpenter, Franke, Jacobs, Fennema, & Empson, 1998; Fosnot & Dolk, 2001; Henry & Brown, 2008; Ma, 1999; Wright et al., 2002).

Mary and Jane both talked about teaching addition and subtraction in isolation from one another and then found that the students were often unable to determine the correct operation to use to solve a problem. Mary shared an incident with a subtraction worksheet from the previous year. Although it was supposed to be a review of subtraction problems from a few months previous, a large number of the students solved them using addition and had the right answer. She had the students redo it because they had used the wrong operation from her perspective at that time. Many educators would counter that those two operations are interchangeable and should be taught simultaneously (Carpenter & Fennema, 1999; Fosnot & Dolk, 2001; Kilpatrick, Swafford, & Findell, 2001).

In that case, a student could solve the following problem in two ways: Jan has four kittens. She sold two. How many does she have? One way would be to think two and how many makes four. The other would be four and two less makes how many. In my experience teaching Mathematics Additional Qualifications courses, I found this to be a common misconception that meant that teachers spent an inordinate amount of time trying to teach the difference between addition and subtraction without helping students find the
common concepts.

In several models of teacher community (Carpenter, Fennema, & Franke, 1996; Schifter, 1996; Wilson & Berne, 1999), it was found necessary for teachers to re-learn the mathematics curriculum. To teach concepts well, teachers need to know them well, and as indicated earlier, they often have had limited experience with mathematics. An important component of effective mathematical learning communities is the mitigation of teachers' difficulty with the concepts (Schifter, 1996).

In the first transcripts of the PLC dialogue, it is obvious that several themes are becoming apparent. The teachers have the initial skills to make collaborative decisions about goals that will improve student learning of mathematics. They are motivated to move forward toward those goals, but some inherent misconceptions about mathematics teaching are evident. In addition, the broader political context was identified as affecting their students’ learning, namely, the overabundance of expectations for students to learn between grades two and three, and the added factor in grade three of the Ontario Education Quality and Accountability Office (EQAO) test. Jane, who had a grade one and two combined classroom, stated:

I find that the grade three students really have a heavy curriculum. They come in still struggling with addition and subtraction and they have to quickly learn multiplication and division. All that by the time the EQAO test begins in May.

The importance of these initial discussions is that the teachers were able to frame some of their own problems. It also highlighted some of the misconceptions that they brought to the problems.

In their first few meetings, the group shared some of their values and beliefs about teaching and learning mathematics. This was an important component of the PLC.
Articulating values and beliefs are crucial first steps in setting up a professional learning community (DuFour, 2004; Grossman et al., 2000; Hord, 2008; Little, 1999). Shared values and beliefs help a group move forward with greater efficacy and synchrony. Hargreaves (2003) has stated that only PLCs focused on real, as opposed to superficial, values of teaching and learning are effective.

Each one of the group members spoke of the value of problem solving, manipulatives, assessment driving instruction, and the primacy of understanding over rote memory. These are all components of a reform view of mathematics (Ball, 2000; NCTM, 2000; Schifter, 1996; Van de Walle, 2001).

Jane: I went through without good instruction in mathematics.
Ruth: I did well in mathematics but I don’t think I really understood it. I abandoned it after high school.

At the end of the discussion, Melanie said:

We seem to have mostly had bad experiences with math and we all seem to want to teach it differently than we were taught. I think the most important thing is to remember to teach through problem-solving as much as possible. I know I am not doing enough of it.

In retrospect, some of the values and beliefs these teachers appeared to share were an illusion. There was consensus in some areas such as the importance of drawing meaning from mathematical learning. However, greater dissection of their values and beliefs would have been helpful at this first juncture of the PLC. Views on mathematics education seemed to arise from a common perspective but in reality did not.

Because their conversations were at high levels of generality, they obscured the implicit beliefs teachers had about reform type mathematics teaching and learning. Each member attributed their own meanings from the discussion based on their personal lens of what it means to teach and learn mathematics. For instance, Sara, spoke out about the
importance of manipulatives and there was apparent consensus for her view. She stated:

One of the most valuable things I learned in my student teaching days, was using manipulatives to teach mathematics. I realized I really didn’t know what multiplication really was until I did it with base ten blocks.

Later in the project, it became obvious that there was a wide range of variance in the incorporation of manipulatives into lessons. In some cases, the manipulatives simply took on the role of a concrete worksheet with rote rules on how the manipulatives were used (Van de Walle, 2001). Melanie stated:

I let my special education children keep a set of counters in their desk so they can get at them easily. I only let the other children have them sometimes because I don’t want them to begin to rely on them.

In other cases, the manipulatives were used as tools for thinking with a more open approach to how the students used them (Van de Walle, 2001). Ruth shared:

I try to give them questions that are pretty hard but which I know they will get if they use tools. The base ten materials are good for that. You can give them higher numbers in a problem than you normally would and yet they can see the similarities between using two counters to find 1 + 1 and using two one hundred blocks to find 100 + 100.

Although all of the teachers had been consistent in their praise of the use of manipulatives to generate models of mathematical concepts, there were some critical differences in the interpretation of how manipulatives assist understanding. Part of the group viewed manipulatives as a crutch for those students who were less successful in their mathematical thinking. The others viewed manipulatives as a tool to be used at each stage of mathematical learning to help illuminate high-level mathematical concepts. In that view, manipulatives were as valuable to the highest achieving students as to the lowest ones.

Those who favoured the former model of manipulative use tended to spend more
time at the front of the lesson ensuring that the students knew exactly how to carry out a procedure. Those using the latter spent more time at the middle of the lesson looking at what students had done, sharing the different strategies among the students, and having students explain their procedures. Wilson (2003) confirms this dichotomy between what teachers espouse as beliefs, but enact in practice. She contends that it is the effect of not providing teachers with in-depth opportunities to explore their beliefs and share their practices.

This incongruity between what the teachers seemed to be saying they believed and what they actually practiced had some ramifications for how the two groups conducted themselves when they met in their separate groups later in the project. It created a tension between the participants. How the teachers viewed the manipulatives influenced how the students used them. This, in turn, affected the observations of the teachers when they worked with the students in each other’s classes. What looked like appropriate use of manipulatives to one teacher was judged inappropriate by another.

The teachers in this PLC had participated, as their school’s primary mathematics lead, in the Ontario Ministry of Education training over a three-day period. Although much more significant professional development than many other teachers were receiving, it was not sustained over time, nor did it allow for teachers to go into any one area of mathematics in-depth. The use of manipulatives as 'thinking tools' was a central component of the training (Van de Walle, 2001). The teacher change that the training anticipated had not occurred with all these teachers because it required a qualitative shift in their values and beliefs.

Teachers hold implicit knowledge or beliefs, often hidden from view, within the
isolation of their own classrooms. For the unveiling of this implicit knowledge (Schon, 1983) there is a need for solvency in our values and beliefs.

The facts of life do not penetrate to the sphere in which our beliefs are cherished…they can aim at them continual blows of contradiction and disproof without weakening them; and an avalanche of miseries and maladies coming, one after another, without interruption into the bosom of a family, will not make it lose faith in either the clemency of its God or the capacity of its physician. (Proust, 1913)

Wideman (1991) found that, in order to change beliefs, teachers first have to change their practices. In this respect, professional learning communities offer an important opportunity to both unwrap and reformulate implicit beliefs about mathematics. Over the course of the PLC, there were multiple opportunities for the teachers to take risks and to use manipulatives in ways that were more open. The opportunity to change practice in the comfort of collegial support was an important component of this project for the teachers. As is analyzed more fully later in this chapter, the teachers needed to feel success before they were going to change the tried and true practices that had, in their opinion, served them well in the past. The opportunity to learn by doing, talking with others, and self-reflection (Wenger, 1998) allowed the teachers opportunities to move along a personal learning trajectory that helped lead them to more "expansive patterns of thinking" (Senge 1990, p. 3).

In the initial meetings, the teachers reflected on their students' prior learning of basic facts. For many of their students doing basic facts meant memorization. Those who were weak at memorization modeled the facts using counters or their fingers, if the numbers were low enough. They did not have a repertoire of strategies for finding out the answer if their memory failed them or if they wanted to double-check their answer.

The teachers' discussion indicated that their students developed their understanding
of basic facts through a traditional approach that emphasized memorization over understanding. They stated that the students learned the facts in Grade 1, and sometimes in kindergarten, by working with concrete materials. Sara said:

At first, students are given counters of some kind to directly model addition. For instance, to do a basic fact such as $3 + 8 = 11$ they would put together three counters with eight counters to show $3 + 8 = 11$. This is used with each of the facts. Once students recognize that addition is a joining computation, the rest of the teaching would involve memorizing the facts in groupings such as $3 + 8 = 11$, $8 + 3 = 11$, $11 - 3 = 8$, $11 - 8 = 3$ and then in random groupings of basic facts, $8 + 3 = 11$, $9 + 1 = 10$, $7 + 4= 11$, $6 + 3= 9$, $5 + 5 = 10$, $4 + 5 = 9$.

The intention of this last grouping type was to ensure that the students had the facts memorized and could answer the questions in randomized situations. Some of this same process was followed as review for the students in Grade 2. (Field notes, January)

Memorizing mathematics facts in this way has been a standard practice in many elementary schools for much of a century and has been invalidated as the most effective way of learning mathematics facts since at least the 1950s (Brownell, 1956), and by much research from all over the world during the last 30 years (Fosnot & Dolk, 2001; Fuson, 2003; Hiebert & Carpenter 1992; Ma, 1999; Van de Walle, 2001; Wright et al., 2002).

The teachers were anxious to find meaningful ways of teaching students their facts. They were aware, from their own in-servicing sessions, that it was important for children to understand the underlying concepts in mathematical procedures, and they wanted to improve their own teaching practices in this regard.

The importance of focusing on student learning has been apparent in all of the literature I was able to find on professional learning. Just as medical research that is not focused on keeping patients healthy probably has little relevance, effective educational research takes as its first principle, the educational care of students (Englert & Tarrant,
Student improvement in mathematics was a primary motivator for these teachers. Their sense of self-efficacy and self-worth (Bryk & Schneider, 2002; Rosenholtz, 1989) was dependent on their positive contribution to the mathematics learning of their students. Students who were having difficulty learning mathematics were an ongoing concern and provided the impetus for investigation into research around some of the issues. Sara said:

I have several students who must be learning disabled in mathematics or very developmentally delayed. The others are at different stages but I don’t find them as strong in mathematics as they could be. Especially as they are quite strong in reading and writing.

Melanie had a similar story. She also had a student in the same situation and that she was searching the internet, particularly the NCTM website, to find activities to help the children who were having difficulties in mathematics.

Not one of the teachers said that they felt that their students were achieving their best. Kelly said, “We focus so much on literacy and we see the rise in achievement there but in numeracy, we just have not had the same drive forward.”

Their discussions demonstrated how they shared their new knowledge of mathematics learning and engaged in an intellectually stimulating enterprise. They scrutinized new knowledge in light of experience and developed new strategies based on the combination of research, evidence, and their practical knowledge. This type of thoughtful dialogue is at the heart of any effective professional learning community. The knowledge sharing is particularly effective as a professional learning tool, and the teachers in the group obviously enjoyed this opportunity for such rich conversations.

“participation” (p.15) for professional learning communities. I think they make an important point about any group of individuals sharing mutual experiences.

Each person is unique, both in personal and professional dimensions. Some of this group was more cognizant of newer models of teaching mathematics than the others. Some were more adept and confident working in mathematics and this seemed to be related more to their attitude towards mathematics than from any specific training or the influence of others. If we can think about differentiated professional learning for teachers in mathematics much as we consider differentiated instruction as crucial for meeting all students’ needs, the inherent logic becomes obvious. Thinking of multiple corridors provides a metaphor of different entry points to a common destination. Any group of heterogeneous professionals deserves the respect that allowing different entry points provide.

The teachers set themselves a challenging task. They had a repertoire of teaching strategies from their literacy training, which had been very extensive over the previous five years. They were aware of the importance of student talk, focusing on inquiry, and identifying prior learning. A one-hour literacy block was the norm with this group, and they had used it to good effect to ensure that students were able to approach new literacy skills from a variety of entry points, rather than rigid adherence to any one literacy strategy. This, together with the Ontario Ministry of Education training, gave them a foundation for laying down new mathematics pedagogical content knowledge.

Still, incorporating so many new ideas into their lessons and their teaching strategies put them at the very edge of their own zones of proximal development. It created cognitive dissonance. The acquisition of competencies in new pedagogical strategies is
compounded in mathematics because of the unfamiliarity with the content that is rarely a consideration in elementary literacy. My notes from my earliest interviews with the teachers indicated that they were at various stages of mathematics reform in their classroom. (Field notes, January)

Mary and Kelly had previously engaged in reform-like teaching practices. They routinely allowed their students to use manipulatives, and they provided opportunities for students to share their findings with other students. They also tried to keep problem solving as the focus of their instruction. The greatest challenge, Mary had found, was keeping the students motivated to persevere with mathematical problems. Kelly found that some of the children would use the manipulatives to represent a problem accurately but their subsequent work did not reflect the same understanding.

The balance of the teachers had also adopted some reform-like strategies, but on a smaller scale. Mary, Kelly, Jane, and Ruth were allowing their students to use manipulatives all of the time. The other teachers allowed them only in certain circumstances, such as if the child was having difficulty with the mathematics. None of them felt they were providing enough time in their lessons for reflecting and connecting even though they all agreed on the concept. Mary expressed that she had provided that time when she taught in the junior division, but was not sure how well Grade 2 students would cope with the experience. In subsequent meetings, the teachers began to look deeply at issues and used research to defend or defeat ideas that would influence student learning. They educated themselves about mathematical issues and through their discourse, created a continual learning loop that fed into their practices in the classroom. However, when an innovation too greatly deviated from past practice, it was too far
beyond the bounds of their personal zone of proximal development to be understood or assimilated. (Field notes, February)

There were issues that arose out of their readings on “invented strategies.” Their discussions regarding “invented strategies” indicated hesitation in adopting it as a new strategy. There was almost a 50/50 pro and con split. There was a level of conservatism within the ranks of the teachers. It is hard to be a pioneer in tradition bound institutions like schools. By their own admissions, the teachers who were most hesitant to undertake such a radical strategy were cautious because of the cultural milieus of their school environment, but also by their own comfort levels. Deviating so far from the comfortable type of addition algorithm with which they were familiar was too radical for some of the teachers. The group reached no consensus over the use of “invented strategies.”

As Shulman (1986) suggested, pedagogical content knowledge requires the convergence of knowledge of subject content with knowledge of how best to teach that content. There is the added complexity of few models or exemplars of what it looks like when it is done well. Together, these teachers were responding to the challenge of improved pedagogical content knowledge from their individual positions on a learning trajectory that began with their prior learning and moved according to their capacity.

Using Research

The teachers had chosen single and multi-digit computations as the area of greatest need and they wanted to address this need by using research. They especially focused on mathematics texts by John Van de Walle and Juanita Copley, and some of the research from Karen Fuson, Catherine Twomey Fosnot and Maarten Dolk, Constance Kamii, and Liping Ma. The teachers were particularly intrigued by the use of thinking strategies,
such as the use of problem solving, and by the use of manipulatives such as ten frames, hundred charts, number lines, and using simple mathematics games. Before the PLC, none of the teachers had used ten frames, hundred charts, or number lines. The types of manipulatives they had used in the past included pattern blocks, counters, and some minor use of base ten materials.

In the next couple of meetings, the teachers discussed some of their readings. It is important to consider their discussions about these readings, and what it says about the nature of the PLC.

Lifelong learning is a fundamental expectation of teachers. Teachers preparing for a performance evaluation would ignore this term at their peril. Although the term is ubiquitous in education, its defining features are often murky. Does lifelong learning mean superficial participation in professional development or meaningful engagement in professional learning? These teachers were lifelong learners of the meaningful engagement variety. Their introductory discussions made it apparent how much work they had done in literacy, and how it had transformed their practice. Mary said:

I remember when we first began doing leveled books and guided reading, how impossible it seemed at first. Especially, getting the students to learn how to be independent while I was working with a group. Now, it is so much easier to manage. I teach reading in a very different way than when I first started out.

Sara concurred and added:

I don’t have a way to organize my students through mathematics the way I can take them through guided, shared and independent reading strategies. It is just harder for students to work independently in the same way as in the reading block.

Their off-hand discussions about shared, guided, or independent reading strategies came from a well of deep understanding about literacy. Their discussion about literacy also made apparent their “core values-based identities which relate[d] to strongly held
purposes and principles of care and commitment to pupils’ learning and achievement” (Day, Elliot, & Kingston, 2005, p. 577).

The readings that the teachers did, mainly on their own time, formed an important component of this research. The following section outlines the teachers’ discussions about their readings. I think they are important because they reflect considerable self-directed learning and a sincere concern for helping students learn mathematics.

