

**A Case Study of a High School Mathematics Professional
Learning Community in Ontario**

Kelly McKie

Thesis submitted to the
Faculty of Graduate and Postdoctoral Studies
In partial fulfillment of the requirements
For the Master of Arts in Education degree

Faculty of Education
University of Ottawa

Acknowledgments

I would like to acknowledge and thank my thesis advisor Dr. Chris Suurtamm. Since the day that I met Dr. Suurtamm, she has been a thoughtful, respectful and patient advisor. Her knowledge and experience in the area of mathematics education is vast, and I have benefitted greatly from her expertise. Without her, I would not have been able to accomplish this task of submitting my MA thesis.

Dr. Suurtamm has been instrumental in guiding my progress at the University of Ottawa. Her thorough knowledge of the graduate program at the Faculty of Education insured that my course selection supported my growth in my area of interest. At the same time, she challenged me to push beyond my comfort zone and consider options that would expand my understanding of both mathematics education and research. I am beyond appreciative of the extensive support she has selflessly provided to me throughout the past three years.

I would also like to thank the members of my thesis committee, Dr. Joel Westheimer and Dr. Ruth Kane. I appreciate all of the time they have dedicated to providing feedback and alternative perspectives relating to this study. While completing an assignment for Dr. Kane, I latched onto Dr. Westheimer's work on community. This initial interest became a springboard for this inquiry, and I am truly grateful for the level of support I have received since then.

I would like to thank my supportive and patient family, my husband Marc and my children Luc and Sydney. Your endless support and pride in my work has made the last three years that much more enjoyable.

Dr. Sharon Friesen, the late Dr. Pat Clifford, and the rest of the Galileo team, have all played important roles in my journey to completing this Masters degree. Through my work with Galileo I was exposed to the possibilities of inquiry and the role that supporting teachers plays in the field of Education. Thank you for planting that seed.

Lastly I would like to extend my heartfelt thanks to the members of the PLC at Fields High School for their generosity, inclusivity, and kindness. I always looked forward to visiting your school because you made me feel welcome. You have taught me so much about teaching and learning mathematics and I am excited to see where our collaborations will take us in the future.

Abstract

This qualitative study offers an in-depth description of a high school professional learning community (PLC) as it focuses on enhancing the teaching and learning of the Grade 9 Applied Mathematics curriculum. The teachers' goal in this PLC is to implement strategies they believe best meet the needs of their students. Over the course of one school year data was collected during PLC meetings and through individual participant interviews. Data was analyzed and used to answer the following research questions: How is a PLC formed and sustained, and how does it evolve throughout the process of teachers examining their practice? What happens when a professional community of learners comes together to discuss, dissect and reflect on their own practice with the intention of broadening their understanding of teaching mathematics?

Analysis of the data revealed that teachers came together through their shared work of teaching in ways that address the needs of students in applied level mathematics. Through external funding and strong leadership and support from the school Principal, this PLC created opportunities to meet and collaborate. During meetings the PLC members discussed their pedagogical challenges, focused on the needs of students and student learning, designed lessons that would specifically target the needs of their students, observed each other teach these co-designed lessons, and finally discussed and reflected on the taught lesson. This process was repeated throughout the year, each time building on lessons learned from previous experiences. Although the PLC members described how being out of their class to collaborate did pose some challenges, overall they described their experience in the PLC as the most powerful professional development of their careers.

Table of Contents

ACKNOWLEDGMENTS.....	II
ABSTRACT	IV
TABLE OF CONTENTS.....	V
LIST OF TABLES AND FIGURES	VII
CHAPTER 1: INTRODUCTION	1
PURPOSE OF THE STUDY.....	1
PERSONAL SIGNIFICANCE.....	2
RESEARCH QUESTIONS.....	3
SIGNIFICANCE OF THE STUDY.....	4
THESIS OVERVIEW	6
CHAPTER 2: REVIEW OF THE LITERATURE	7
CURRENT PERSPECTIVES ON MATHEMATICS AND MATHEMATICS TEACHING AND LEARNING	7
AIMS FOR TEACHING AND LEARNING MATHEMATICS.....	8
CHANGING ROLE OF TEACHER.....	11
CHALLENGES TEACHERS FACE IN TEACHING MATHEMATICS.....	14
PROFESSIONAL DEVELOPMENT FOR MATHEMATICS TEACHERS.....	19
PROFESSIONAL LEARNING COMMUNITIES	24
DEFINITION OF A PLC.....	24
CHARACTERISTICS OF A PLC	27
ROLES OF KEY STAKEHOLDERS.....	30
EFFECT OF PLCs ON STUDENT LEARNING.....	32
EFFECT OF PLCs ON TEACHERS	33
CHALLENGES TO ESTABLISHING A PLC.....	34
GAPS IN RESEARCH.....	35
SUMMARY.....	36
CHAPTER 3: CONCEPTUAL FRAMEWORK.....	38
COMMIT TO VISION AND STANDARDS.....	41
ANALYZE STUDENT LEARNING AND OTHER DATA	43
SET GOALS	46
PLAN AND DO.....	52
EVALUATE RESULTS.....	54
SUMMARY.....	55
CHAPTER 4: RESEARCH DESIGN	56
OVERVIEW OF THE RESEARCH	56
RATIONALE FOR QUALITATIVE CASE STUDY.....	57
MY ROLE AS A RESEARCHER	58
RECRUITMENT STRATEGIES	59
PARTICIPATION IN THE STUDY.....	59
DATA COLLECTION AND INSTRUMENTS	60
DATA CONSTRUCTION ANALYSIS AND INTERPRETATION.....	64
CREDIBILITY AND VERIFICATION.....	68
CHAPTER 5: CASE STUDY.....	69
DESCRIPTION OF THE OAME PROJECT	69

DESCRIPTION OF SCHOOL.....	70
DESCRIPTION OF THE PARTICIPANTS	72
DESCRIPTION OF THE PLC.....	76
DESCRIPTION OF PLC MEETINGS AND ACTIVITIES.....	79
PLC INITIATIVES	80
SUMMARY	81
CHAPTER 6: FINDINGS.....	83
ADDRESSING RESEARCH QUESTION ONE: HOW IS A PLC FORMED?.....	84
ADDRESSING RESEARCH QUESTION ONE: HOW DOES A PLC EVOLVE?	91
ADDRESSING RESEARCH QUESTION ONE: HOW IS A PLC SUSTAINED?.....	92
SUMMARY OF ADDRESSING RESEARCH QUESTION ONE	95
ADDRESSING RESEARCH QUESTION TWO: WHAT HAPPENS WHEN A PLC COMES TOGETHER?	96
SUMMARY OF FINDINGS.....	110
CHAPTER 7: DISCUSSION OF FINDINGS	113
COMMIT TO VISION AND STANDARDS.....	114
ANALYZE STUDENT LEARNING AND OTHER DATA	119
SET GOALS	124
PLAN AND DO.....	131
EVALUATE RESULTS.....	131
SUMMARY OF DISCUSSION	132
CHAPTER 8: CONCLUDING COMMENTS	134
CONTRIBUTIONS OF THIS STUDY	135
EXEMPLARY MODEL OF A PLC.....	137
IMPLICATIONS OF THIS STUDY.....	144
LIMITATIONS OF THIS STUDY	147
MOVING FORWARD	147
CONCLUDING THOUGHTS	151
REFERENCES	152
APPENDIX A: SHULMAN'S NECESSARY KNOWLEDGE FOR TEACHING (1987).....	165
APPENDIX B: WHAT TEACHERS NEED TO KNOW TO TEACH MATH.....	166
APPENDIX C: INTERVIEW PROTOCOL - FOCUS GROUP.....	167
APPENDIX D: INTERVIEW PROTOCOL - PRINCIPAL INTERVIEW	168
APPENDIX E: INTERVIEW PROTOCOL - TEACHER INTERVIEW	169
APPENDIX F: WAYNE - LESSON PLAN	170
APPENDIX G: WILLIAM - LESSON PLAN	173
APPENDIX H: TASHA - LESSON PLAN.....	176
APPENDIX I: STUDENT BELIEFS AND ATTITUDES SURVEY	181