Melanie was the first to share her readings. She said that her interest was piqued by the development of children’s understanding of computations. In particular, she gave the example of students moving from a counting-all strategy for solving computations to a counting-on strategy, which is a more efficient way of calculating. She demonstrated the example that, at an early stage of development, students will model a problem with cubes or pictures such as putting seven cubes on one side and four on the other and then 'counting all' to determine the total. At a later stage, they may be able to use a “counting on” strategy. A student who had counted seven counters into a container would not need to recount them in order to add four more. Instead, they would begin the count at 7 and continue counting through to 11 as represented below:

```
"7 … 8 … 9 … 10 … 11.
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Mary’s reading was less about developmental levels and more about specific, pragmatic strategies that seemed most effective for student learning. She read that
students seem to learn certain basic facts such as doubles (e.g., 3 + 3 and 6 + 6) more easily, and that they can use such known facts to derive answers for unknown facts (e.g., 3 + 4 is related to 3 + 3 and 6 + 7 is related to 6 + 6). She gave the example of using a known fact such as 6 + 6 = 12 to determine an unknown fact such as 6 + 7 by reasoning that the answer would be one more than 12. (Field notes, February)

Carole, who had taught a grade one previously, shared that in her experience students did seem to find doubles easier to remember. She shared a strategy she had used with grade one such as having students think of a spider's legs as an example of 4 + 4.

Carole: I have my students make posters to help them remember the doubles: Double 3 is a bug double: three legs on each side. Double 4 is the spider double: four legs on each side. Double 5 is the hand double: two hands. Double 6 is the egg carton double: two rows of six eggs. Double 7 is the two-week double: two weeks on the calendar. Double 8 is the crayon double: two rows of eight crayons in a box. Double 9 is the 18-wheeler double: two sides with nine wheels on each side. (Ontario Ministry of Education, 2003a)

Sheila shared a strategy for multi-digit computations that focused on adding the tens together first, then adding the ones that combined to make the next ten and then adding on the remaining ones. She demonstrated the following example: 38 + 26 can be further decomposed into 30 + 20 and 6 + 8, which can be recomposed into 50 + 14, which equals 64. She said she thought it might be a good strategy for some of her students since she had already started using it for her own mental computations and found it effective.

Mary shared the 'making tens' strategy. This involves adding on to get to a friendly ten number first, and then adding, tens, and ones. For example, students might find 8 + 5 by adding 2 to 8 to get 10 then adding 3 to 10 to get 13 as follows:

\[8 + 5 = 8 + 2 + 3 = 10 + 3\]

or 18 + 38 by adding 2 to 18 to get to 20; then adding 30 to 20 to get to 50; and then 6 to
50 to get to 56 as follows: \((18 + 2) + 30 + 6 = 20 + 30 + 6 = 50 + 6\)

Mary also talked about another strategy that she liked although she had never seen it done before. This strategy was the open number line. She found that it was a common strategy in the Netherlands (Fosnot & Dolk, 2001). Below is a facsimile of her demonstration of this strategy.

Mary explained that the student uses an open number line such as this one to calculate \(36 + 35\). By showing computational steps as a series of jumps (drawn by arrows on the number line), students can visualize the number relationships and focus on jumping to the next ten in the computation: \(36 + 10\) takes them to 46, plus 10 takes them to 56, plus 10 takes them to 66 plus one, plus one, plus one, plus one, plus one takes them to 71. She said that this strategy was touted as particularly effective with students who were having significant difficulty with mental mathematics.

Mary mentioned she was interested in base ten materials as a manipulative. Only one of the teachers, Carol, had used base ten materials with grade two students and she did not find them very successful for her purposes. Carol did not have base ten materials available so she showed the other teachers by making a drawing of base ten materials
similar to that shown below:

![Diagram of base ten materials and ten frame](image)

Carol explained that having 10 or more ones requires that each group of 10 ones be grouped to form a ten (and that 10 tens be regrouped to form a hundred, etc.). After combining the base ten materials (e.g., ones with ones, tens with tens, hundreds with hundreds), students would determine whether the quantity was 10 or greater, and if so, regroup the materials appropriately.

A final strategy that was of interest to the group was using ten frames. One of the books that they had shared amongst themselves was *Elementary and Middle School Mathematics* (Van de Walle, 2001). It contained a section on ten frames and they were interested in using them with their students. Each number on a ten frame is represented by a black dot such that a ten frame for the number 1 would have one dot, for the number 2, two dots etc. So, for instance, in answering a question such as five plus six, four of the counters from the five would be added to the six to fill up the ten frame which would leave one filled ten frame and one ten frame with only one counter for an answer of 11 as
follows:

\[ 5 + 6 \]

\[ \begin{array}{c|c}
\bullet & \bullet \\
\bullet & \bullet \\
\bullet & \bullet \\
\hline
\bullet & \bullet \\
\end{array} \quad \begin{array}{c|c}
\bullet & \bullet \\
\bullet & \bullet \\
\bullet & \bullet \\
\hline
\bullet & \bullet \\
\end{array} \]

becomes 10 + 1

\[ \begin{array}{c|c}
\bullet & \bullet \\
\bullet & \bullet \\
\bullet & \bullet \\
\hline
\bullet & \bullet \\
\end{array} \quad \begin{array}{c|c}
\bullet & \bullet \\
\bullet & \bullet \\
\bullet & \bullet \\
\hline
\end{array} \]

Ten frames are models of the representations of relationships in mathematics. Each number in an addition sentence is represented on each of the ten frames using counters. Then the numbers are added by taking counters off one ten frame and adding to the other to make a full ten. The answer becomes one full ten frame plus the number of counters left on the other frame. Ten and another number are ‘easier’ numbers to add than say 7 + 6 or 8 + 9.

The teachers further discussed the use of ten frames for multi-digit addition. The example below shows how a question such as 25 + 24, could be modeled:

\[ \begin{array}{c|c|c}
\bullet & \bullet & \bullet \\
\bullet & \bullet & \bullet \\
\bullet & \bullet & \bullet \\
\hline
\bullet & \bullet & \bullet \\
\end{array} \quad \begin{array}{c|c|c}
\bullet & \bullet & \bullet \\
\bullet & \bullet & \bullet \\
\bullet & \bullet & \bullet \\
\hline
\bullet & \bullet & \bullet \\
\end{array} \quad \begin{array}{c|c|c}
\bullet & \bullet & \bullet \\
\bullet & \bullet & \bullet \\
\bullet & \bullet & \bullet \\
\hline
\end{array} \]

The model could then be solved by combining all the ten frames into as many full ones as possible making the answer of 50 easily recognizable.

Jane was most interested in the ten-frame concept. The teachers were not familiar with ten frames and had not used them in their own practice. Although the teachers were
introduced to the ten frames during the Ontario Ministry of Education training, they were not sure how to actually use them with grade two students. They decided to develop a lesson introducing ten frames to the students as a tool for understanding the concept of 'making tens'. Helping students develop strategies around making tens became an important goal for this group and using ten frames seemed to be an appropriate way to develop this concept.

The teachers also discussed some of the concepts introduced during the Ontario Ministry of Education training. There were some pedagogical tools that they wanted to implement. One was that lessons be divided into three parts, Getting Started, Working on It, and Reflecting and Connecting. The three parts are described below and Appendix B (Lesson Design) provides a blank lesson design sheet that they used when planning:

Getting Started:
- Pose a thought-provoking question or problem.
- Use a balance of shared, guided and independent mathematics.
- Keep the focus on reasoning and problem solving. Encourage students to work on the task in pairs and to talk about their strategies.
- Encourage the use of representation - either concrete or pictorial.

Working on It:
- Use probing questions.
- Encourage the sharing of ideas.
- Encourage students to work on the mathematical task in pairs or groups and to talk about their strategies.
- Encourage students to share a variety of solutions.

Reflecting and Connecting:
- Allow time at the end of the task to have a class conversation to ensure that the students 'get the mathematics'.
- Highlight and emphasize the key mathematical concepts (Ontario Ministry of Education, 2003, p. 3:13).

The teachers wanted to incorporate this into their lessons. There were also recommendations to:
- encourage students to communicate their understanding;
- use manipulatives or other drawings to make representations of
mathematics concepts;
• keep the focus on problem-solving and inquiry;
• identify prior learning as the starting point for working with students. (Ontario Ministry of Education, 2003, p. 3:14).

After the teachers had done an initial set of lessons, with similar goals to the one discussed earlier, they came together again. In the second group meeting, the teachers revamped some of their ideas about how to approach the lessons and how to open them up to less inhibited instruction and more open acceptance of multiple solutions. Below is a description of some of the pertinent elements of their discussion and decisions.

The teachers shared some of the ideas from Van de Walle's book, *Elementary and Middle School Mathematics: Teaching Developmentally*, (2001) particularly the common errors around the use of manipulatives. Van de Walle says that when using manipulatives, teachers often structure the lesson so that students are directed exactly how to use a model as a means of getting an answer. The problem is that children follow the instructions without understanding the concept being modeled. A rote procedure hampers real learning.

A natural result of overly directing the use of models is that children begin to see them as answer getting devices rather than as thinker toys. When getting answers, rather than solving problems, becomes the focus of a lesson, children will gravitate to the easiest method available to get the answers. (Van de Walle, 2001, p. 10)

The teachers liked the idea of manipulatives as “thinker toys.” It was a way of self-assessing the use of manipulatives. They discussed the topic: “Were they genuinely introducing them as 'thinker toys' or as restricted templates for one way of learning?” They also discussed Van de Walle's (2001) features of good problems in mathematics with the intention of incorporating the attributes into their own learning. Van de Walle (2001) suggests that good problems must begin where the students are in their
understanding taking into consideration their prior learning. It should be interesting enough that students want to pursue it and solving it should help develop significant mathematical ideas. It should also be solvable in many different ways. Students should understand that the responsibility for determining if answers are correct and why they are correct is their responsibility. They should also know they will be called upon to explain their thinking (Van de Walle, 2001). He states, "It is a process that requires faith in children, a belief that all children can create meaningful ideas about mathematics" (Van de Walle, 2001, p. 11).

The teachers also read some articles from Fosnot and Dolk (2001) and Fuson (2004) that further elaborated on the manipulative trap teachers can fall into: using manipulatives as a model to illustrate a concept and assuming that what is described is what is actually perceived in the students' mind. Students need to make their own connections between the mathematics and the models or tools used.

Again, the teachers had used research and other mathematics literature to clarify their understanding and to acquire new knowledge about strategies for teaching and learning mathematics. As a group, the teachers discussed making some improvements for their lessons. In particular, they decided to open up the lesson to allow for multiple entry points into the problems. To do this, they decided to allow the students to choose their own strategies using manipulatives, or not, depending on the choice of the students. The students would solve their problems and then share their strategies with the whole class with the students explaining what they had done. Some further discussion ensued about the third part of the lesson:

The teachers discussed allowing more time for the sharing of different strategies by
the students at the end of the lesson. Often, this third part of the lesson, “The Reflecting and Connecting” part is missing because of time constraints, as the middle part of the lesson often expands into the time for the final reflection piece.

A decision was made to make the lesson revolve around a realistically problematic situation and to place more emphasis on the reflecting and connecting phase of the lesson. To allow for more time for this phase, the number of problems contained in the lesson was reduced. The teachers also wanted to use larger numbers as recommended in Fosnot and Dolk (2001) so as to encourage students to use strategies that were not necessarily dependent upon their memorization of basic facts. The problems contained two-digit numbers, and the wording of the problems was carefully chosen.

The teachers had read some sections of Van de Walle's (2001) book, *Elementary and Middle School Mathematics: Teaching Developmentally*, which described the different problem types that were conducive to higher level thinking in children. See Appendix C for a description of the problem types. Similar problem types can also be found in Hiebert and Carpenter (1992). Instead of just problems such as "There are 71 rabbits and 15 ducks. How many animals in all?" which is often referred to as a join problem with result unknown - they also used problems where the change was unknown, such as, "There were 71 rabbits and some of the rabbits had babies. Now there are 89 rabbits. How many babies were added to the group?" Another problem type is one where the first amount is initially unknown, such as there were some rabbits at the farm. The farmer bought 15 more. Now there are 89 rabbits. How many did the farmer buy?

The teachers also discussed broader issues of mathematics learning in the primary grades. As they moved to a concentration on developing conceptual understanding and
problem solving in their students, they talked about large gaps in the students' knowledge and understanding. They had read some parts of Ma's (1999) work on Chinese and American teaching of mathematics. They recognized a new spectrum of underlying concepts in what looks like simple mathematics, such as multi-digit computations. They were particularly intrigued at how the Chinese teachers could investigate a child's learning by probing for their understanding of key concepts that undergird basic fact computations. Ma (1999) gave the following question to her study participants who taught Grade Two:

53 - 26

The Chinese teachers pointed out that there are several ways to solve a question such as that: 53 can be decomposed into 40 and 13. Then 26 can be subtracted by decomposing it into 6 and 20 with the 6 subtracted from the 13 and 20 from the 40 for an answer of 27 as follows:

Or they said they could decompose 53 into 40 and 10 and 3, then decompose 26 into 20 and 3 and 3. The advantage of the second way is that it is easier to subtract 6 from 10 than from 3 as follows:
Alternatively, they could simply regroup the subtrahend 26 as:

\[
\begin{align*}
53 - 26 & \quad \rightarrow \quad 53 \quad \text{is} \quad 40 \quad \text{and} \quad 10 \quad \text{and} \quad 3 \\
3 - 3 & = 0 \\
10 - 3 & = 7 \\
40 - 20 & = 20 \\
0 + 7 + 20 & = 27
\end{align*}
\]

Subtract one 3 from 53 and get 50. Then we subtract the other 3 from 50 and get 47.

Finally, we subtract 20 from 47 and get 27.

The Chinese teachers expected their students to do a simple multi-digit fact, as shown above, in a multiple of ways depending on which way made the numbers easier to subtract. There was not only one-way to solve a question like the one shown. Students
handled such questions flexibly in a manner that made it the most effective for them. The Chinese students were much more flexible in their thinking, using decomposition of the minuend or subtrahend in whatever way made the most sense within the context of the numbers being used. There was an expectation that students recognized that a number like 53 decomposed into 50 and 3; 40 and 13; 30 and 23; 20 and 33; 10 and 43, etc. The teachers in this research had never thought about having 53 divided into anything other than five tens and three ones. The implications of being able to decompose 53 or 27 into whatever way made the computation easiest for the students was a novel concept for the teachers.

The PLC group discussed the implications of Ma’s (1999) research. They identified with the North American teachers in Ma's study. The North American teachers in Ma's study did not have the same understanding of subtraction, nor did they find it important to teach decomposition of numbers in the same way as the Chinese teachers. The North American teachers taught the formal algorithm in which students borrowed from the five to make the three into 13 and making the five into a four. Although what was really happening in the traditional algorithm was that 53 was being decomposed into 40 and 13, the North American teachers, in general, did not explain it that way, nor did they expect their students to understand it that way. Consequently, students thought in terms of “borrowing” and “carrying”, without understanding that it was a regrouping action. They also had no other strategy to help struggling students understand what they were doing other than more practice and repetition of the rules.

In general, the teachers in this study were intrigued that students did not need to learn basic facts and that such facts were not routinely taught around the world, and
specifically, not in some of the high achieving school systems like China's (Ma, 1999). Rather than memorizing facts, a student could be taught the strategy of making tens, which involves thinking of all numbers in relation to 10 so that 12 is 10 and 2 more, 7 is three less than 10, to better understand how numbers can be decomposed so that they are easier to work with. The group's fascination with this strategy became a main driver of their conversations about students’ learning in the post-lesson discussions. Thus, the focus for this community became both a new way of looking at the mathematics for themselves, as well as looking at the teaching and learning strategies that would improve students' understanding of the concepts in multi-digit computations, especially as they pertain to the importance of 10.

The prominence of the 10-facts as the single best predictor of over-10 addition fact memorization resonates with international findings. Students from high-performing countries, such as China, Japan, Korea, and Taiwan, have been reported to frequently use derived-fact strategies involving 10 during Grade 1 (e.g., \(7 + 8 = (5 + 2) + 8 = 5 + (2 + 8) = 5 + 10\)) prior to developing confident retrieval for the majority of the basic facts (Fuson & Kwon, 1992).

The PLC teachers looked at Ma’s concept of “knowledge packages.” Ma (1999) introduced the concept of the “knowledge packages” that Chinese teachers use to think about mathematical concepts. The teachers discussed the Chinese teachers “knowledge package” (Ma, 1999) for subtraction with re-grouping:

They began to think of a knowledge package for addition of multi-digit numbers (Figure 8) and brainstormed the following based on the one that Ma (1999, p. 19) had developed.
With this knowledge package, the teachers felt that they would have a framework for diagnosing problems that a child was having with the multi-digit computations. The following is a summary of their discussions in this regard: The teachers decided that one key strategy might be simply to go back to composing and decomposing ten. Their discussion included introducing students to the commutative property to help them understand that if $7 + 5 = 12$ then $5 + 7 = 12$. One way to do that would be to provide opportunities representing combinations of numbers with counters on a sheet of paper, such as five on the left side and seven on the right to make twelve. Explorations that included turning the sheet around so that seven is on the left side now and five is on the right side, and having students explain why it is still the same amount, might reinforce the concept. This way, teachers could observe whether the students still needed to re-count.
If so, then the students did not understand the concept of commutativity. The teachers discussed ways of providing multiple experiences to assist students in becoming confident in the commutativity of the numbers.

The teachers also discussed the knowledge package above as something that would have been helpful for teachers in kindergarten and Grade 1. Simple things such as a very strong understanding of the quantity of five and 10 in kindergarten and how numbers relate to those two important anchors would have provided important background understanding for Grade 2 students as they tackled the more difficult concept of two-digit addition. They felt that students introduced to some of these critical concepts in kindergarten and Grade 1 would not have the difficulty that they were having in Grade 2.

The teachers’ sharing of their reading of research and other evidence-based material was a consistent contributing factor to their discussions across all of their meetings together. One of the principles of adult learning is that it needs to include some degree of choice and the conviction that new learning is of some value to the day-to-day realities of the adult (Broad & Evans, 2006). Adults need to make connections between research and their professional identity (Broad & Evans, 2006). Teachers request professional development that (a) is current research-based; (b) addresses pedagogy and content knowledge within the context of the teachers’ learning experiences; and (c) provides opportunities for sharing (Ball & Wilson, 1996; Lieberman, personal communication, May, 2008; Loucks-Horsley et al., 2003; Sykes & Darling-Hammond, 1999).

Cases

This section describes five cases: Melanie’s First Lesson, Mary’s Classroom, Sara: Finding New Ways, Sheila: Parental Boundaries and Jane: Mathematician’s Chair. Taken
together these cases help to explore the realities and challenges of implementing change in
the classroom.

**Melanie’s First Lesson**

Melanie conducted the first lesson. This lesson confronted the complexity of
changing practice in mathematics and hence, the onset of cognitive dissonance in the
teachers. Melanie’s lesson uncovered a deep rift between what is envisioned for a lesson
and what actually transpires. It highlighted the challenge of changing practice within the
realities of the context of the classroom, especially as it pertains to both the students’ prior
knowledge and the teachers’ comfort zone with new strategies.

The following excerpt provides a vehicle to deconstruct the challenges of change in
practice but it also, in its aftermath in the PLC, demonstrates the ways in which the
collective can provide the impetus for change in the face of that challenge.

Melanie was one of the first teachers to do a lesson with her class. She introduced
an activity with ten frames using a picture book called "The Mitten" (Jan Brett, 1998).

The students entered the classroom at the beginning of the day. They had well-
honed routine skills, independently organizing their outdoor clothes, and finding
something to do while they waited for the morning announcements. Melanie appeared to
have remarkable classroom management skills. Melanie had a warm, companionable
relationship with the students. When they first came in the door, they were anxious to tell
her new information about baby brothers, baby kittens, dance recitals, and the fact that the
kindergarteners were eating icicles off the side of the fence. The students were also
excited about being observed by so many other teachers. They knew in advance that there
were going to be guests in the classroom, and that they would videotaped, so a few had
dressed for the part in their best outfits. One little boy with wet, well-combed hair, whispered to his friend, “My mom said we might be on VR Land [TV station] tonight.”

After the announcements, Melanie called the students to sit in a circle on the carpet. This is the “Getting Started” part of the lesson described earlier. This is a class that is immersed in literature all day long, and Melanie has previously shared her belief that using picture books is an important stimulus for exciting children about mathematics.

Melanie read the storybook "The Mitten" about the loss of several mittens. As her class does with all picture books, they read the copyright date, name of the author, etc. The class figures out the age of the book based on the difference of the copyright date and the present date. The students count up from the copyright date. The class also counts the different characters in the book. The reading of the book takes about seven minutes. The storybook does serve to generate interest in the students and it is obvious that the students are very familiar with the use of story as the introduction to a lesson in mathematics.

Melanie then explained the activity and the grouping arrangements. Students are to work in pre-assigned groups (the lists of which are written on the board) and solve a problem related to the information in the picture book using ten frames, which are a manipulative that they have not used before.

Melanie introduced the task:

Melanie: In your groups, everyone is going to get two mittens: a blue mitten and a yellow mitten. Everybody gets an envelope that says, The Mitten. You will be working together. The first thing you need to do is to pick one of the cards, and they’re all numbered. What number is that Dustin?
Dustin: Twelve.
Melanie: Twelve. And everybody gets one of these sheets and whatever number is on these cards will be on these sheets. So if you pick number twelve, what would you be looking for on this sheet? Nicole.
Nicole: Twelve.
Melanie, to a student next to her: Can you find number twelve?
Student: Right there
Melanie: Right there. Okay. Twelve and twelve. Because you'll be filling out information on this sheet. Can someone read what this says? Brittany.”
Brittany: Eight bears plus eight wolves.
Melanie: So what we’re doing is using all of the characters from the book and we’re going to be adding with our cubes and with our mitts, which are our ten frames. Okay so if I want to show eight bears, how do I show eight bears on my first ten frame. Okay, Trisha, come up and do it for us.
Trisha puts cubes on the ten frame.
Melanie: So how many cubes is she going to be putting on the first ten frame? Gregory?
Gregory: Eight.
Melanie: Eight. Representing eight bears.
All right. Thank you Trisha, that’s great. Now I have eight wolves. How am I going to represent eight wolves on my next ten-frame mitt? Andrea, come and do it for us.
Andrea puts eight cubes on the ten frame.
Melanie: Okay, finished? Great. Thank you. So we’ve got eight bears and eight wolves. How are we going to use up our first ten frame? What are we going to do? Cause we’re thinking tens. Alex?

![Image of ten frames]

Alex: You move some of those ones on to the other one.
Melanie: Can you come and do that for us please?
Alex moves two counters over from one ten frame to the other.

![Image of ten frames with moved counters]

Melanie: Okay. Is this right?
Class: Yes.
Melanie: [Pointing to the full ten frame]. Okay how many do we have here? On my ten frame. This is my what? Cassidy.
Cassidy: Ten.
Melanie: No. How many full ten frames do I have completed?
Cassidy: One.
Melanie: One. Everybody see that? It’s got all ten spaces filled. So how many ten frames is that? Carrie.
Carrie: One.
Melanie: How many left?
Mackenzie: Six.
Melanie: Six, all right. So what you need to do on this sheet is fill in how
many ten frames. It says right on the sheet “how many ten frames?” What am I going to put down? How many ten frames? Adrianna, how many ten frames do I have?
Adrianna: One.
Melanie: One. So I’m going to put next to number sixteen, one ten frame. Can everybody see that? All right, and how many ones do I have left over? How many units do I have left over? Units and ones are the same.
Student: Six.
Melanie: Six. Got that? Okay that’s one done. Let’s go through one more very quickly. What does it say here Scott?

In the “Getting Started” section of the lesson described above, the students were having obvious difficulty with the ten frames. There were few hands up as Melanie asked the questions. Melanie herself reflected later that it felt like pulling teeth to get anyone of them to answer and she was relying on her most mathematically inclined to answer the questions. Still, Melanie needed to do a lot of prodding even of her strongest students to get an answer. The lesson had devolved into a lesson about the pragmatics of using the manipulative tool, rather than a lesson about understanding the mathematics that may or may not have become more understandable through the use of the manipulative. Melanie was teaching a procedure, not a concept, and both of those elements seemed to become more opaque as the lesson continued.

Students, who had moments before, during the story, been faultless models of studious attention, began to wiggle in place with surreptitious glances into space. It was an awkward moment for the observing teachers. We were also wiggling in our seats and trying to avoid glancing at one another. This excerpt is not shared to point to a lesson gone awry. It was a pivot point, a marker for an important discussion about the use of manipulatives and the difficulties of introducing them well.

The discussion after the lesson referenced the challenges addressed above. At first, there was no discussion of this part of the lesson. There was an empathetic air to the
group. They were all in this together, and any one of them could have been first up to be observed. No one, not even in the gentlest of terms, began the discussion on this first part of the lesson until Melanie broached it herself. I saw this as professional propriety.

In face-to-face encounters around a small table, these teachers knew the rules of congenial relationships, and they were not going to open themselves up to charges of professional conceit by criticizing another teacher. Melanie finally broached the topic. She made public her private concerns about the lesson. Melanie said she had wanted to avoid “teaching by telling”, but the difficulty the students had with understanding how to use the ten frames kept forcing her back into that role. She felt she was clear in her plan about the mathematics she wanted them to explore, and she liked the construction of the problems but the students’ difficulty with the ten frames detracted from the problem-solving component and hindered understanding, rather than enhancing it. She said that if we had not been there, she would have abandoned and re-thought the lesson as it was.

Melanie’s admission of her own dissatisfaction with the lesson opened the gates for the other group members. There were boundaries that they were not willing to cross until Melanie signaled, through her own words, that she wanted to have a conversation about it. This would be a milestone for any professional learning community. Moving from congenial to collegial (while remaining congenial, which I still think is important) is a difficult step as other researchers have found before us (Sergiovanni, 2004). There was consensus in the group that the lesson was too prescriptive, but they also affirmed Melanie’s pluckiness in being the first one to venture forth as the guinea pig for the rest of them. The interchange of thoughts and ideas about manipulatives, difficulties of teaching them to students who were not introduced to them previously, and students who had their
own ideas by Grade 2 about the “right way” to do addition ensued. The teachers also discussed alternatives to how a lesson on ten frames could be introduced. They were experienced teachers who had introduced many new things, many different times. They decided that the old, but true strategy of giving students a chance to explore would help the students become more comfortable with the manipulative.

Their interchange suggested unwritten, unvoiced codes of behaviour for how they planned to interact with one another. They were congenial to a fault, sensitive to each other’s feelings, but also willing to engage in difficult conversations about mathematics teaching and learning, once they were assured they would not be overstepping some boundary of professional courtesy.

The rest of their discussion then moved to the second part of the lesson, “Working on It”, in which the students worked on the problems Melanie had provided. In this section, the students had shared their ideas in pairs and then further shared them with the larger group. The teachers distributed themselves around the room, observing a group of students.

Appendix D is the “Chart for Recording Group Work – Grade Two” that the group had designed specifically for “The Mitten” lesson. It provided a lens for concentrating their observations on the specific learning of the students. Of benefit to the host teacher was the fact that, after the lesson, she had a significant amount of anecdotal data on each of the students in the classroom. These charts also helped keep the focus on discussions on student performance.

The teachers discussed Melanie’s lesson and how the students were obviously not familiar with either ten frames or the use of tens for constructing single-digit addition.
Jane mentioned that the ten frames became the focus for the students rather than the understanding of the mathematics. The others agreed. They felt that the students thought the most important component of what they were doing was to fill the ten frames correctly, rather than to consider the mathematical understanding they were to acquire. As Van de Walle (2001) has noted, manipulatives are best used as the means to an end, not the end itself. They are best used as thinker toys (Van de Walle, 2001) or models for interpreting problems (Fosnot & Dolk, 2001). In a California large-scale mathematics initiative, Wilson (2003) found that manipulatives were often insufficiently touted as evidence of reform mathematics when the more important evidence would have been why and how manipulatives were used.

Melanie identified the difficulty the students had with the concept of using tens to work with single-digit addition. Some of the students already knew their basic facts so many reverted to solving the question in their head. For instance, they appeared to be thinking the following: "I know the fact 7 + 6 = 13, so instead of actually making a 10 by taking 3 from the 6 and adding it to the 7 and then adding on the other 3 to make 13, I will simply fill one ten frame with counters and then the other with 3 counters without actually using the strategy that was being highlighted in the lesson.

Ruth said that the group she observed appeared to be finding the strategy useful and they were students who did not seem to have the basic facts automatized. Using the frames, they were able to get the correct answer. However, they were using some regressive strategies such as recounting all the counters on the ten frames, even when they should have known it was 10, so no recounting was needed. Other discussion focused on the fact that although the students were getting the right answers for the questions, they
were not making the connection between the facts themselves and using the making tens strategy. For instance, they did not solve 7 + 5 by making the 10 and then adding on the remaining 2. They related many instances where they asked the students what the digit 2 represented in a number such as 23, even when they were looking at two full ten frames and a ten frame with three counters, they still said 2 rather than 20 or 2 tens.

The teachers concluded that most of the students were following the pattern that they had seen Melanie model, and then they followed it routinely, but mindlessly, without understanding the concept of making tens, which the lesson was meant to elicit. They were following a procedure, albeit using manipulatives, but without making the necessary connections that would move it from a rote activity to a more meaningful understanding of number. Secondly, the repetition of the problem in which the only change from problem to problem was the number of bears and wolves constrained the students opportunity to learn. It became a low-level counter pushing activity as the counters were moved from one ten frame to fill the other.

This lesson demonstrated a common challenge that teachers face when trying to teach using a novel tool or strategy. The students do not see the mathematics in the tool or recognize the pattern of the ten frames designed to help them think in terms of tens. In this lesson, the use of the ten frames was a rote activity. The students made one number on one ten frame and then another on the next. Then they joined the two by moving counters to fill one ten frame fully so that the sum was one full ten frame and a partially filled ten frame. The lesson used direct instruction to teach the strategy.

In a reform mathematics-based classroom, a more common approach would have been to use the manipulatives in a more nuanced fashion – providing the students with a
problem, then suggesting that they find multiple ways of solving the problem using the ten frames or other methods, and encouraging the students to communicate their ways with their peers. In that context, the students' work could be shared in the “Reflecting and Connecting” section at the end of the lesson. That way, the teacher would have the opportunity to help highlight the different methods used and let the children think about how they would have done the question in a different way than they did.

Ma (1999) found that it is:

One thing is to study whom you are teaching, the other thing is to study the knowledge you are teaching. If you can interweave the two things together nicely, you will succeed.... Believe me, it seems to be simple when I talk about it, but when you really do it, it is very complicated, subtle, and takes a lot of time. (Ma, 1999, p. 136)

Melanie’s lesson above demonstrates a few things that were critical to the teachers' early learning. It shows the difficulty of teaching the use of manipulatives to students. It also indicates that teachers, no matter how well intentioned, when in a stressful situation in which students do not seem to be getting the concept, move into a fallback position of making the lesson and the teaching very prescriptive. The most surprising consideration about this lesson is that it was enacted after the Ontario Ministry of Education training which promoted a different notion of teaching mathematics, both after Melanie’s own research and reading, and by a phenomenally strong teacher who was chosen by her administration to be the primary division mathematics lead. Melanie recognized her retreat into old default positions of teaching and learning mathematics, and she was able to draw new lessons from it to share with the group.

The professional learning community meeting after the lesson portrays the larger group formation issues. Melanie was a risk-taker in opening herself up to the scrutiny of
others, especially when students were not getting the concept. The incident was an important learning opportunity for the group about how they would interact with one another. The emerging ethos of the community was uncovered. They had adopted a group dynamic that adjusted for social niceties while still allowing for intellectual discourse that was critical, student-focused, and research-based.

This hesitancy to broach criticism was also recognized in the work of Hargreaves (1999). He found that participants are often hesitant to leave their zone of comfort and to confront dissension that might reduce the congenial nature of the group. By staying within that zone, though, the opportunity for growth and improvement of the group is constrained. In this case, Melanie broached the dissonance herself thus opening up discussion by the whole group without risking group disharmony. The problem that can arise from PLCs is the possibility that they simply share ignorance, unable to transcend the horizons of their own narrow experiences (Hargreaves, 1999). However, the adjustment for social niceties did continue to circumvent honest discussion in some cases. Although the lesson had much to criticize, the group did not do so until Melanie herself opened it up to discussion. Without tacit permission from whoever was the teacher of the classroom under discussion, the rest of the group approached difficult criticisms hesitantly.

Some of the unique characteristics of this entity called a professional learning community were beginning to become apparent. In a professional learning community (DuFour, 2004), it is important that the primary responsibility is to students’ growth, and I agree that this is an important factor that is reinforced in most of the literature that I have read on professional learning communities.
Interestingly though, Grossman et al. (2000) have a slightly different slant to that theory. They describe the beginning stages of community formation as narrowly focused on responsibility to students’ learning. In the more mature stage, the group is committed to colleagues’ learning as well. This PLC had just witnessed through Melanie’s experience, the reality that sometimes colleagues’ learning comes at the expense of student learning, and although no professional would want to consistently espouse the benefits of students’ non-learning, a one-off experience of this nature creates the crisis that encourages change.

**Mary’s Classroom**

The teachers explored the use of open-ended questions, opportunities for whole group sharing, and the use of manipulatives. They also shifted to a deeper discussion of the developmental levels of the students themselves, becoming more articulate about describing what students could or could not do. They pursued ways of helping students become conceptually stronger in mathematics.

Mary demonstrates this growth in observing students in her anecdote of a small group of students’ learning:

Jacob needed to count all of the counters to determine how many, even though he had already seen that a full frame equaled ten. Only if a frame was not filled would it be less than ten. So you would think they [the students] would have felt confident enough to just add 10 and 1 more without re-counting the full ten frame. In Grade 2, it would be expected that the students would have the concept of “adding-on” instead of ‘adding-all’ to determine the total of the two amounts. Also, if they had a pattern recognition of 10 as being two rows of 5, again they would have recognized that the one ten-frame represented one 10 and did not have to be recounted. You would also expect them to be "subitizing'. [Note: Subitizing means automatically being able to tell that a group of objects represented a certain number without counting. By Grade 2, students can subitize up to eight objects if they are discretely arranged, but they can subitize even larger amounts once they recognize patterns in numbers, such as the two rows of five making 10.]
In her own reflection she says:

I feel I am beginning to find that my assessment is becoming more specific. I find if I write down things like, Jake can subitize; or Joseph can count-on, it provides me with valuable information for thinking about what to do next and also for the report card.

Mary’s growing confidence was mirrored by the mathematical confidence of her students. The following is a description of one of the later lessons in Mary’s class.

Mary’s classroom is a very math and child friendly classroom. There are two bulletin boards dedicated to mathematics. One is a math word wall with brightly coloured index cards pinned to it. On the cards are math words written in a variety of children’s handwriting with hand drawn pictures in some cases. On the other bulletin board is a problem of the day and a ‘just for fun’ section which has a couple of cartoons. Behind Mary’s desk is a series of Escher pictures in black and white. Mary introduces the lesson from the front of the classroom and the children sit themselves on the carpet in front of her. Behind Mary is a whiteboard on which there is a hundreds chart as well as samples of ten frames representing the numbers 1 to 10. At the top of the board was a number line from 1 to 100. Along one side of the classroom was a set of shelves with bins full of math manipulatives. The bins were labeled by name and with a picture of the appropriate manipulative. Mary told them a story about how she likes to do beading and showed them some necklaces that she had made in the past. She then presented them with the following problem:

Amie went to the store to buy some beads for the necklace she wanted to make her mother for Mother’s Day. She needed 27 beads. Her sister also wanted to make the same necklace for her Grandmother. How many beads would Amie need to buy?
The students were encouraged by Mary to solve the question in the most efficient way for them and to be prepared to explain their answers. The students worked in pairs. When the students were finished, Mary chose a few students to demonstrate their answers in front of the class. There were manipulatives, an overhead projector, a chalkboard, and chart paper available for the students to use to help communicate their understanding if they needed it. One of the students, Jeff said, “I know 20 and 20 is 40 plus 7 is 47 plus one more 7 makes 50 and then 54.” He demonstrated this on the board using a three-step strategy:

20 and 20 is 40  
40 and 7 is 47  
47 plus 7 more makes 54

Ava presented her solution using the 100 chart. She said:

I just keep a picture of the hundred chart in my brain and I know that if I start at 27 and then go down two spaces, it is just like adding to 37 and then 47 and then I have another 7 left over and three of that takes me to 50 and 4 more gives me an answer of 54.

Ava demonstrated on a hundred chart so the other students could see her thinking.

Kaitlin used the open number line (a strategy that Mary had previously shown the class) and did jumps of 27, 37, 47, 50, 54.

Brianna said, “27 and 23 is 50 and there are 4 left, so it is 54.” She modeled her understanding on the overhead projector using base ten blocks.

Adrianna said that she thought about money and she knew 25 cents plus 25 cents is 50 cents and that left another 2 and 2 so the answer is 54.
Mary’s class was a Grade 1/2 split. Two of these students, Adrianna and Brianna, were in grade one. Their number sense was very impressive for any primary student, but the fact that they were so young shows the significant mathematics that students can learn when they are encouraged to become mathematical thinkers. The students were flexible in their thinking. They came up with their own strategies and then Mary encouraged them to try each other’s strategies and decide which one they preferred. Mary obviously worked hard at having her students explain and justify their answers to problems in a variety of ways. They were encouraged to use flexibility in determining which strategy to use in a given situation. (Fieldnote: April)

In their PLC discussion after the lesson, the teachers reflected on some of the benefits of using a variety of strategies for solving multi-digit computation as Mary had done. The students were able to answer questions mentally. Mary shared that in her previous classes most of her students could mentally answer questions such as 20 + 30 because they knew 2 + 3 and just tacked the zeroes on. However, they would not have been mentally able to answer more complex questions such as 27 + 35. Many of the students in this class were able to do the computations mentally as long as they could look at a hundreds chart. She also said that these students made fewer errors because they were not solely relying on their memory of basic facts. When a student gave the response to a basic fact such as 7 + 6, they were asked to tell their teacher another way of proving that the answer was 13, rather than just because they knew it or because they counted on from 7 by 6 counts to 13. She reinforced with them daily the importance of using a strategy such as ‘making tens’ to make every question easier to answer.
Mary also said that she found that the open number line strategy was helpful for students who were particularly challenged when learning mathematics. She introduced it to the class and reinforced it by modeling its use whenever she could. Not just during mathematics class, but also when counting money for pizza orders, and other everyday mathematical routines. It was a strategy that her students could use throughout the multi-digit combinations and some were using it for harder computations such as $350 + 242$, which they did not need to learn in Grade 2, but which came up when they were calculating things such as measurements with centimeters.

Following Mary's lead, several of the teachers began to use a hundreds chart on a daily basis for short five-minute mini-lessons review. They found it to be helpful for students. Mary said, “I feel the hundred chart gives them a mental model of the number system.”

The patterning of numbers found on the hundred charts was especially useful for those students who did not naturally come to an understanding of place value, and the consistencies of place value throughout the number system.

Later in the project, Mary shared a videotape of one of her students explaining his answer to a question using the hundreds chart. One of the principals had been a high school math teacher. He commented, “I had many students in my applied classes who would not have been able to do that.”

**Sara: Finding New Ways**

Sara, who worked with a pair of children who were using ten frames and having significant difficulty, shared this observation about her students’ learning. She said:

Once they moved them [the counters on the ten frames], they knew they had one ten frame and three more. But, they didn’t know it was thirteen. They had to go back
and count.

And one little girl said, ‘So you have eight and five and…’ she has her fingers under her desk. And I said, ‘Well, look at the paper and tell me what you’ve got’. She still couldn’t come up with the number. Even though she had the answer on her paper, she had the one in the tens column and three in the ones column. It wasn’t like a number to her. She couldn’t make the connection that she knew the answer to five plus eight.

Because of these types of observations, the teachers began to reflect on how they could move their students forward in their understanding. They talked about the difficulty that the students had when they were still so reliant on counting-all and even counting-on.

At one of their early meetings as a whole group, their discussion turned to some of the materials they had read in *Elementary and Middle School Mathematics: Teaching Developmentally*, by John A. Van de Walle (2001). Sara suggested that they follow his chapter, *Strategies for Whole-Number Computation*. Sara’s suggestion included many of the things they had begun to try, such as the use of base-ten materials or ten frames to help develop the “making tens” grouping concepts. However, of some contention to the group was an alternative strategy that Van de Walle’s book suggested which was using “invented strategies.” Sara liked the strategy. The examples and research that Van de Walle produced in his book were compelling. There was, however, hesitancy amongst some of the teachers in the group to go that route. This reflects an issue that professional learning communities need to consider. It is the zone of proximal development that teachers, as all learners, operate within in any learning situation.

The next excerpt unveils this issue:

Jane: I can see how the strategy would be helpful, but what would happen when they go to the next grade. Their teacher will expect them to do addition the same
way as usual. I couldn't do that at my school.
Carol: I want to do the invented strategies with my class, but I know I am going to have to get them to relearn some of the mathematics because they learned the old way last year. Some of the kids won't want to change now that they think they have it right. Their parents might not want them to either.
Sara: I think I would do the invented strategies so they can understand the mathematics. I like what Van de Walle says about them being able to do the math mentally better and I know my kids have difficulty with mental math.
Mary: Yes. Mental math is something parents are always impressed with.
Jane: I am going to do the invented strategies first and then move to the traditional way, but let them do it whichever way they wish. That way I have covered all the bases.
Sara: We could all draft up a common letter to the parents explaining what we are doing so they understand the rationale.

Despite Sara’s enthusiasm for the ‘invented strategies’ approach, other than Jane, Sheila, and Mary, no-one else of the group was willing to make such a dramatic deviation from their strategies of the past.

An issue that arose to the surface during one of Sara’s lessons was the use of place-value mats. Place-value mats were a standard tool used by all the teachers. The place-value mats have columns for showing ones, tens, hundreds, thousand, etc. One of the lessons by Sara focused on place-value mats.

Sara’s classroom was bright and cheery. Light streamed in from her large south facing windows. Manipulatives were neatly placed in bins across one side of the room. A hundreds chart and a number line were evident at the front of the class. The children’s desks were arranged in groups of four. Sara presented her lesson from the front of the classroom. She distributed place value mats and base ten materials to the students as well as a sheet with a variety of two digit numbers. The students’ task was to make numbers on the place-value mat using the ones and tens columns and then to fill in the blanks beside each number to indicate how many tens and how many ones. Sara used the overhead projector to demonstrate how to do it. She then called Megan to the front to
demonstrate a different number. Sara asked Megan to make the number 63 using the base
ten blocks on the place value sheet. Mary placed the 6 ten rods and 3 unit cubes in the
appropriate place.

Sara: So how many tens and how many ones?
Megan: 6 tens and 3 ones.
Sara: How would you fill in this chart on the worksheet?

Megan demonstrated by writing on the overhead sheet that was projected on the
wall so everyone could see it. She put both numerals in the appropriate place. Sara
asked, “Does anyone have any questions?” No one responded so the students were told to
get started on the task.

The students began to work and the teachers from the PLC group distributed
themselves around the room. It was immediately apparent that very few of the students
were actually making the number with base ten materials on the place value chart. Instead
they skipped to the written part, putting the numerals in the correct columns based simply
by the appearance of the number. If the number was 71, a 7 was put under the tens and a
1 was put under the ones. The teachers began to probe the students understanding by
asking them questions such as what does this numeral stand for?

After the lesson, in the PLC, the teachers discussed their unanimous concern that the
students had little understanding of what the place value chart actually represented. The
students could get all of the answers correct, but not connect the numbers on the place
value chart with the numbers that they had been given to represent. If a teacher pointed to
the numeral ‘5’ in 54 and asked what it represented, the students would say ‘5’. Even
with prodding by the teachers to get the students to link the ‘5’ with the tens shown on the
place-value chart they had just completed, the students did not get the connection.
They discussed a video they had seen of a grade two student doing a task similar to the one these students were doing. In the video clip, the girl was asked to count out 26 counters and then to sort them into piles of tens and leftovers. The instructor in the video then pointed to the number 6 in the 26 and said could you show me the number of cubes this represents. The girl pointed and counted out 6 counters. The instructor asked her about the number 2 in the 26 and asked her to show those counters. The girl showed two counters. The instructor asked if she was sure. She nodded. The instructor then said what about all these other counters. The girl was mystified. She just shrugged. She did not understand that the numeral 2 represented twenty cubes.

The PLC teachers had found the same problem with the majority of students in Sara’s classroom. They did not understand place value in any true sense. The teachers connected this to their previous reading of the research from Liping Ma (1999). They decided using place value charts hampered an understanding that a number such as 53 could be more than 5 tens and three ones. It could also be 4 tens and 13 ones, or 3 tens and 23 ones.

This was a defining moment for the PLC. They recognized that a staple of primary mathematics instruction, the place-value mat, was not providing the type of understanding they wanted their students to achieve. One of the teachers, Sheila, had taught special education in the past, and she mentioned that in special education, place-value mats were the most frequent strategy used to help students who were having significant difficulties in mathematics.

The teachers were thinking critically about a common strategy pervasion in their instruction and a mainstay of the interventions they (and the special education teachers)
used to help struggling students. They were looking at the contemporary structure of their practice and the practice of those around them, and refuting an aspect of its relevancy. It was a small indicator of the reconstruction of their professional knowledge. The effectiveness of place value maps was part of the tacit knowledge, “the way we do things around here” (Deal & Kennedy, 1982, p. 4) that was being unwrapped. Some researchers consider this unwrapping as the first step to creating new mental models that are the hallmark of educational change (Hannay, Wideman, & Seller, 2006). “The first step is for educators to reconstruct their personal professional knowledge through identifying and challenging their tacit knowledge (Hannay et al., 2006, p. 20).

As the meetings progressed, the group's discussion also entered into different realms of professional learning. They debated issues and recognized inherent differences in the realities of their school cultures and their own tolerance for educational ambiguity. Sara’s experience caused them to rethink their use of place value mats.

**Sheila: Parental Boundaries**

Teachers often find resistance from parents to new ideas about teaching mathematics. Sheila was the first participant to discuss this issue in the PLC. Some of the strategies that she was encouraging her students to use were not familiar to the parents creating some parental anxiety demonstrated by a few notes and phone calls. Although her principal was supportive, he needed her to be able to articulate the why, what, and how of what she was doing. Her ability to share the research around a new strategy was important to the principal and he appreciated that she could defend what she was doing. However, to Sheila, parental anxiety was translating into pressure to return to more traditional models of mathematical teaching. This is a finding that was also confirmed by
Hendrickson, Siebert, Smith, Kunzler, and Christensen (2004). Hendrickson et al. (2004) found that it took intensive communication with parents, including information sessions leading parents through reform type activities, to help parents see the benefits of learning mathematics with understanding, rather than just relying on rote procedural knowledge. Their work also found that it was important to include the whole school faculty in these sessions.

Each of the participants in this professional learning community was the sole representative from their school, so there was not the same opportunity for presenting a united school front to parents. This meant that although Sheila was using some of these strategies in her Grade 2 class, the teacher across the hall was doing something different.

Sheila shared the fact that parents talk to each other, and if they see a discrepancy between the familiar traditional methods of one teacher and the unfamiliar newer strategies of another teacher, they may become anxious. A project by Hendrickson et al. (2004) found a similar situation. The introduction of invented strategies for multi-digit addition and subtraction created tension with parents. By "actually engaging parents in doing mathematics and sharing their solution strategies, parents were better able to appreciate the flexibility and understanding that come from invented solution methods" (Hendrickson et al., 2004, p. 2).

In any kind of new initiative, it is important to keep the parents informed. Parents who are positive about what a teacher is doing can become powerful advocates for new ways of doing things. "If parents are with you, they will bring the community with them. If they are not, they will stop you dead… You need their protection when hostile winds begin to blow" (Dolan, 1996, p. 157). Communication with parents is one of the most
crucial elements for acceptance of instructional change in the school or classroom (DuFour, 1998).

Sheila had to ride the wave of parental disapproval. She was able to keep her balance by being very articulate about what she was doing and she had research to backup her strategies. She also had a principal that was willing to support her as long as she could defend her position.

**Jane: Mathematician’s Chair**

One tool that facilitated the development of learning community in the classroom was demonstrated by Jane and then taken on by several of the other teachers. In Jane’s classroom, the students used the Mathematician’s Chair in the “Reflecting and Connecting” part of a lesson. The use of the Mathematician’s Chair as a tool for sharing information was adapted from the Guide for Effective Instruction (Ontario Ministry of Education, 2003a), which describes the use of the technique which is similar to the “Author's Chair” used in literacy (Routman, 1999). It was used so that the students could display their manipulatives and use them as props to explain their thinking to the rest of the class or to a small group. At one of Jane’s lessons, a student named Cyndi was the mathematician of the day and she was presenting a math picture book which was her reading homework from the night before. The book was about feet and there were various illustrations showing different combinations of feet.

Cyndie sat in a cozy armchair with a small table in front of her. A group of five students sat across from her. Cyndie pulled out her book and began to read. There was approximately one sentence of text on each page. She was a good reader and the text was simple with lots of illustrations. After reading the sentence on the page, Cyndie would
point out to the students the different combinations of feet. She said, “See here. There is one snail and two dancers so that is 2 and 2 and 1 which are 5 feet.”

Cyndie was enjoying her role and the students were interested in her book. At different points she would ask one of the group how many feet there were on that page and she would coach them as they put the numbers together to get the total. The other students appeared engrossed and engaged in the activity.

The Mathematician's Chair provides students with the opportunity to take on the role of a mathematician. They explain their own particular way of solving a problem, and then open up the discussion to the questions of the other students. Using this technique opens mathematics learning in several ways. It encourages the presenter to think about how to communicate his or her understanding. It also encourages the other students to grapple with their own understanding as they see it through the lens of someone else.

The use of the Mathematician’s Chair also provided Jane a quick and easy opportunity to make anecdotal observations for their assessments. Watching children explain their understanding allowed Jane to identify what children know, rather than just what they do not know.

Jane shared that, on one occasion, a child who had just presented an erroneous explanation and incorrect answer to a problem had to respond to the questions of a determined student who wanted to know how that could possibly be the correct answer when he had a different one. In the presenter’s response to her persistent questioner, she actually discovered her own mistake and was able to rectify it on the spot. The reciprocal relationship between presenter and questioner helped both children move from misunderstanding to understanding. A worksheet would not have provided the same
information for a teachers' assessment or for students' growth in understanding. It took mathematics out of the narrow scope of worksheet-induced endeavours into the deeper realm of mathematical explication of complex Grade 2 ideas. The teacher’s' observations while a child was the mathematician provided a detailed assessment of learning; an assessment that was valuable for helping a child think about their own learning.

The use of the Mathematician’s Chair was a stimulant for discussion amongst the students. They enjoyed the formality of sitting in front of their peers and presenting. Jane said that this simple addition to her lessons elicited better discussions from the students. It gave them something tangible and concrete to discuss. As Applebee (1996) stated:

If we do not structure the curricular domain so that students can actively enter the discourse, the knowledge they gain will remain decontextualized and unproductive. They may succeed on a limited spectrum of school tasks that require knowledge-out-of-context, but they will not gain the knowledge-in-action that will allow them to become active participants in the discourse of the field. (Applebee, 1996, p. 56)

Discourse was no longer dominated by the literacy component of the curriculum; discourse was also a numeracy strategy. The PLC teachers were strong in literacy so the use of the Mathematician’s Chair made a lot of sense. They knew enough research on oral expression to know the benefits of this type of strategy on any subject area.

Professional Learning Community Norms

This PLC evolved over the course of their meetings. They followed their own unique trajectory from individualism to community, but they still wanted retention of their distinctiveness. Grossman et al., (2000) point to a “sense of individualism” that “overrides responsibility to group’s functioning” in the beginning stages of group formation. In the evolved, mature stage, there is identification with the whole group and “development of new interactional norms” (p. 45).
The group did evolve to a state of recognizing the importance of the ‘group’s functioning’, but they also had very specific professional needs that included their own style of teaching, the specific cultures of their schools, and the idiosyncratic nature of their classrooms year to year. The idea of using the same lessons for each of their classrooms was problematic. They had such a wide range of diversity in their classrooms, it was not reasonable to expect the students to be at the same level of understanding. The teachers also recognized that they each had different styles and different classroom cultures that responded more favorably to certain teaching techniques than to others.

The teachers negotiated new norms, which would allow for more independence in how they conducted their lessons. The teachers decided to go their different ways as far as the particular design of their lessons, but remained committed to covering the same concepts but not in a lock-step manner. For these teachers, there were some aspects that warranted communal actions, but there were others for which they wanted creative control. Traversing the tide of personal preferences and professional partiality in a PLC can be treacherous. The teachers decided wisely, I think, early in the PLC to recognize their individual differences, and while staying true to their original goal, to accept that each one of them had different ways for setting up lessons in their own classrooms. New conditions for the lessons were negotiated within the group. Each of the teachers decided to develop their own problems based on the interests of their students and from other areas of the curriculum, such as books they were reading in class. They did not develop a set lesson plan that they would all do in their own classrooms, although the lessons were still based on common concepts. It was apparent that they needed flexibility to adapt lessons to the context of their classrooms and students’ interests. They decided on the parameters
of the lessons, but allowed the creative components, such as the context and other particulars, to come from the teachers' individual classroom interests.

It is a truism to say that teachers’ engagement is much like student engagement, but it is probably something that is constantly forgotten as new “sit n git” (Wren, 2003, para. 12) models of teacher learning are repeatedly reinvented. Just as children's learning depends on their attention and engagement in the learning process, teachers need to be attentive and engaged. Greene (2000) observed that “Once granted the ability to reflect upon their practice within a complex context, teachers can be expected to make their own choices out of their own situations” (p. 12).

Teachers are professionals. Their learning needed to follow an adult model which included autonomy and self-direction. These teachers wanted the flexibility to manage their teaching; to have dictated rules of engagement at this point would have created a "prison of micromanagement that [would] constrain[s] it" (Hargreaves, 2003, p. 165). As Wenger (1998) stated, learning is doing and experiencing and these teachers needed control over the doing and experiencing, while still accommodating their common goals.

There were several challenges that arose in the PLC, namely, the diversity of the make-up of the classrooms which mean they were working at different speeds, misconceptions about the research, and assessment. Those areas are discussed below.

**Moving at Different Speeds**

One challenge was the fact that different classrooms were at different stages of working with multi-digit computations. The reality of classroom make-up often influences the pace at which concepts can be introduced. Gladwell (2008) talks about the inordinate advantage that hockey players, born in January to June have over younger
players and how this manifests itself in the predominant number of ‘born from January to June’ players who make it to the National Hockey League (NHL). In education, we ignore this reality. The Ontario testing agency, the Education Quality and Accountability Office (EQAO), does not even collect data on this for Grade Three students who, because they are so young and birth date still matters, are the most vulnerable to the effects of being a year younger than the other students and in a split grade up to two years younger.

Sheila had a Grade 1/2 combined class with only a small group of five Grade 2 students. The Grade 2 students were placed in this classroom because of difficulties they had encountered with the Grade 1 curriculum the year before. Jane had a Grade 2/3 split with many more Grade 3 students than Grade 2 students. In this case, the Grade 2 students were already advanced in many of their understandings of mathematical concepts. Only four of the teachers, Ruth, Kelly, Melanie, and Sara had non-combined classes.

In keeping with the philosophy of teaching to the needs of students in their classrooms, the teachers decided to alter their lessons accordingly. Although the consistency across classrooms was somewhat lost at this juncture, in reality, it provided rich information for becoming aware of the range of mathematics development that governs the understanding of young children as they learn mathematics. This also demonstrated the very real considerations that any professional learning opportunity should address. An important consideration in designing professional learning communities across classrooms is the recognition of the different contexts for any one classroom, especially when the various levels of split grades (2/3, 1/2) are considered.

**Misconceptions**

In their readings and research, the teachers came across the idea of allowing
students to use their own “invented strategies” to calculate computations. There was a long discussion about the technique at one of the PLC meetings. An interesting offshoot of their PLC discussions about “invented strategies” was that it later became obvious that the teachers who were willing to adopt the strategy actually missed some of the point of invented strategies as a concept. They missed that it was a strategy that children invent for themselves based on their prior knowledge of mathematics. The technique usually involves having the students take what they already know about a concept such as addition and then develop their own strategy for the answer to a problem that involves computations that are more difficult. The students then share their strategies, try each other’s strategies, and then come to a consensus about which one is easiest for them to do. The teacher remains a guide in all this, helping to lead them to the importance of algorithms being efficient and accurate (Fosnot & Dolk, 2001; Van de Walle, 2001).

However, the PLC teachers who did adopt the strategy took it on as if it was a new formal algorithm with exact procedures that needed to be followed. They began to call it the three step strategy. The three steps involved breaking the numbers into their component parts and then adding them up. For instance, in the case of 23 + 29, the first step would be to add 20 and 20; the second step would be to add 9 and 1 to make 10 and the third step would be to add on the remaining 2 to make 52. This term was used in their discussions and in their classrooms. At first, this was a cause for some minor alarm on my part. Later I was able to see it as a step along the trajectory of their learning. The teachers in this case could have used some support. With a scaffold of support, they would have been able to use the strategy in its usual way. But in the end, the use of the “three step strategy” did not impede the students’ learning and did lead the students to new
insights about the composition of numbers. There are implications to this. They had relied on their own reading of the literature on invented strategies and had misconceived the process.

*Professional Learning to Reshape Teaching* states that, based on their research, “it is clear that educators acquire what they know by being told some things, by creating some knowledge themselves as they go about doing what they do, and by sharing their experiences, and reflecting on them with colleagues” (Hannay et al., 2006, p. 10). The teachers in this research were able to accommodate the strategy into something that worked for their purpose of getting their students to understand better the composition of number and the combining of numbers. They missed the point of what might have been a strong teaching tool in the use of “invented strategies” based on extensive research by others (Fosnot & Dolk, 2001), but that was not knowledge that they could attach to their prior understandings. It fell outside their zone of proximal development where only a guide or a mentor could lead them through and help them see the benefit of the strategy. Millet et al. (2004), in their research, developed the concept of “zone of enactment” (the levels at which teachers were able to implement change based on their own cognitive readiness).

Teachers can only implement change, which is within a realistic range of their capability based on their experiences to date. I think that is an important point. It fits with what we know about learning. Learning occurs within a learner’s zone of proximal development (Vygotsky, 1986). This is relevant to adults as much as to children. These teachers moved along a trajectory from prior learning to new knowledge that did not extend outside their zone of proximal development. The zone of proximal development is
actually a place of some discomfort (Vygotsky, 1986) and the tension of that discomfort plus the scaffolding of a knowledgeable guide is what moves learners along a growth trajectory. However, the level of discomfort that takes one outside that zone of possibility is too extreme for some, and maybe all, learners. I had a choice at this point to interfere and try to become the scaffold of new learning, but it was not a role I wanted to assume and I also did not think that all of these teachers were ready to move in that direction anyway. “Not all professionals learn in the same manner or are at the same point in their thinking or careers” (Hannay et al., 2006, p. 23).

Assessment

Especially in the primary grades, there is less concrete evidence of a child's learning than is available in the later grades. The teachers, in this study, talked about the importance of observation and anecdotal learning. Often what was shown in a paper and pencil task did not indicate where a child was going wrong in their reasoning, and sometimes their reasoning was actually very good, but not reflected on paper. In one of the later PLC meetings, Carol and Mary discuss a misunderstanding they had about a student’s work. They thought the child had little to no understanding of the concept, but on review of the videotape changed their minds. Carol said, “It is amazing how much more information you get when you can review what the students are doing on videotape."

Mary responded, "It makes me wonder how many times I have made that mistake; have assumed a child was wrong, when if I had probed a bit, I would have seen that they had it." The gist of that discussion continued over many of the sessions together. The teachers struggled with what to assess and when to assess.