List of Tables and Figures

Tables

TABLE 1: INTEREST GROUPS AND AIMS FOR TEACHING MATHEMATICS (ADAPTED FROM ERNEST, 1991).....	9
TABLE 2: BELIEF ORIENTATION TOWARDS MATHEMATICS TEACHING (ADAPTED FROM ASKEW ET AL., 1997).....	10
TABLE 3: COMPARING DIFFERENT FRAMEWORKS FOR PLC CHARACTERISTICS	27
TABLE 4: CHARACTERISTICS OF EFFECTIVE PD AND PLCs.....	36
TABLE 5: CONTEXT FACTORS AFFECTING PD INITIATIVES (ADAPTED FROM LOUCKS-HORSLEY ET AL., 2010)	43
TABLE 6: CRITICAL ISSUES THAT MAY AFFECT PD (ADAPTED FROM LOUCKS-HORSLEY ET AL., 2010)	47
TABLE 7: SUMMARY OF DATA COLLECTED.....	62
TABLE 8: SUMMARY OF ARTIFACTS COLLECTED	64
TABLE 9: COMPARING GRADE 9 APPLIED AND ACADEMIC DEMOGRAPHICS AT FIELDS HIGH SCHOOL	71
TABLE 10: MEMBERS OF THE FIELDS HIGH SCHOOL PLC.....	72
TABLE 11: KNOWLEDGE AND BELIEFS OF PLC MEMBERS.....	117
TABLE 12: STRUCTURAL CONDITIONS & HUMAN/SOCIAL RESOURCES NECESSARY FOR A PLC (ADAPTED FROM LOUISE, KRUSE, AND BRYK, 1995 & ROBERTS AND PRUITT, 2009)	143

Figures

FIGURE 1: FRAMEWORK FOR PROFESSIONAL DEVELOPMENT FOR MATHEMATICS TEACHERS.....	39
FIGURE 2: OAME AND 4SI MEMBER OVERLAP	79
FIGURE 3: FRAMEWORK FOR PROFESSIONAL DEVELOPMENT FOR MATHEMATICS TEACHERS.....	113

Chapter 1: Introduction

Purpose of the Study

This research study is a case study of a high school mathematics professional learning community (PLC) and the experiences of its members. This study describes the experiences of the members of the PLC as they engage in professional development designed to help them reflect on and respond to self-identified problems of practice. Members of this PLC represent various levels of the educational system and include the school Principal, the Mathematics Department Head, two Teachers of Applied Mathematics, and the Student Success Teacher. The study considers their perspectives and experiences as they focus on enhancing their understanding of the Grade 9 Applied Mathematics curriculum and on implementing the curriculum in ways they believe best meet the needs of their students. Data sources include audio recordings of monthly meetings, individual interviews, classroom artifacts that participants share with me, and my observations recorded in a research journal.

This PLC was selected as one of 10-school team PLCs to participate in a province wide project funded by the Ontario Ministry of Education (OME) and managed by the Ontario Association of Mathematics Educators (OAME). I describe this project in more detail in Chapter 5. One criterion for participating in this provincial project was that several teachers within a school, supported by an administrator and resource teachers, identify an area of their classroom practice that they would like to focus on over one academic year. I was assigned to this particular school as part of the research team associated with the OAME Grade 9 Applied Mathematics project in the role of research

assistant (RA). My role as an RA involved being a resource for the members of the PLC, to support them as they explored their problems of practice, and to keep records and collect artifacts in order to describe the journey of this PLC.

The purpose of the study in this dissertation differs from the OAME project in the sense that this is a single-case study rather than a cross-case study. My area of interest and focus in my Master's work is the learning and interactions of mathematics teachers within a PLC. This PLC was therefore the ideal setting to allow me to dig deeper in both the data collection and analysis and to be able to address my own research questions. Through access to this PLC I was able to ask additional questions that related to my research questions and to dig further into issues I deemed relevant to my study.