Kelly: I like what Van de Walle says here. You don’t have to assess everything. But you can do those things that are really preliminary. The curriculum doesn’t really adjust for any of that preliminary learning, like Grade 2 addition strategies, which are necessary for understanding Grade 3 multiplication.

Melanie: And I think there are some expectations that should just be exposure because it will be good for them later on. But we don’t have to assess them. We know that a lot of what we are doing is pre-algebra and there aren’t really any algebra expectations [for number] for Grade 2. They are really just patterning expectations. So although you want to assure that they are using algebraic reasoning, you are not formally assessing that. You just know you are ensuring that they are learning that way.

Ruth: I think there is too much emphasis on measured value instead of learning. Or, too much value on reaching a common standard, rather than thinking, okay, this child started here and I got him to there. That is where the value is, but you lose sight of the whole thing.

The teachers’ deliberations around assessment also focused on how much more they were able to see when they actually observed students, especially in the small group sessions that this project allowed for.

Observing students creates its own dilemmas. It is difficult for teachers to carve out the time for such in-depth observations, and as some of the comments above indicate, without time to really probe a child's learning, it is difficult to know what they are thinking and hence how to help them overcome any hurdles in their learning. It also takes a level of expertise to be able to “assess on your feet.” In other words, to know what to do right at the moment that a child's misconceptions, or other difficulties with mathematics learning, are revealed.

Assessment is a main driver of educational change (Wiggins & McTighe, 2005). Teachers who can identify where their students are in their learning, where they need to go, and how they are going to get there have a distinct advantage for implementing effective educational change in their classroom. Those who do not will have little
motivation to make change, if only because they cannot be sure that the status quo is not already working well enough. Much of the pressure from the Ontario Ministry of Education and from Ontario’s Education Quality and Accountability Office has been on improving assessment practices.

According to Growing Success (Ontario Ministry of Education, 2008), assessment has three distinct and interrelated purposes:

- assessment for learning (diagnostic and formative assessment—to guide learning and teaching);
- assessment as learning (to engage in peer and self-assessment as they are learning); and
- assessment of learning (evaluation and summative assessment—to confirm what students know and can do, and to demonstrate the extent to which they have achieved the curriculum expectations). (p. 7)

The parameters of this thesis do not extend to “assessment of learning.” In other areas of assessment, some considerations need to be part of any PLC discussion. To assess for learning, teachers need to have a robust understanding of what learning in mathematics looks like. How do you know if a child has assimilated and accommodated new learning if you rely on worksheet types of assessment? The observations that the teachers made of both their own students and of the other students informed them of the many different ways in which students engage in learning mathematics that on the surface may appear to be misguided. Once prodded to explain their understanding, it is often obvious that the students do understand, or that just the right query of their learning can scaffold them into a zone of understanding.

In the case of assessment as learning, the students were engaged in this when they shared their learning with their peers, received feedback, and sometimes altered their work and understanding based on the input from their peers.
The teachers also modeled metacognitive strategies. Sheila worked through a problem with the students while using an open number line to model her thinking. Many of the students, when it was their turn to share their solutions with the class, would also use a version of self-talk to explain the decisions they made as they worked their way through a problem. An example of that was the student’s explanation of his thinking for a problem concerning 28 + 28 that did not involve money. In his explanation of his thinking, he shared how he changed the amounts to money to make it easier to calculate mentally. He said, “I know a quarter and a quarter is fifty cents and that leaves 3 and 3 to add to 50 so the answer is 56”.

Sheila shared how her modeling of meta-cognitive strategies provided her students with a self-assessment learning tool. By monitoring their own learning, students can scaffold their own learning. Self-talk, such as, “What strategies do I use when I see a problem that is difficult”? Sheila had taught her students to think about what their options might be, such as drawing a picture; using manipulatives; or replacing the numbers with easier numbers to work with so that the question’s solution path becomes more transparent.

Good formative assessment provides immediate feedback and loops directly into a student learning. It has been demonstrated to provide significant results in improving student learning and self-efficacy (Black & Wiliam, 1998; Reeves, 2008). The goal within a goal for the teachers of this PLC was really good formative assessment. Although it was not articulated that way at the beginning of the PLC, it was apparent as the PLC continued. Good assessment is the destination of choice for teachers, and formative assessment provides a roadmap through the diverse pathways of student
learning.

**Becoming a Community**

In the first meetings of the PLC, they were just that: “meetings” lacking the depth and reflection that marks real learning. Over the course of the project, the discussions became richer and deeper as the teachers evolved into a community of learners. A transcript from early and later dialogue reflects some of this transition:

Carol: Your class is so great. They hardly ever talk. Wait until you come to my class – they can't stop talking. I am trying the point system but it still isn't working that well.
Sheila: This class is pretty good. I would like to let them do more group work, but as soon as I let them work together, they get off track and start playing with the manipulatives or gabbing about something else. If I am sitting right there, they are okay, but I can't sit with every group all of the time. [Early Dialogue – January]

In the initial stage, the teachers’ discussions often focused on the mundanities of classroom life, such as classroom management, discipline, etc. Over time, however, they were able to use the dialogue to delve into issues more specifically related to teaching and learning. They modeled the social construction of knowledge (Vygotsky, 1986) that they were encouraging in their own classroom.

Mary: I notice that most are able to recognize that the full ten frame represents a quantity of 10. They are actually subitizing the ten frames when they look at two full frames plus five more and say 25 without having to go back and re-count the ten frames. You can see lots of concepts that they have developed: they recognize patterns; they are all counting-on, rather than recounting the whole group. They are using strategies to tackle the questions they can't instantly figure out. They are using what they know about 10 to figure out the answers.
Sheila: Yes, I know. When I opened the questions up, I got such great answers. They had so many different strategies, and even the weakest kids could tackle the question using the strategy that was easiest for them.
Mary: I wish I had done this with earlier classrooms. I am amazed at the level of math they are able to do. Some of them have been explaining these strategies to their parents. One parent said to me that her son said that they couldn't help him with his math anymore because they didn't know how to explain their thinking. The parents were a little taken back, but they were teachers so it was okay. They just laughed when they told me.
Carol: The thing I keep wondering about though is that if the next teacher just teaches them the algorithm, will they still be able to do this? Will they still use this way? What happens to them in the next grades? The teachers at my school don't really understand what I am doing. Half of them are using really old textbooks. They don't even use the newest ones we got two years ago." [Later Dialogue – April]

DuFour (1998) discusses the importance of professional learning communities moving away from low-level discussion of pragmatics, such as scheduling, discipline, etc., and into deeper discussions about teaching, curriculum, and assessment. The low-level discussions are appropriate for staff meetings but not for the valuable learning time provided by PLCs. As he says, a "learning community is not created by completing a series of tasks but rather by beginning a process of perpetual renewal” (DuFour, 1998, p. 284).

Newmann et al. (1996) describes the five most essential characteristics of professional learning communities as (1) shared norms; (2) focus on student achievement, (3) reflective dialogue; (4) making teaching public; and (5) collaboration among colleagues. This PLC reflected these characteristics from the beginning but only at a superficial level. Such characteristics take time and work. In the beginning, it is easy to say we share norms, focus on student achievement, etc., but it does not mean there is a true understanding of what this means for each individual in the group.

Newmann et al. (1996) does elaborate on what these five characteristics really mean. However, in other situations, they are sometimes taken as prima facie evidence that a professional learning community has effectively been formed without deconstruction of what each of them meant within the context of the professional learning community being discussed. Anyone of those five characteristics and all of them together could also be evidence of a very ineffective community committed to regressive practices
of teaching and beliefs about learning.

It is in the intervals between and throughout first formation and ongoing emergence that the integrity of the learning is established. It is the quality of in-between discourse about these issues that propels personal and communal efficacy. Shifts in learning occurred. The group mediated their own learning through stories of their students and classrooms within a jointly created communal space in which they felt safe and acknowledged. At this midpoint of the project, they knew each other's classrooms, students, and teaching style quite well. They had established group norms committed to ensuring both their professional learning and the learning of their students. Within this environment, they were able to grow in knowledge, breadth, and understanding of their students, the subject, and each other. Researchers often implicitly treat professional community as generic, but the nature of teacher community differs, just as teaching does, by grade level, subject matter, and by student population.

The teachers established relational trust (Bryk & Schneider, 2002). Through their interactions with each and through their strong commitment to the PLC, they displayed the four attributes of relational trust: respect for each other, the ongoing pursuit of competence, personal regard for each other, and integrity. Respect for each other was evident in the professional nature of their interaction. The pursuit of competence was reflected through sharing of resources. They constantly brought new resources to the group.

One of the members, Jane, had a teacher friend in Australia who forwarded some of the materials teachers were using there. The friend also sent information about changes that were taken place there in the area of early childhood learning in mathematics. The
teachers considered those changes in light of their own research. They were critical thinkers who could analyze the Australian policies and make informed opinions. Sara was a collector of picture books. She came to every meeting with a new piece of literature and information about how it linked to concepts in the mathematics curriculum. Other teachers brought in student work to share with the group and to ask their opinion about next steps.

Personal regard was evident when a situation arose around a parent communication gone awry. The PLC discussed some solutions. Together, they worked on a letter that could be used to share information more fully with parents. The members of that PLC followed up with the teacher in the situation to ensure that the letter had been helpful.

Integrity was demonstrated through the ongoing commitment to student learning. The teachers knew changes in practice take a lot of work and can be anxiety producing. They remained consistent in their pursuit of student achievement despite the roadblocks of time and stress.

An important component of the PLC was the opportunity to reflect on teaching and learning. Schon (1983) says people do not know what they are doing until they reflect about it. By reflecting on practice, the implicit becomes explicit (Schon, 1983). The teachers reflected on their practice through what they were seeing in their own students and in the students in the classes they had observed. The student stayed at the centre of these discussions. The teachers used their collective experiences to inform their personal instructional practices. In each group of teachers, they shared approximately 100 students working on similar concepts. They could be confident that their interactions with so many children at similar stages of development gave validity to their observations. Repeatedly,
they had seen similar behaviours in students that impeded learning, which included: a reliance on procedures without understanding, a lack of persistence when tackling a difficult problem, and difficulty articulating their learning. They also saw and shared their actions that helped students overcome those behaviours, such as allowing students time to share and talk; keeping problems open-ended enough that all students could participate at some level; encouraging the use of manipulatives as thinking tools and avoiding their rote use; and fine-tuning lessons so that topics of interest to the students were included in the lesson, such as the use of picture books or games.

This need for reflective practice in a PLC was also identified by Newmann et al. (1996) as one of the five most important characteristics of self-efficacy. As Lyons and LaBoskey (2002) state, an important pedagogical tool for acquiring knowledge is "intentional, reflective activity…socially and contextually situated" that interrogates "aspects of teaching and learning by storying experience" (p. 21).

Below is an excerpt that demonstrates some of their reflections:

Sara: I think it’s always about what the kids are doing. They’re learning in so many different directions. I noticed that with the classes that I looked at and my own. There was that different range. They’re going to make mistakes as they struggle with the concepts. They all make similar mistakes. You could actually chart the types of mistakes they are going to make. It makes me feel wiser as a teacher knowing that there are so many commonalities among students in Grade 2.

Jane: It would be nice to have known all of this at the starting of the year.

Mary: I find it interesting to look at the developmental levels of the kids and compare it with their experience. I find that experience can change that development. If you’ve never had experience with numbers you’re going to be lower on the development continuum. If you get more experiences, you will achieve better, right. I think it is tying those two things together not just sticking with ‘Well that’s development, we can’t move beyond that’. But it is also knowing how to get the child to the next level. Sort of like going through the level books in literacy. How do you get them to the next level, recognizing that some kids are going to start out in different places?

The PLC provided the teachers with a forum for vetting new ideas from their
readings, but also from other colleagues. They questioned assumptions. Rather than accept at face value a new strategy just because of its novelty, they analyzed it based on research, experience, and on beliefs about how children learn mathematics.

Mary: A teacher I was talking to was telling me about ten houses that she uses. I had never heard of them. They’re little boxes and every time they get 10, they put them in a little cart and that’s what she was teaching them.

Sheila: Do they put all of the ten back in?

Mary: They trade. So they get a stick with a different colour.

Sheila: It seems too abstract. Because if it’s a different stick and it’s 10 there’s still that part that they don’t always get. I know when I did my practicum a long time ago, the host teacher used to have different coloured sticks and one colour would be a ten, one would be ones, another hundreds, etc. I did not find that the students understood anything about unitizing. They really didn't have a solid grasp that the numbers were increasing by 10 each time you moved to the right. I think she felt she was using manipulatives to explain something, but I actually think she made it harder on the students.

There is sometimes a mismatch between new strategies that are enthusiastically introduced into the system, the research from the field, and the experiences of teachers. One stick (albeit in different colours) to represent each of the ones, tens, and hundreds in a number would not provide children with a model of numbers that had any connection to 10 being a collection of 10 things or one hundred being 10 collections of 10 things. The teachers' own experiences of children's understanding of number did not support it as an effective strategy. The strategy would not engage children in actively building their understanding of a new idea. Through professional dialogue, these teachers were able to come to this conclusion. Possibly, they would have come to it individually. However, the PLC offered the opportunity for group inquiry that confirmed the appropriateness of hesitancy in adopting the strategy. Just as teachers urge their students to become critical consumers of new knowledge, teachers need the same opportunity to make discriminating decisions about new strategies. The safety of solidarity with others who give the same
problem careful scrutiny allows teachers to withstand the pressure of conformity they might otherwise feel.

Professionals in any field are expected to stay current – to learn about emerging concepts of "best practice." However, they are not expected to suspend their professional judgment and embrace every new theory or idea that is presented. New concepts warrant consideration, experimentation, debate, and assessment before they become part of standard practice. The ongoing analysis of advances in research on curriculum and teaching is vitally important in improving schools, however, this analysis requires that teachers function both as "students of teaching" and as "consumers of research" (Dufour, 1998, p. 230).

Many researchers have found that a focus on student learning is crucial for a successful PLC (McLauugin & Talbert, 2001; Newmann & Wehlage, 1995; Stoll & Seashore, 2007; Supovitz, 2002). This PLC kept students' learning at the centre of the educational process and as part of that process, teaching practices that improved learning. At the end of the PLC, there was no direct tool available to the teachers to calibrate the level of learning. From their own past experience, they shared that they thought the students were better able to explain their thinking and that many of the students were actually much better at mental math than any of the students had been previously. We had several discussions at the end of the PLC in which the teachers wondered what results these students would have on the next year's EQAO tests. They also wondered if instruction was much more traditional in the next year and in future years, what influence it would have on the students. Would the student return to a focus only on the answer and diminish the importance of learning with understanding?
Building Learning Communities in the Classroom

Not only did the teachers work within a professional learning community, they also developed communities of learners in their classroom. Four features of classrooms that operate as learning communities are: the expression of students' ideas is valued; students are encouraged to use a range of strategies that they must be able to explain to their peers; use of mistakes as opportunities for learning; and developing a culture that supports learning (Kilpatrick et al., 2001).

The teachers made certain that there was time for the students to share their strategies with other students, justify their conclusions, and engage in mathematical discourse. The following is an excerpt from two students in Mary's class:

Jeremy: Paul, why did you use a hundreds chart to solve that question?
Joseph: Because I find it easier to keep track of the numbers. To add the 23 [to 27] I just go down two lines because that is 20 and then move three spaces to 50.
Mary [teacher]: So you go down two lines and over three. What does that mean?

Joseph then explained more fully that he was adding the tens first and then adding on the ones, and he re-demonstrated his actions on the hundreds chart. These types of conversations were new to these students and new to the teachers as facilitators of the conversations. Students were not accustomed to questioning each other’s answers. They were adopting the role of young mathematicians (Fosnot & Dolk, 2001) engaging in mathematical conversations with each other and with their teachers. They also discussed that it may have also begun to put mathematics on an equal footing with literacy, which was an area the students more commonly engaged in critical questioning, talking, and sharing.

New practices take time to take root. Weeding out the old does not ensure cultivation of the new. But growth in small things can sometimes cultivate much larger
gains. The teachers had begun to expect more than a right answer. The simple addition of “How do you know?” type questions opened up lessons to better communication. This is not a technique that becomes status quo overnight. By their own admission, the teachers varied in their feelings of efficacy in adopting new pedagogical strategies. Ruth said that she often reverted to previous strategies because they had been effective for her, but the one strategy that was easy to accommodate was simply asking “How do you know?” or, “Why?” and then not accepting, “I just knew it”, which was what one child had replied during the videotaping.

Expecting students to explain their learning also opened up the opportunity for teachers to scaffold student learning (Vygotsky, 1986). By questioning, the teacher could probe into the learning, marching "ahead of development and lead[ing] it (Vygotsky, 1986, p. 188). The teachers were seeking conceptual understanding (Kilpatrick et al., 2001), not just procedural accuracy. It is a path least taken because it is the rockiest route. Many times in my own experience, I have delighted in the acuity of understanding of a select few of my students while blithely ignorant of the fact that most of the class had not attained the same grasp of the concepts. The old cliché that I teach it well, but they just don't learn it, did not hold with this group. Teaching well had to be synchronous with students’ learning well. When students have the opportunity to explain their learning, whether or not learning is actually happening becomes apparent.

**Summary: A Movement, a Journey, and a Voyage**

The teachers collaborated as a learning community to find new strategies for overcoming the difficulty of meeting the range of learning needs in their classes. This is both a worthy and ethically significant way of doing professional learning. The findings
link the relationship between a specific professional development model and its impact on the learning of these specific participants. An overview of the findings is displayed in the Professional Learning Community Overview (Figure 9) shown below:

**Professional Learning Community Overview**

![Diagram showing the PLC process]

**Figure 9: Professional Learning Community Overview**

The PLC group began by seeking new knowledge about mathematics. They then began to implement the knowledge through new strategies and practices. At this point, it became an iterative process of trying things, abandoning some, and reinforcing others. The opportunity to reflect with colleagues at each stage of this process made it a richer experience. The opportunity to observe so many grade two students tackling the same concepts expanded the benefits of the PLC.

The teachers found that learning varies so dramatically from one class to the other, especially when comparing the students in a grade one/two with those in a grade two/three
that it was imperative that the PLC remained respectful of those individual classroom needs, rather than being dictatorial about what concepts, what lessons, or what assessment should be happening in all of the participating classrooms at the same time.

From my experience, working in professional development roles both at the board and provincial levels, I know that PLC's are expected to focus on some instructional or curricular strategy that everyone in the group is to apply in their classroom, with the expectation that such actions will provide measurable results. In fact, I began this project with the same expectation. The reality is that teachers do know a lot about their classroom. They are ultimately responsible and accountable for student learning. They cannot be expected to follow other teachers with higher achieving classrooms in a lock-step manner without sacrificing the very real need for differentiation of instruction that connects to the prior learning of their students in their classrooms. DuFour (1998) in his earlier work recognized the difficulty often encountered in PLC models. He said that:

Because of the factory model that has dominated the thinking of the twentieth century, there is a tendency to think of improvement in terms of production – develop a design, reduce the process into sequential steps, and proceed from step to step until the finished product has been created. The challenge of creating a professional learning community demands a new way of thinking about improvement because it does not accept the premise of a finished product. (DuFour, 1998, p. 284)

The teachers' view of mathematical learning was affected by their readings, observations of their students, and interactions with the teachers in their PLC. In the words of Fosnot and Dolk (2001), they were recognizing the need for children's "mathematizing" (p. xix) without undue teacher intervention. Probably the most important component of the PLC is that the teachers became both critical and reflective about their own practice. Just as students learn, teachers need time to pass through cycles
of moving forward, struggling a bit, and moving forward again. The best way to do that is through experience, practice, through community and self-reflection (Wenger, 1998).

As I stated earlier in this thesis, although there is no certainty that organizing professional learning communities will eliminate all problems, there is the potential for professional efficacy through the intellectual stimulus of many heads pursuing the same problem. Rather than the factory model, DuFour urges us to think in terms of Toynbee's (1958) description: "It is a movement…and not a condition, a journey and not a destination, a voyage and not a harbor" (DuFour, 1998, p. 284).
Chapter 5: Discussion and Conclusions

At the beginning of this thesis, I describe the genesis of this professional learning community. It evolved out of a large provincial mathematics initiative in which I was involved as a lead writer and trainer. I worked with others, who like me, were enthusiastic and positive about the new day in mathematics that we hoped would evolve from the training. We were not naïve. We knew the limitations of workshop models of professional development. However, three days of workshop training was all we had, so we prepared training materials that we thought would give teachers a wide sweep of the field of mathematics instruction, but not so much that it would overwhelm them. We were hoping that the seeds of the training would meet fertile soil in the minds of the primary mathematics leads and cultivate a growing interest in furthering their knowledge and expertise.

From the larger initiative came the opportunity to follow a small group of these teachers who were the primary mathematics leads in their schools into the relative privacy of their classroom lives. The opportunity presented the possibility of opening a window on one microcosmic aspect of the training’s effect. I wanted to see if a small group of teachers would overcome the limitations of a three-day professional learning session, and yet use it as a springboard to more in-depth contemplation of mathematics teaching and learning.

At the same time, professional learning communities were becoming ubiquitous in the education sector. The research on professional learning communities strongly propositioned their effectiveness, especially as a possibility for real reform in teaching practices (Berry, Johnson, & Montgomery, 2005; Hord, 1997; Little, 2003; Shulman,
1986; Supovitz & Christman, 2003;)

It was my belief that large-scale initiatives of the kind that I was part of still have a place and a benefit at the large-scale level of educational reform, but that the benefit is a zero sum gain if the micro level of teachers’ daily practice is not embedded within the reform. This was my opportunity to look at mathematics teaching and learning in the smaller details of life in the classroom through the eyes of a group of experienced and dedicated teachers. As Shulman (1996) wrote:

The teacher must remain the key… Debates over educational policy are moot if the primary agents of instruction are incapable of performing their functions well. No microcomputer will replace them, no television system will close and distribute them, no scripted lessons will direct and control them, no voucher system will bypass them. (p. 5)

With the above in mind, this research explored the relationship between a specific professional development model and its impact on the learning of its participants by addressing the following questions:

1. How does participation in a professional learning community affect teachers’ pedagogical content knowledge and their understanding of students’ learning of mathematics?

2. How do primary teachers develop an effective mathematics professional learning community?

This chapter is divided into four sections. The first section, “Growth in Teachers’ Pedagogical Content Knowledge”, will answer the first question about the professional learning community (PLC) and growth in pedagogical content knowledge in mathematics. The second section, “Developing an Effective Professional Learning Community”, answers the question about the development of the professional learning community itself.
I wanted to illuminate the benefits of a PLC for extending a professional development initiative, such as the provincial one described earlier, and at the same time, address the difficulties and dilemmas that arise out of a mathematics collaborative structure like a PLC. The third section provides considerations for future research and the fourth section provides a summary.

**Growth in Teachers’ Pedagogical Content Knowledge**

Professional learning communities have many advantages as a model for professional growth. However, are they sufficient for developing instructional proficiency in elementary mathematics teachers and, therefore, for improving students’ learning of mathematics? This section will recount some of the most effective components of the PLC, but also some of the concerns about the limitations of this type of PLC and suggestions for improvement.

As discussed in the literature review sections, theorists and researchers of teacher professional learning communities are in accordance on PLCs most effective components. Concentration on student achievement and content are two of the most compelling attributes (Astuto et al., 1993; Berry, Johnson, & Montgomery, 2005; Bolam, McMahon, Stolt, Thomas, & Wallace, 2005; Bryk & Holland, 1993; Buysse, Sparkman, & Wesley, 2003; Cochran-Smith & Lytle, 1999; Darling-Hammond & McLaughlin, 1995; Englert & Tarrant, 1995; Hord, 1997; Little, Gearhart, Curry, & Kafka, 2003; Little, 2003; Louis & Marks, 1998; Newmann et al., 1996; Supovitz, 2002; Supovitz & Christman, 2003). In interviews, the teachers confirmed the positive benefits of a PLC focused on content and student achievement. At the end of the final PLC meeting, teachers were asked to summarize what was most pertinent to them about the PLC. As Mary stated, "I think my
students have improved in their mathematics because my understanding has improved. I don't know that I would have persisted with some of the strategies without the group of us working on them at the same time."

From the beginning, this professional learning community committed to improving student learning and student work. Other studies found that models of professional learning communities with a similar focus were the most effective in creating change in instructional strategies and improvement in student learning (Bolam et al., 2005; Guskey, 1997; Little et al., 2003; Louis et al., 1998; Supovitz, 2002; Supovitz et al., 2003). Meeting together with colleagues who shared student concerns kept the focus of the discussions on the important mission of improving student learning. It shifted the focus on teaching to a focus on learning—and more importantly, learning for all learners.

As Cochran-Smith and Lytle (1999) found in their early research on professional development, the gap between expert knowledge and expert day-to-day experience is what needs bridging. The teachers in this study were able to "treat their own classrooms and schools as sites for intentional investigation at the same time that they treat[ed] the knowledge and theory produced by others as generative material for interrogation and interpretation" (Cochran-Smith & Lytle, 1999, p. 272). Their dialogue reflects the evidence of knowledge expansion. The teachers became critical consumers of resources and research. They cross-examined their assumptions about curriculum expectations, use of manipulatives, and instructional practices. They wrestled with thorny issues of parental support, differentiated instruction, assessment, and change.

Their professional shift included a movement from teaching by telling to learning by doing and focusing on understanding concepts rather than rote procedures. The teachers
felt that as the students became familiar with a variety of strategies, their confidence and engagement improved. The learning became a social enterprise that included sharing and discussion.

The teachers also created knowledge in other ways. They developed their own formative assessments to monitor student growth and discussed criteria for quality of student work. At each meeting, they brought in the work of their students or anecdotes of student responses to share. From these samples, they were able to develop common criteria for identifying the problems that students were encountering.

As a group, the teachers also made missteps. They had to work through the lapses, keeping their instruction open to multiple strategies created dissonance. As described in the first lesson they attempted, the instruction on using the ten frames became very prescriptive. The meaning of the mathematics concepts was lost as students lock-stepped through the motions of using the ten frames without connecting it to the computations they were solving. Sometimes the habits of a lifetime of teaching were hard to overcome for the teachers. Letting children struggle a bit was especially difficult. We have a teaching culture that rarely gives credence to the importance of allowing children to struggle, which has been recounted in research of high-achieving countries (Stigler & Hiebert, 2003).

Schools that have strong professional learning communities also have greater student achievement (Bolam et al., 2005; Louis & Marks, 1998). The teachers reported that the students' dispositions to learning mathematics showed improvement. There was greater participation in lessons and discussions than previously.

The strength of this professional learning community was the opportunity to work
with teachers and students of the same grade from other schools. This was also one of its weaknesses. It gave the teachers a breadth and depth of understanding about one grade level that from a content and context standpoint is an efficient and effective way to develop expertise in one area of education. It was my assumption that teachers would take some of their new knowledge back to their colleagues in their school and continue the dialogue, thus generating change at the grassroots level.

In reality, it is much more complex than that. Towards the end of the research, the teachers often spoke of their frustrations and their fears. The frustration was that their colleagues at their schools had strongly held beliefs about how to teach computations, and they saw no reason to change their practice. The fear was that now that their students were going on to Grade 3 and onwards, their newfound confidence and competence would wash away in the wave of traditional algorithmic dominated teaching. This is a real concern for teachers when they embrace new practices. At the very least, teachers like physicians, follow the Hippocratic Oath to do no harm. They did not want to think that their teaching might put the students at a disadvantage when confronted with the rigid practices of some of their colleagues.

A second limitation of this PLC is the need for a critical friend or expert other to be accessible at certain points in the PLC. The teachers in this PLC came together out of their own volition, and they had a clear idea of what they wanted to accomplish, as well as some background knowledge from the Ministry initiative. However, new ideas about the teaching and learning of mathematics may be outside the zone of enactment of teachers (Millet et al., 2004) not overly familiar with reform mathematics of the past couple of decades (NCTM, 1989; NCTM, 2000). Trying to work within a zone of proximal
development (Vygotsky, 1986) is difficult without someone to help scaffold the learning. For a PLC concerned with such a complex curriculum area for elementary teachers, it would be prudent to have someone in an advisory role; someone to meet regularly with the group and help them overcome any hurdles, and especially any misconceptions about the mathematics or the strategies that they are undertaking.

The role I played as facilitator and researcher was constraining. It was predicated on the initial belief that the teachers had received enough inservice preparation that they could move forward on a personal learning trajectory that suited their individual needs with only minor assistance on my part in providing resources and research. Over the course of the PLC, it became apparent that access to a mentor would have enriched the learning process. In a subject area as complex as mathematics, and for which many teachers do not have a robust understanding, there is a need for more concentrated collaboration not only with peers but also with ‘expert’ others who can scaffold the learning more completely than a facilitator. The role of mentor would have allowed more opportunities for directly modeling certain strategies with the students. Looking at research is beneficial but these teachers did not have the benefit of seeing the research in action. They relied upon their own and each other’s experiences with implementing the strategies. This created some problems that observing teachers who were proficient at the strategies may have avoided. Recent research by Han (2008) found that using what she calls “boundary brokers” who provided appropriate learning opportunities on an “as needed” basis helped expand teachers’ “visions of teaching and learning” (para. 1). A broker of this nature may have been effective in closing the breach between research and practice.
There are three other points that I need to make about the value of PLCs in mathematics education. One is the nature of the knowledge and skills teachers have about mathematics; secondly, the speed of change in mathematics educational theory and policy; and thirdly, the genuine possibility of mathematical instruction for alleviating educational inequity.

Teachers come to their profession with a package of knowledge and skills generally acquired through their pre-service time in teacher education. The most motivated teachers take time to expand this package through summer institutes, additional qualification courses, etc. For those who do not, the knowledge and skills from their pre-service years are outdated in less than a decade (Grossman et al., 2000).

In mathematics, especially, there has been exponential growth in the way researchers view the teaching and learning of mathematics (Ball, 2000; Fosnot & Dolk, 2001). Any teacher who has taken a one-year maternity leave knows the frustration of coming back to a revamped curriculum and the implementation of new professional and political strategies (e.g., closing the gap, raising the bar, and differentiated instruction). Education moves at the speed of light, in some ways, creating new lexicons and new demands. Staying up-to-date becomes a consuming task.

There is a real concern we need to have about the teaching and learning of mathematics. In most cases, elementary teachers come to the field inadequately prepared; the field of elementary mathematics is changing at exponential speed. The teachers in this PLC were certainly aware of these challenges and wanting to make significant changes in their practices. We also know how important mathematical understanding is to opening up multiple career paths to children when they grow up and of erasing the largely socio-
cultural inequities in the mathematics achievement of students. How to ameliorate the inadequacies, address the speed of change, and forge new possibilities for students comes back to the issue of long term, sustainable, professional learning in mathematics. The teachers in this research were capable and committed leaders in their schools but it was evident, even to themselves, that they needed more opportunities for professional discourse on mathematics and opportunities to learn more mathematics. Teachers who may be less inclined or capable than this group would be unlikely to adopt long-term changes in their practice no matter what the intensity of short-term professional development initiatives. Only sustained, on-going, professional learning that addresses the specific needs of students and teachers in their local contexts will be effective at producing long-term changes in practices.

A point in favour of a revitalizing mathematics professional learning is the influence of mathematics in closing equity gaps in education. Teachers’ influence on students’ learning of mathematics may be even greater than their influence in literacy. I once heard a speaker from England’s literacy strategy (John Stannard, personal communication, May 2005) say that literacy is often of great concern to parents even before their child goes to school. Many parents are much more likely to do literacy type activities with their child, than numeracy type activities so there is a wide range of experiences that children come to school with in literacy. A child from an education friendly home where 1,200 books have been read to them by the time they enter school has a significant advantage over children who come from a literacy-deprived home. However, because our culture rarely focuses on numeracy issues with young children the way that they do in Asian countries (e.g., use of games, parental expectations, interests, etc.), when a child comes to school they have
not had the same level of numeracy influence from their parents as they had in literacy. As such the students’ achievement, or non-achievement, is more intrinsically influenced by the capability of the teacher than the effects of parenting. Stannard’s premise was that our efforts as teachers are much more significant in numeracy than they are in literacy. In literacy, there is a wide experiential literacy gap when students enter school. In numeracy, there is also a gap but it is not as dependent on prior experience. In our culture, there are fewer tendencies for families to provide mathematics enrichment to their children before they come to school. The opportunity for teacher influence in both closing the gap and raising the bar on learning reaches much further. Teachers who have a strong repertoire of pedagogical content knowledge in mathematics can help students achieve at their best possible level. Long term, sustained professional development is the route to helping teachers gain that pedagogical content knowledge.

Improving student learning in mathematics might be the most difficult aspect of student learning in our math-phobic culture. In their learning communities, the teachers reflected critically on their teaching practice. Sheila confirmed the group's beliefs when she stated, "I wish I had had this opportunity years ago. To have taught this long and never really had the opportunity to observe students in other teachers' classrooms and then really have a professional dialogue seems sad."

Improving student learning is arguably the most important and one of the most difficult social justice issues of our time. Mathematics education levels the playing field, tunneling through poverty’s barriers, and exposing opportunities. These opportunities in medicine, engineering, science, etc. are areas traditionally unreachable for poverty’s constituents. Lack of teacher training further impedes students’ progress in mathematics
whether impoverished or not). PLCs offer a solution to this dilemma. They allow teachers to meet to challenge assumptions, create new knowledge, and explore new practices. PLCs provide a structure and impetus for ensuring teachers remain informed, confident professionals, resilient in the face of new mathematical practices, and sensitive to the diverse mathematical needs of their students. Eliminating mathematical disadvantage requires action-oriented dialogue and the intellectual stimulus of many heads pursuing the same problem.

**Recommendations Related to Question One of the Research**

For others planning to implement a professional learning community centered on mathematics learning, I would make some recommendations:

It is important to gather ample data at the beginning of the PLC to establish a comprehensive picture of the values, goals, and resources of the group. Attached, as Appendix E is a form (Initial Professional Learning Community form) for obtaining this information at the first meeting of a PLC.

A PLC needs to look at research that supports or contradicts its values and goals and have a deep discussion about the implications of the research. Teachers are people with little time and many obligations. Because of this, teachers need good research resources that fulfill two requirements: easy to read research that is specifically pertinent to the topic undertaken and consistent with up-to-date research so that it can be used with confidence. In our case, John Van de Walle’s book, *Elementary and Middle School Mathematics: Teaching Developmentally*, (2001), was a useful resource and one that the teachers had been given previously. The teachers also found issues of ‘Teaching Children Mathematics’ (NCTM) to be easy to use resources. Other useful resources included the
Journal articles were less effective for a PLC because they involved a greater commitment to at-home reading. PLC’s might want to consider providing release time to teachers to simply sit and read some of the research. As an add-on to a school day, particularly when report cards or other added responsibilities were imminent, the extra reading might become a workload issue for some teachers. In this case, the teachers had committed to the project of their own volition and their reading goals were self-chosen so workload did not become an issue. As well as research reading, access other forms of expertise. Webcasts, podcasts, websites, and guest speakers often provide an Ontario context to new knowledge gathering.

At the beginning, teachers may not know what it is they do not know. The use of mentors who are knowledgeable about new teaching strategies and who are proficient at modeling such strategies help teachers see research in action. This also avoids some of the pitfalls that could arise from a poorly executed use of a strategy, thus discouraging a novice from using such a strategy.

Engagement with other experts can serve to clarify goals and sharpen the focus on what research to use. Include other professionals who work with the students in the professional learning community. Although difficult (and costly) to get special education teachers and teacher assistants included, it will bring coherence to how the students are being taught and how their learning is assessed.

Other partners in the classroom need to be aware of the goals of a lesson and to be cognizant of the strategies that are being utilized. In some situations, other educational
partners (e.g., special education teacher or teacher assistant) might be unfamiliar with problem-solving focused lessons and default to teaching rote procedures without understanding to the students with whom they work to the detriment of the goals of the classroom teacher.

Of vital importance to a PLC is to provide many opportunities for teachers to work together in each other’s classrooms. It was in the multitude of experiences working with many students at the same grade level (as well as some slightly higher or lower in grade level) that the most valuable learning happened. Observing and interacting with one hundred plus children over the course of the research opened a window on the vast horizon of children’s learning. There is excitement in recognizing some of the commonalities in how many students grapple with mathematical ideas as they reason their way to both the right or wrong solution.

Student observation and interaction at such high volume also raises the level of professional knowledge about mathematics teaching. In this case, it made the teachers more critical of long established practices and this may be an important impetus for shifting beliefs. The observations and interactions with so many students working on place value charts, initiated their joint belief that, place value charts were at best, a distraction from doing any real thinking on the part of the students, and at the worst an actual deterrent to the understanding of the composition of multi-digit numbers.

Working in each other’s classrooms was an education that could not be duplicated in any textbook. Together the teachers identified the diverse learning trajectories their students were travelling. The observations gave a context and relevancy to their discussions. Being able to observe a student with significant math learning difficulties
succeed with the help of a teaching strategy or series of strategies, provided a significant impetus for other teachers who recognized the same difficulties in some of their own students. Observing the hundred plus students enlightened all of us to the varied, yet often consistent levels of mathematics understanding through which students travelled.

Educators are clear in their preference for professional development, specifically tailored to the individual needs of schools, and embedded within the classroom itself. There are valuable instructional practices that have shown positive results in student learning and deserve implementation in the classroom through thoughtful and sustained professional development. As Darling-Hammond (1996) states, “schools are now expected not only to offer education, but to ensure learning” (p. 5). Combine with this, the exhortation from Fosnot and Dolk (2001) that children need to become young mathematicians coming to their own understanding of mathematics just as mathematicians did many centuries ago (Fosnot & Dolk, 2001), and you realize what an enormous task the requirements of 21st century professional learning requires of us.