Personal Significance

I was first introduced to the concept of teachers working on self-identified problems of practice during my student teaching work placement. I had enrolled at the University of Calgary in 2000 to pursue a degree in mathematics education. Teacher candidates were required to complete two practicum experiences and one work placement experience. The thinking behind the work placement is to expose students to alternate careers that a bachelor's degree in education would allow you to pursue. I was placed with the non-profit organization, Galileo Educational Network Association (GENA), based out of the University of Calgary. One goal of GENA at that time was to help teachers integrate a mandated technology component in the classroom. This mandate, introduced in 1997, required the integration of technology across all subject matters and grade levels in Alberta. A second goal was to assist teachers as they explored ways to integrate inquiry-based learning into their classrooms. My six-week placement at GENA turned into a full

time position upon graduation. Due to my engineering background and secondary mathematics degree I was asked to assist with the mathematics initiatives, one of which was a program called SumTalk.

SumTalk invited teachers from across the province to meet on a monthly basis, on their own time, to discuss identified problems of practice in their own classrooms. Teachers organized themselves into groups based on grade level and began to co-design lessons to address concepts they found challenging or that students were struggling with. If teachers were available they would observe each other teach otherwise I would video record the lesson and the other teachers would observe the taped lesson prior to the next monthly meeting. Often teachers taught at different schools and it was not always possible to attend each other's lessons. During the follow-up meeting teachers would debrief about the lesson and redesign components of the lesson as they saw fit. I found this work immensely rewarding and continued to work with GENA until our family moved back to Ontario in 2006.

My goal in pursuing a Masters degree was to continue to explore issues related to professional development for mathematics teachers. I feel rather fortunate to have been presented with the opportunity to be involved in a research project that directly relates to my interests and allows me, once again, to work directly with teachers as they engage in this type of work.

Research Questions

The purpose of this study is to investigate and describe the experiences of a practicing PLC as participants work collectively to examine and enhance their own

practice. Further, through this study I gain a better understanding of the challenges teachers face as they engage in this professional learning.

This study is guided by the following research questions:

1. How is a PLC formed and sustained, and how does it evolve throughout the process of examining practice?
2. What happens when a professional community of learners comes together to discuss, dissect and reflect on their own practice with the intention of broadening their understanding of teaching mathematics?

Significance of the Study

This study documents a collaborative professional development initiative that is not a directed intervention designed by outside agents. The initiative, although funded by the Ministry of Education, is a teacher directed initiative that focuses on teachers' own identified problems of practice. The teachers involved in this project are doing so out of a personal desire to enhance the teaching and learning in their own classrooms. It is a unique opportunity to observe teachers as they engage in professional learning of their own design and focus of interest.

There has been a great deal of research on effective professional learning (e.g., Borko, 2004; Evens & Ball, 2009; Loucks-Horsley & Matsumoto, 1999; Loucks-Horsley, Stiles, Mundry, Love, & Hewson, 2014) and professional learning communities (Cogshall, Rasmussen, Colton, Milton & Jacques, 2012; DuFour, 2004; Louis, Dretzke, Wahlstrom, 2010; Louis & Marks, 1998; Miller, Goddard, Goddard, Larsen, & Jacob, 2010; Saunders, Goldenberg, & Gallimore, 2009; Stoll, Bolam, McMahon, Wallace & Thomas, 2006). Yet research that adequately describes the conditions necessary to

promote a PLC within a school setting and the effectiveness of PLCs is limited (Attard, 2012; Stoll et al., 2006). Westheimer (2008) suggests, “the specifics of what these communities look like and of how to create and sustain them remain varied” (p. 757). This study provides a description of how one PLC came to exist, how it is sustained, the conditions that promote it, as well as what it looks like and the activities it engages in. Through this study I gain an understanding of the challenges, issues and successes this community experiences as it attempts to improve its members’ efficacy for teaching mathematics. This experience may add to the body of knowledge that exists for understanding, establishing and sustaining professional learning communities, specifically related to the subject area of mathematics.

PLCs have become a common method for professional development across many subject areas but there are few documented accounts in the research that describe what occurs during this type of initiative (Attard, 2012; Crespo 2006). In their review of research, which studied the impact of PLCs on teaching practices and student learning, Vescio, Adams and Ross (2008) stressed how difficult it was to find studies that detailed not only how teaching practices have changed but that also described what teacher practices looked like before the PLC was active in a particular setting. Knowing that this type of data is limited in the research literature directed my attention to gathering this information in my own study. I made sure to ask the participants to describe their teaching both before their engagement in the PLC and after. I describe not only how teacher practices have changed but also what teacher practices looked like before the participants began working collaboratively. In this way my study can contribute to this particular area of research that others have described as limited.