Professional learning communities help reconcile these high demands of mathematical learning and professional development needs. Work in self-sustaining, supportive, and intellectually stimulating communities bridges the gap between theory and practice, making learning specific and attainable. Professional learning communities also provide the context for bridging the gap between professional development initiatives at the macro level of province or local board of education implementation and the personal construction of knowledge required by teachers at the micro level of their daily teaching experiences. If we are serious about engaging in high-quality professional development that motivates teachers, improves student learning, and allows for deep discussions about
mathematical issues, we need to invest in professional learning communities. I would also add that these professional learning communities need to include opportunities to work with the students in each others’ classrooms.

**Developing an Effective Professional Learning Community**

A professional learning community is a relationship. Relationship building creates the social and professional affinity needed to sustain a community as it delves into complex issues of instructional change that may challenge the status quo. Professional relationships are cultivated through respect, competence, personal regard for others, and integrity (Bryk & Schneider, 2002). Together, those four qualities were apparent in the teachers and they nurtured and solidified the strong relationships within this PLC. Those four attributes may also have contributed to administrative decisions to choose the teachers in this research as mathematics leads at their schools in the first place, and thus indirectly contributed to the cohesion in the group.

The sharing of confidences about mathematical insecurities in teaching and in learning reaped mutual trust. This was especially true as it pertained to their training in mathematics. Mutual commiseration seemed to reassure them that they were not alone in this and that they would support each other rather than make judgments as they moved forward in learning. Trust was an important component of their relationship.

Also, these participants took on the added PLC responsibility of their own volition. Choice and volition are critical in motivation for adult learning (Knowles, 1980; Wlodkowski, 1999) and are again markers of the leadership in this group. The voluntary nature of the project contributed to the level of goodwill that they brought to the endeavour, which in itself influenced the respect and personal regard that they held for
each other and thus contributed to relationship building.

It is important to address the issue of the membership make-up of this group. They would not be considered representative of a PLC that was formed out of “voluntolding.” The voluntary nature of their membership was important. Joyce and Showers (2002) divide teachers into four categories based on their response to professional learning. Some are “Gourmet Omnivores” seeking and initiating learning opportunity at every opportunity. “Active Consumers” participate in and utilize professional learning opportunities, but rarely initiate them. “Passive Consumers” will participate, but rarely integrate new learning into practice. “Reticents” are active resisters who are suspicious of new ways of doing things. The teachers in this PLC would fit under the category of “Gourmet Omnivores.” They were curriculum leaders in their schools and were always seeking new learning experience. In most randomly assigned groups, you would expect a broader range of consumers, reticents, and omnivores. Therefore, the research in this thesis is specific to a select group of participants: Gourmet Omnivores. These teachers held a unique position as leaders in their schools and in their unsated appetite and positive predispositions for professional development.

Having the best people was a significant advantage to this PLC, but developing effective professional learning communities is a complex and multi-dimensional undertaking. Even when there is a framework in place, the multi-variant characteristics of individual teachers and the classes they teach will have a significant influence on the format of the PLC and the type of learning that transpires. Cochran-Smith (2003) suggested that an inquiry such as this one “is intended to capture the ways we stand, the ways we see, and the lenses we see through” (p. 8). This thesis provides a lens to
illuminate the path of one small, particular PLC, spotlighting its unpredictable challenges
and everyday achievements. It highlights the reality that learning relationships are rarely
pristine and orderly, without complexity or contradiction. They are a messy business.

The teachers in this group took what I saw as wrong turns (e.g., the invented
strategies fiasco; the teaching by telling in the first lesson). However, they were not
wrong turns, they were simply ruts in the road. Teachers change in the same way as all
learners do, mostly through experience, reading, and interactions with others. Maturity
and experience guide us along a learning path with greater speed, but the path still needs
to be followed; there are few shortcuts to learning, and it is usually a bumpy ride.

In the early stages of the PLC, the group was collegial about such things as sharing
resources or practical types of advice. It was not until they had met a few times and their
relationships had solidified that they began to discuss the deeper issues and critical
questions of teaching and learning. Once rapport had been established, their discourse
became more reflective, focusing on student development and instructional issues.
Identifying the source for the group’s effectiveness is complex. The teachers were from
different schools, and I think that the lack of proximity promoted a level of freedom that
membership in the same faculty would not have allowed. Disclosures exposing
professional vulnerabilities, especially around mathematics, to teachers who were not part
of the school did not hold the same potential for conflict as sharing with teachers on staff
(in other divisions) who were possibly at a higher level of mathematical comfort.

This is not to say that the teachers in this group only wanted a PLC with non-
colleague participants, but for this initial attempt, it provided them with a very specific
focus and it eliminated inter-faculty tension. The group’s early conversations included the
prior learning of their students. Talking about that in the presence of their students’ previous teachers would have inhibited total honesty for the sake of maintaining staff harmony.

Newmann et al. (1996) describes one of the five most essential characteristics of professional learning communities as shared values and norms around "views about children and children's ability to learn” (p. 182). Articulating values and norms is an important consideration for a professional learning community. Collaborating in one another's classrooms allows free access to each other's students. This entails a significant amount of trust that the visiting teachers are going to interact with the hosting teachers' students in ways that meet with her approval. Beliefs about how to encourage learning, how to use manipulatives, and how to help a struggling student need to be discussed and possibly challenged to ensure that each teacher feels comfortable opening his or her class to the various teaching styles of other teachers. This PLC did not spend adequate time on this. However, they were a resilient group, so misapprehensions did not create the level of tension that could have been present.

Conversations about how to interact with students would have been useful before heading into another teachers’ classroom. The idiosyncrasies of classrooms and students need to be respected. Not knowing that a student may have Asperger Syndrome or Tourette Syndrome has implications on how the behavior of a stranger in the classroom effects the classroom atmosphere. A form that I developed for a PLC that I worked with in a later capacity would have been beneficial here (PLC Information Form, Appendix F). It is a simple form, but it makes sure teachers are informed about the students before then enter a room to observe.
The most valuable aspect of this professional learning community was the opportunity to observe students in each other’s classrooms. The power of the PLC came from the classroom participation of the teachers, the use of classroom observations, sharing of information, and reflective dialogue about one’s own students and the students of others. In the generic model of professional learning communities, this is not a common component.

Classroom participation helped keep student learning as the driving force for the teachers’ discourse and subsequent changes in their practice. It also kept goals at a simple, practical level of results orientation. From one class to the other, learning successes or lapses were easily observable and immediately analyzable. As Newmann et al. (1996) detailed, good professional development should make teaching a public, rather than private, venture. Other researchers have also confirmed the importance of classroom embedded professional development (Elmore, 2002; Leiberman, 2008; Loucks-Horsley, Love, Stiles, Mundry, & Hewson, 2003; Putnam and Borko, 1997). Possibly the use of video clips, audio clips, and written case studies will help keep professional learning communities focused on student learning, but the visceral experience of interacting with large groups of students, and then immediate dialogue and reflection with teachers who shared the same moments, presented a particularly powerful motivator for change in the practice of these teachers.

Within this professional learning community, there were moments, such as those warned about by Little (2003) in which the teachers were "limited by their own horizons of observation" (p. 917). Some of the preconceptions that the teachers had about mathematical concepts, manipulatives, and allowing students to work in pairs or groups
could have remained dominant in the group and curtailed some of the instructional strategies they wanted to implement. They used external perspectives from the books and articles they read to overcome the elements of “groupthink” that can take over any group who substitutes congenial interactions with collegial learning structured interactions. They used each other as critical friends who accessed resources and each other to solve problems.

At the beginning of this PLC, the teachers committed to use research and other evidence to generate their discussions and inform their actions. The research itself became a stimulus for changing practice. They opened up their practices to encourage the students to use a variety of ways for solving computations. Manipulatives, problem solving, and time for group reflection became consistent components of their classroom practice. The teachers themselves experimented with the manipulatives to solve problems using multiple models and discussed their thinking of the mathematical concepts. They made predictions about roadblocks to student learning and rehearsed possible questions or strategies as interventions. They also made mistakes as highlighted in the data analysis. They had to work through the messiness of mixing theory and practice.

Learning through dialogue is not learning by dictation. It involves social creation of ideas and understandings about what you do not know, rather than what you do know. It is an evolution over time. As Duckworth (1996) said, “the virtues involved in not knowing are the ones that really count in the long run. What you do about what you don’t know is, in the final analysis, what determines what you will ultimately know” (p. 68).

Research provides a pathway to the creation of new ideas and understandings. However, sometimes it is a circuituous route. Research can be misinterpreted. The
teachers misunderstood the concept of using invented strategies as a method of teaching computations (Van de Walle, 2001; Fosnot & Dolk, 2001). Instead, they used a more prescriptive method they called the three-step strategy. It was helpful to the students' learning because it allowed them to see the computations in a different way. However, it was not consistent with the description or intention of the research. This dilemma probably permeates all professional learning communities. How do you interpret research without the guidance of a knowledgeable other? The teachers had received the Ontario Ministry of Education training, which included cursory instruction on some of the research on computations. Now, in their professional learning community, they needed a knowledgeable other to help redirect or challenge their thinking. It seems to be important that professional learning communities have ongoing opportunity to reconnect with outside sources of expertise.

There are limits to the horizon of any closed system and PLCs are generally a closed system. As open as its members may be to new ideas and practices, they may still misinterpret a practice or may simply not know that one exists. A recommendation for any PLC would be to include opportunities to broaden the horizon of their learning by consulting with expert others, attending conferences, or other outside professional learning opportunities. Otherwise, there is a very real possibility that the community might unknowingly starve the possibility of new knowledge simply because there is no external source of intellectual sustenance.

The most useful construction of the PLC, next to the opportunity to observe students, was the opportunity for teacher talk. Talking through the process of teaching and learning is a gift of time and intellectual stimulation that few teachers receive. Filling
conversations with the whole array of researched teaching ideas and strategies, reviewing alternatives to traditional practices of assessing, and collaborative enterprises of designing learning experiences for students enriches the enterprise of education in the schools it serves. The connection and interactions of many minds creates a synergy for teacher change that is thoughtful and student-centred. Just as a belief in constructivism means students, through their actions and experience, construct all knowledge, so too for teachers.

**Recommendations Related to Question Two of the Research**

Professional learning communities, while benefitting from the lateral capacity building of working with a cohort of same grade teachers, also need some mechanism for integrating the learning vertically. The teachers in this PLC found the experience of working with same grade teachers from other schools the most helpful aspect of the PLC. However, they also wanted some way to expand it to include opportunities to bring new knowledge back to their school colleagues and participate in a PLC with teachers in the other grades. To do this requires the participation of teachers in prior and subsequent grades within the same school. Figure 10 is a structure representing how such a lateral and vertical structure might work. Teachers first meet to set their own goals for their classrooms as well as for the school overall. An invitation can then be sent out to other schools to identify others who want to pursue similar goals. A general committee from each school would meet to set up the logistics such as a plan of action and communication. Then teachers participate in a PLC consisting of same grade or same division teachers from other schools for a set period of meetings and classroom observations. Finally, the school group reconvenes with its own teachers to share new
knowledge and develop a school wide plan that builds on what the teachers have learned from their cross-school grade groupings PLC.

The model below (Figure 10) allows grade level teachers to meet and discuss specific goals, content knowledge, and practical strategies appropriate for their grade level with same grade level teachers. However, the opportunity is also grounded within the school-based model that allows individual teachers to share their knowledge across grades.

<table>
<thead>
<tr>
<th>School Level</th>
<th>Across Schools</th>
<th>Grade Level</th>
<th>School Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>• School staff meets to identify a goal in mathematics that is relevant to every grade level (e.g., problem-solving; use of manipulatives or models) and based on student needs.</td>
<td>• Form general committee to meet with other school(s).</td>
<td>• Set PLC dates; set sub-goals related to main goals.</td>
<td>• Share grade level PLC findings (include expert other in the meeting).</td>
</tr>
<tr>
<td>• Invitation to other schools with same goal.</td>
<td>• Each school committee meets/develops a plan of action.</td>
<td>• Refer to known experts in the field to identify research.</td>
<td>• Develop division level plan related to PLC findings.</td>
</tr>
<tr>
<td>• Goal is chosen.</td>
<td>• Consultation with expert re: evidence and research base.</td>
<td>• Conduct sessions of PLC; opportunities to observe each other's classrooms.</td>
<td>• Share division level plans across divisions.</td>
</tr>
<tr>
<td></td>
<td>• Prepare and communication package to parents/others.</td>
<td>• Keep records of student work and other assessments &amp; audio/videotaping .</td>
<td>• Co-ordinate division level plans into school wide plan.</td>
</tr>
</tbody>
</table>

*Figure 10: A Cross-School Model of PLC*

As teachers share strategies within their divisions and across divisions, they can eliminate several problems that arose out of this PLC and provide them with:

- common goals across the school;
- coordination of practice across grades;
- communication to parents that shows consistency across grades;
- collaborative professional learning that meets the specifics of individual grades while still coordinated through a whole school approach.

If possible, link different professional learning communities together, either electronically or otherwise, to allow for breadth of discussion. The value in a qualitative
study is best demonstrated through many studies focused on the same issue so that the
conversation can be broadened and deepened.

Journal writing by the participants give a living story of the experience. Even the
emails from the participants helped to identify the trajectory of their experiences.
Teachers' reflections on paper allow an articulation of their understandings, questions, or
concerns that make for a richer discussion when brought to the table of a professional
learning community. As well as journal writing, keep minutes of the PLC meetings.
Attached as Appendix G (Minutes of PLC) is a form that I have used for subsequent
PLC’s as a means of provoking discussion and monitoring changes and to keep minutes.

Future Research

There are a number of areas that emerged from this research that would benefit from
further exploration.

Divisional Professional Learning Community

This PLC focused on a group of Grade Two teachers from eight different schools.
One of the quandaries they discussed was making change in their teaching practices that
might not be understood and/or extended into the next grade that their students entered.
They were afraid this might cause confusion for their students. A lot is learned by
watching many students of the same grade, but real change as students go through a
system requires the participation of all the teachers in that school. It would be valuable to
conduct research of a PLC that consisted of all the teachers in the primary division but
with opportunities to observe teachers in similar grades at other schools. The research
could focus on the common challenges teachers face with the diversity of their
classrooms and the constraints of the curriculum on differentiation of instruction. It could
also explore how setting division level goals for mathematics that are reflective of the needs of the students in that specific community might improve mathematics achievement.

**Mentorship**

A mentorship program for mathematics-based PLC’s would be useful. Teachers do not necessarily have the experience from preservice or inservice opportunities in mathematics to be able to make critical decisions about what to focus on to assist their students learning. Teachers are often able to diagnose the problems their students have and they may be open to doing research to find solutions. However, the field of mathematics research is vast and teachers’ time is limited. There is always the possibility that they might spend a significant amount of time pursuing a fad that is not truly supported by the literature and not realize that until they have spent precious hours of PLC time. A mentor would be very useful especially in the beginning stages of the PLC. Research that helped define the role of a mentor and the affects of such mentoring would be a useful addition to the field.

**Role of the Administrator**

The principals at the schools in this research did not participate in the PLC. At the end of the PLC, the teachers did a presentation to all the principals in the board with a video to demonstrate the learning of their students. One of the questions from the principals was what their role should be in a PLC and how they could be involved at a certain level when they were already so overwhelmed with the administrative responsibilities of their jobs. Research that could identify a fully developed role for the principal in a mathematics PLC would be valuable for administrators. It could identify a
few key factors that principals need to focus on to help staffs work in mathematics PLC’s to improve the mathematics achievement of their students while providing ways of reducing the added workload that such participation might entail.

**Summary**

Learning “is an activity that is voluntarily initiated and undertaken to solve a problem that is personally felt (authentic)” (Hannay, Wideman, and Seller, 2006, p. 68). New learning demanded by fiat from above has little evidence to support it as a process for generating practical change. Piaget was a leader in moving the educational discourse away from teaching by telling and rote learning. He stated, “Education for most people, means trying to lead the child to resemble the typical adult of his society…but for me and no one else, education means making creators…You have to make inventors, innovators—not conformists” (Bringuier, 1980, p. 132). Conformity in mathematics practice has not overcome the extensive gap between those who get mathematics and those who do not. Inventors and innovators in mathematics education, an area of significant difficulty for elementary teachers, offer the promise of an invigorated educational renewal.

The other important point is the relevancy of context to a professional learning community. This professional learning community’s members represented a range of personal and professional circumstances. Hammerness et al. (2005, p. 389) emphasize that teachers’ career trajectories are influenced by the context of their professional experiences and milieu. They state that:

Teacher educators are now emphasizing the interrelationships between teachers’ learning and development and the context of teachers’ learning. In turn, they are beginning to focus upon the particular features of those contexts and experiences that might help teachers develop these capabilities. This perspective parallels the
development of learning theory over the past twenty years, as psychologists have moved from behaviorists’ quest for a direct relationship between stimulus and response, to cognitive psychologists exploration of how individual learning unfolds, to the broader focus offered by sociocultural theory on the contexts and conditions that promote learning. (Hammerness et al., 2005, p. 389)

Recognizing the importance of context means that relying on a linear model of professional learning is unrealistic. Teacher expertise and professional confidence develop over time within the reality of the culture of their school, their prior knowledge, and the demands of the subject. It evolves in response to individual strengths and needs. This requires enormous flexibility in the type of learning approaches that work best for each teacher. No large-scale initiative could imagine servicing that range of professional development requirements. Even the most effective of PLCs could not hope to administer to such a range of needs, but at least with a PLC there is a greater possibility of accommodating more of them and making the learning particular and relevant to the teacher. One thing teachers do not have much of is time. A focused professional learning community that is responsive to the context is least likely to waste that precious commodity. As Thomas J. Sergiovanni (2004) says:

Under the right conditions, both students and teachers will take responsibility for their own learning: groups can transform themselves into caring learning communities; under the right circumstances, all teachers can become leaders if the issues are important to them. (p. 34).

Professional learning communities provide the opportunity for teachers to develop their leadership.
Glossary

**Achievement Levels.** The Ontario Ministry of Education has policy that separates achievement of the provincial curriculum expectations into four levels. These are clearly described in the achievement chart in the curriculum documents for each subject area. Level 3, is the provincial standard and identifies the characteristics of student achievement that represent the expected level of achievement of the provincial expectations in that grade.

**Big Ideas in Mathematics.** The key concepts that underlie mathematical reasoning. They help students to make connections across and within mathematical strands.

**Boards of Education.** In Ontario, the education system is broken into 6 regions which are further divided into approximately 5 – 8 boards of education. The boards of education supervise the schools under their jurisdiction in accordance with the requirements of the Education Act of Ontario.

**Developmental Stages.** Points in a child’s learning of mathematics that reflect a consolidated understanding of certain concepts and a readiness to move to new levels of understanding.

**Expert Panel.** The Ontario Government convenes groups of experts in a field to provide advice for use in developing policy in that area.

**Expectations (curriculum expectations).** The term used by the Ontario Ministry of Education to indicate the knowledge and skills students are expected to demonstrate in each grade and subject in the curriculum.

**In-Service.** This is a general term used to refer to professional development for
teachers who are practicing professionals as opposed to teachers who have not entered the field yet and therefore received pre-service professional development.

**Intervention.** The term used by the Ontario Ministry of Education to indicate the type of assistance students may need to remediate or prevent learning difficulties.

**Manipulatives.** Tools students can use to construct an understanding of mathematical skills and concepts. Some examples include hundreds charts, number lines, base ten blocks, ten frames, and tiles.

**Mathematics Additional Qualifications Courses.** Educational courses focused on the teaching and learning of mathematics. The courses are certified by the Ontario College of Teachers and available to all teachers in the province. The courses consist of three levels, each of which can be completed in a 3 month term of about 100 hours each.

**Pedagogical Content Knowledge.** A body of knowledge distinctive to teaching a particular subject. It reflects the blending of content and pedagogy to meet the needs of diverse student needs.

**Pre-Service.** This is a general term used to refer to professional development for teachers who have not yet entered the field of education but are in training to enter the field.

**Scaffolding.** A process of identifying the learning strength and weakness of a student in a specific area and then providing assistance and other supports that help the student learn with confidence.

**Strand.** In Ontario, the mathematics curriculum is divided into five strands. The five strands for Grades 1-8 are: Number Sense and Numeration, Measurement, Geometry and Spatial Sense, Patterning and Algebra, and Data Management and Probability.
References


Boyd, V. (1992). *School Text: Bridge or barrier to change?* Austin, TX: Southwest Educational Development Laboratory.


*Elementary school Journal, 97,* 3-20).


Association for the Education of Young Children and National Council of Teachers of Mathematics.


stage for learning from teaching. Santa Cruz, CA: Center for the Future of Teaching and Learning.


In National Council of Teachers of Mathematics, A Research Companion to Principles and Standards for School Mathematics.


Leithwood, K. (2002). *Organizational learning and school improvement*. Greenwich, CT, JAI.


Lyons, N., & LaBoskey, V. K. (Eds.) (2002). Why narrative inquiry or exemplars for a scholarship of teaching? In N. Lyons & V. K. LaBoskey (Eds.), *Narrative
inquiry in practice: Advancing the knowledge of teaching (pp. 11-27). New York: Teachers College Press.


York: Longman.


TIMSS videotape classroom study: Methods and findings from an exploratory research project on eight-grade mathematics instruction in Germany, Japan, and the United States. (NCES 99-074). Washington, DC: National Center for Education Statistics.


December 14, 2008


Cambridge: Cambridge University Press.


ASCD.

Haven and London : Yale University Press.

Wilson, S. M., & Berne, J. (1999). Teacher learning and the acquisition of
professional knowledge: An examination of research on contemporary
professional development. In A. Iran-Nejad and P. D. Pearson (Eds.), Review of

Wlodkowski, R. (1999). Enhancing Adult Motivation to Learn. San Francisco: Jossey-
Bass.

Publications.

Wren, S. (2003). The Importance of Professional Development and Teacher Quality in
Reading Instruction. Resources for the Balanced Reading Teacher Retrieved from
http://www.balancedreading.com/profdev.html

Wright, R. J. (1994). A Study of the Numerical Development of 5-year olds and 6-
year olds. Educational Studies in Mathematics, 36, 35-44.

Wright, R.J., Martland, J., Stafford, A.K., & Stanger, G. (2002). Teaching number:


Appendix A: Proposal

A Fine Balance: Teaching for Conceptual Understanding and Procedural Knowledge in the Primary Mathematics Classroom

Purpose: To engage Grade 2 teachers in focused professional development on the instructional strategies that research indicates are most effective in helping children learn mathematical concepts and procedures. The objective of this project will be to familiarize teachers with the research, to explore the practical application of the research in their everyday teaching and to use the teachers’ reflections and feedback as the basis for developing further strategies to improve and/or enhance mathematics teaching.

Resources: The Ontario Ministry of Education’s Early Mathematics Strategy and the related resources that have been developed to support the strategy will be used as the basis for this project. Description of Project: Six Grade 2 teachers from six separate schools within the same school district (as determined by the Superintendent of Program) will be invited to participate in the project. They will be provided with release time every two weeks to meet as a group for half a day in a mutually suitable location. These meetings will focus on professional development in the area of mathematics instruction, especially as it relates to problem solving, communication, conceptual/procedural understanding of mathematics, and assessment. As well as the release time for the bi-weekly meetings, the teachers will also be released once per term to attend and participate in a mathematics lesson that has been developed by the group and that is conducted in a colleagues’ classroom. They will also be asked to provide work samples, tape recordings

1 Note: The original proposal was for six teachers but the board allowed two others to join the group because they did not want to refuse anyone the opportunity.
of children, and pictures as the project progresses. The appropriate parental releases for these documents will be provided for signature.

Participants: Participants do not need a mathematics background. They need an open and inquisitive learning style and the ability to work well in a group.

Research Methods: The participants will be asked to fill out a questionnaire and their discussions and feedback at the bi-weekly meetings will be audio taped and transcribed. The lesson study component will involve videotaping children in a classroom as they work out problems and share their understandings. Permission forms will be provided.

Privacy and Confidentiality: All information will be kept strictly confidential. Work samples from student and teacher feedback and observations will not include identifying information. Pseudonyms will be used in the reporting of this research.

Benefits and Risks: The benefit to the teacher of this project is the opportunity to participate in professional development with a small group of like-minded teachers and to tailor their professional development to the specific needs of their classroom. Teachers can withdraw from the project at any time.

Researcher: This project is being conducted by Lyn Vause as part of her doctoral work on mathematics in the primary years. Lyn Vause is a Religion, Family Life, and Curriculum consultant with this board, presently seconded to the Ontario Ministry of Education as an Education Officer for the Early Mathematics Strategy.
Appendix B: Lesson Design

Teacher: 
Grade: 
Date: 
Strand: 

Concepts/Expectations: 

Getting Started: (whole class activity) 

Working On It: (small group activities) 

Reflecting and Connecting: (whole class) 

Assessment
Appendix C: Problem Types

At the Ontario Ministry of Education training there had been a short (one hour) presentation on the importance of using different types of problems. The teachers wanted to become more familiar with the problem types. They confirmed that most of the problems used to enforce the basic facts were often of the kind, "Jane had two new dolls. She received three more. How many did she have altogether?" which is of a part plus part equals whole variety rather than the more complicated forms such as "Jan had two new dolls. She now has five dolls. How many more dolls was she given?" The second question gives the starting point and the end point but leaves out the middle. Many children used to the first type of problem would automatically add the two and five dolls for an incorrect answer of seven in the second problem. They discussed the types of problems and their own lack of familiarity with them. The four types of addition and subtraction problems – join, separate, compare, and part-part-whole.

A join problem involves a problem in which an amount is increased by adding another amount to it. The situation involves three amounts: a start amount, a change amount (the amount added), and a result amount. A join problem occurs when one of these amounts is unknown.

Example:

There were 25 puppies in the pet sore. After the new puppies arrived, there were 48 puppies altogether. How many new puppies were there? (Change unknown)

The doctor told Lisa that the mass of his kitten increased by 3 kg in the last month. If the puppy weighs 13 kg now, what was its mass a month ago? (Start unknown)

Jesse saved $30 from his allowance. His mother gave him $5 for helping her with
some chores. How much money does he have altogether? (Result unknown)

A separate problem involves the action of decreasing an amount by removing another amount. The situation involves three amounts: a start amount, a change amount (the amount removed), and a result amount. A separate problem occurs when one of these amounts is unknown.

Examples:

Greg earned $21. from his allowance and helping his grandmother. If he spent $12 on comic books, how much does he have left? (Result unknown)

There were 90 students in the gym for the assembly. Several classes went back to their classrooms, leaving 30 students in the gym. How many students returned to their classrooms? (Change unknown)

Ava drew a line on her page. The line was longer than she needed it to be, so she erased 2 cm of the line. If the line she ended up with was 8 cm long, what was the length of the original line she drew? (Start unknown)

A compare problem involves the comparison of two quantities. The situation involves a smaller amount, a larger amount, and the difference between the two amounts. A compare problem occurs when the smaller amount, the larger amount, or the difference is unknown.

Examples:

Ruth and Jane both walk to school. Jane walks 1 km farther than Ruth. If Jane's walk to school is 3 km, how far is Ruth’s walk? (Smaller quantity unknown)

Ben collected $142 in pledges for the read-a-thon, and James collected $56. How much more did James collect in pledges? (Difference unknown)
Boxes of Apple pencils come in two different sizes. The smaller box contains 75 pencils, and the larger box contains 25 more. How many toothpicks are in the larger box? (Larger quantity unknown)

A part-part-whole problem involves two parts that make the whole. Unlike join and separate problems, there is no wording about adding or removing amounts in the way a part-part-whole problem is worded. A part-part-whole problem occurs when either a part or the whole is unknown.

Examples:

Matthew bought 3 kg of fruit at the market. He bought only oranges and apples. If 1 kg of the fruit were oranges, what was the mass of the apples? (Part unknown)

Colin has a collection of hockey and baseball cards. He has 37 hockey cards and 18 baseball cards. How many cards are in his collection? (Whole unknown)

Varying the types of problem helps students to recognize different kinds of addition and subtraction situations, and allows them to develop a variety of strategies.

The teachers discussed these various types and indicated they were going to try to incorporate them into their repertoire of teaching strategies.
## Appendix D: Chart for Recording Group Work – Grade 2

Expectation: compose and decompose two-digit numbers in a variety of ways, using concrete materials (e.g., place 42 counters on ten frames to show 4 tens and 2 ones; compose 37¢ using one quarter, one dime, and two pennies)

Lesson: The Mitten

Activity: Place counters on ten frames to show quantities referred to in story.

<table>
<thead>
<tr>
<th>Name of student:</th>
<th>Recognizes that one filled ten-frame is equivalent to ten</th>
<th>Recognizes the numeral 2 in 22 is two tens, etc.</th>
<th>Determines amount in the ten frames without counting (e.g., one full ten frame and one full frame filled with two counters is 12)</th>
<th>Any difficulties with the concept</th>
</tr>
</thead>
<tbody>
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</tbody>
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Next Steps
Appendix E: Professional Learning Communities Classroom Information

Teacher:  
Grade level:  

Recess breaks:  
Lunch break:  

Special education teacher present:  Yes ___ No ___  If yes, name the students they work with here and indicate their location in the classroom on chart below with an SE:

__________________________________________________________________

Educational assistant present: Yes ___ No ___  If yes, name the students they work with here and indicate their location in the classroom on chart below with an EA:

__________________________________________________________________

Are there any students who need special considerations:  Yes ___ No ___  If yes, name them here and indicate their location in the classroom below with an SC:

Front of Class

[Charts and boxes for location indication]
Appendix F: Mathematics Professional Learning Community Initial Conference Form

Name: Date:

Values

In one sentence, one word or one phrase describe the type of mathematical learner you want your students to become:

____________________________________________________________________________

Setting Goals

What strand of mathematics is of most concern to you?

- Number Sense and Numeration
- Geometry
- Patterning and Algebra
- Measurement
- Data Management and Probability

What concepts within this strand are of most concern to you?

____________________________________________________________________________

____________________________________________________________________________

____________________________________________________________________________

What evidence do you have to support the need for concern?

- EQAO results
- Formative assessments
- Diagnostic assessments
- Observations
- Report card results from previous years
- Report card results from this year
- Parental concerns

Elaborate briefly on this evidence and why it is a concern:

____________________________________________________________________________

____________________________________________________________________________

Action Plan

Dates and times for Professional Learning Community Meetings
What do we want each student to learn?

____________________________________________________________
____________________________________________________________
____________________________________________________________
____________________________________________________________

How will we know when each student has learned it?

____________________________________________________________
____________________________________________________________
____________________________________________________________
____________________________________________________________

What do we need to know to help students learn?

____________________________________________________________
____________________________________________________________
____________________________________________________________
____________________________________________________________

What resources (materials, resources, people) do we need to help us?

____________________________________________________________
____________________________________________________________
____________________________________________________________
____________________________________________________________

Next Steps (plan a lesson; try a strategy; do some research etc.):

____________________________________________________________
____________________________________________________________
____________________________________________________________
____________________________________________________________

What evidence (student work) will be brought to the next meeting?

____________________________________________________________
____________________________________________________________
Appendix G: Mathematics Professional Learning Community

Minutes of PLC Meeting No. ____  Date: __________

Present:

What resources (materials, resources, people) have we utilized to help us?
____________________________________________________________
____________________________________________________________
____________________________________________________________
____________________________________________________________

What did we try with our students?
____________________________________________________________
____________________________________________________________
____________________________________________________________
____________________________________________________________
____________________________________________________________
____________________________________________________________

What practices have been most successful in helping students understanding these mathematical
________________________________________________________________________________________________________________________________________
________________________________________________________________________________________________________________________________________
________________________________________________________________________________________________________________________________________
________________________________________________________________________________________________________________________________________

Identify strengths and weaknesses in student learning
____________________________________________________________
____________________________________________________________
____________________________________________________________
____________________________________________________________
____________________________________________________________
What resources (materials, resources, people, other professional development) do we need to help us?
____________________________________________________________
___________________________________________________________
____________________________________________________________

Next Steps (plan a lesson; try a strategy; do some research etc.):
____________________________________________________________
____________________________________________________________
____________________________________________________________

What evidence (student work) will be brought to the next meeting?
____________________________________________________________
____________________________________________________________
Appendix H: Parent Consent Form

Name of Participant:

School:

Address:

Dear

I am a doctoral student at the Ontario Institute for Studies in Education in the Department of Curriculum Teaching and Learning, University of Toronto. Working under the supervision of Dr. Linda Cameron, I am conducting a research study entitled, A Fine Balance: Teaching and Learning Mathematics in the Primary Classroom. My interest is in research in teacher professional development and how it is affected by a professional development cycle of lesson study, observation of a lesson and then revision of the lesson in light of findings.

In particular, I would work as a participant-observer of five Grade Two teachers as they engage in a three part professional development cycle focused on improving teacher effectiveness in the classroom. The format of the study will be as follows:

The teachers will collaboratively develop lessons (based on lessons they would normally be doing at that time of year in the classroom).

The teachers will observe one of their group as she or he teaches the lesson in their regular classroom. Teachers will observe and interact with students in the class as they engage in the learning activities related to the lesson. After observing the lesson and the students, the teachers will meet in a separate location (not in the classroom) to again
discuss and/or refine the lesson which will then be taught in one of the other teachers’ classrooms and again be observed. This cycle will continue with a lesson on another concept being developed and then taught in one of the teachers’ classrooms while the other teachers observe. The teachers in the group will take rotating turns doing the teaching in their own classrooms and observing in the other classrooms. The classroom teacher will at all times be responsible for delivery of the lesson to her or his classroom.

Observation of the teachers’ as they meet and discuss the lesson and the learning of the students will be the focus of the project. The teachers will be volunteers who are willing to engage in this type of professional development model.

Your child is a student in one of the five volunteer classrooms in which the teachers will be observing lessons as they are taught and they may possibly observe and interact with your child as he or she works on mathematics. The observations of the teachers will form the basis for the discussion they will have after the lesson (in a separate location from the classroom). If your child is observed he or she may become part of the focus of these discussions. Such discussion would be undertaken to determine if the lesson was appropriate to the needs of the students in the class. If you agree to have your child observed by the four teachers (but at all time, the regular classroom teacher will be conducting the lesson and be in the classroom) please sign the attached form.

Yours sincerely,

Lyn Vause
Parent(s)/Guardian(s) Consent Form

I, ________________________________, agree to:

Allow my child to be observed as part of the research study entitled, A Fine Balance: Teaching and Learning Mathematics in the Primary Classroom” as described in the letter above.

I understand what this study involves and have been given a copy of this information/consent form.

______________________________________________
Signature

______________________________________________
Date

If you have any questions or concerns about this study, please contact me directly (705-728-2385). Lyn.vause@edu.gov.on.ca or Dr. Linda Cameron by email at lcameron@oise.utoronto.ca
Appendix I: Consent Form of Participants

Name of Participant:

School:

Address:

Dear [Name],

I am a doctoral student at the Ontario Institute for Studies in Education in the Department of Curriculum Teaching and Learning, University of Toronto. Working under the supervision of Dr. Linda Cameron, I am conducting a research study entitled, A Fine Balance: Teaching and Learning Mathematics in the Primary Classroom. My interest is in research in teacher professional development and how it is affected by professional development job-embedded professional learning opportunities involving the observation of students and the refinement of lessons.

In particular, I would work as a participant-observer of five Grade Two teachers as they engage in a three-part professional development cycle focused on improving teacher effectiveness in the classroom. The format of the study will be as follows:

The teachers will collaboratively develop lessons (based on lessons they would normally be doing at that time of year in the classroom) and work with groups of students on mathematical tasks.

The teachers will observe one of their group as she or he teaches the lesson in their regular classroom. Teachers will observe and interact with students in the class as they engage in the learning activities related to the lesson. After observing the lesson and the students, the teachers will meet in a separate location (not in the classroom) to again
discuss and/or refine the lesson which will then be taught in one of the other teachers’
classrooms and again be observed. This cycle will continue with a lesson on another
concept being developed and then taught in one of the teachers’ classrooms while the
other teachers observe. The teachers in the group will take rotating turns doing the
teaching in their own classrooms and observing in the other classrooms. The classroom
teacher will at all times be responsible for delivery of the lesson to her or his classroom.

If you are interested in becoming part of this research group, please relay your
interest to Gabrielle O’Reilly at the Board Office and she will make the arrangements.

There is no potential risk to you or the students in your classrooms. The precautions
taken to minimize risk will adhere to the ethical standards for research of the University of
Toronto Research Services, University of Toronto. Dr. Linda Cameron, my supervisor,
and myself will have access to the data I collect. Observations from this inquiry will be
kept confidential and pseudonyms will be used in the written report and related materials.
You will have the opportunity to read my research paper and request any changes to the
appropriate section. Participation in this research is voluntary and you may withdraw at
any time for any reason, The data will be collected by anecdotal observations and via
audiotape and videotape to help ensure accuracy in my notes. All data collected will be
locked in a personal filing cabinet and also stored securely in a home computer. I will
maintain the data in my home office and the data will be shredded upon successful
completion of this project. Any audiotapes or videotapes of your child will be used for
transcription purposes only and will be destroyed immediately after my faculty supervisor
has had any access she might need to validate my observations as indicated in the paper.

My supervisor, Linda Cameron, Professor, OISE/UT, can be reached at 416-489-
2822, ext. 4998, or lcameron@oise.utoronto.ca if you have any concerns. You may contact me at 705-728-2385 or at lvause@edu.yorku.ca

Please indicate below, if you consent to be a participant in this inquiry.

Yours sincerely,

Lyn Vause

Consent Form

I, agree to participate in the research study entitled, A Fine Balance: Teaching and Learning Mathematics in the Primary Classroom as described in the letter above.

I understand what this study involves and have been given a copy of this information/consent form.

________________________________________________________
Signature Date