Thesis Overview

This thesis is organized into eight chapters as follows. Chapter 1 provides a brief description of the study, the research questions and the significance of the study. Chapter 2 includes a review of research literature, both theoretical and empirical. It offers a description of the evolving role of teachers in mathematics education, views on effective professional development for all teachers and teachers of mathematics in particular and on PLCs. Chapter 3 offers a conceptual framework that I found helpful while considering my data as it provided me with a clearer understanding regarding effective professional development for mathematics teachers. Chapter 4 outlines the research design for this study including participant recruitment, data gathering and data analysis. Chapter 5 describes the specific case in this study, including a description of the school, individual participants as well as a detailed description of the activities of the PLC. Chapter 6 presents findings that address my research questions and Chapter 7 is a discussion of my findings using the conceptual framework as a lens. Chapter 8 presents my concluding comments as well as implications and limitations of the study and possible scenarios for future research in this area.

Chapter 2: Review of the Literature

Through a review of literature related to professional development for mathematics teachers and specifically PLCs I continually bumped up against issues of perspectives on the teaching and learning of mathematics and how this has shaped the current vision and standards for teaching mathematics. These issues have a direct impact on how organizations approach professional development, including the implementation of PLCs. I was hesitant to begin my study without first exploring how the present reality of teaching and learning mathematics has evolved. In order to do this I discuss current perspectives on mathematics and mathematics teaching and learning, what driving forces helped to shape these perspectives and how aims for teaching mathematics and the needs of mathematics teachers have changed as a result. This leads to the discussion of challenges teachers face as they attempt to teach to these new standards and how the literature informs the educational community in terms of effective professional development and PLCs.

Current Perspectives on Mathematics and Mathematics Teaching and Learning

Ernest (2014) suggests that there are two opposing perspectives on the nature of mathematics, the Absolutist perspective and the Fallibilist perspective. Absolutists believe that mathematics is based on an exact foundation of rules and all mathematical principles can be derived from this foundation. Absolutists believe “all mathematical knowledge is true and beyond any doubt” (Ernest, 2014, p. 5). This perspective generally results in the “image of mathematics as objective, fixed, pure, abstract and wholly logical, which is the traditional and often negative image of mathematics held by many persons” (Ernest, 2014, p. 6). This rigid perspective may also contribute to a large portion of

society viewing mathematics education as training students to be efficient in arithmetic as opposed to developing mathematical thinking and problem solving. Fallibilists believe that “mathematical knowledge is... fallible and eternally open to revision, both in terms of its proofs and its concepts” (p. 6). Absolutists typically subscribe to a more traditional method of teaching mathematics, and believe mathematics should be reserved for a small fraction of the population (Ernest, 2000). Fallibilists view mathematics as a subject with a more human side and believe it should be taught to all members of society, using an open approach. They believe an appreciation of mathematics is a necessary skill for individuals in order to navigate and make sense of the world around them (Ernest, 2000). It is again important to stress that the purpose of mathematics education is more than the study of arithmetic. The Ontario Ministry of Education explains:

Learning mathematics results in more than a mastery of basic skills. It equips students with a concise and powerful means of communication. Mathematical structures, operations, processes, and language provide students with a framework and tools for reasoning, justifying conclusions, and expressing ideas clearly (OME, 2005, p. 4).

Aims for Teaching and Learning Mathematics

Although Ernest might see these competing views as a dichotomy, I see them as ends of a continuum. Those who teach mathematics have perspectives that fall somewhere on the continuum between the Absolutist and Fallibilist perspectives. Ernest (2014) suggests that different interest groups exist each with their own aims for the teaching and learning of mathematics. Ernest (2014) suggests that:

The aims of mathematics teaching are expressions of intent, and thus educational aims are the expression of the values, interests and even the ideologies of certain individuals or groups. Furthermore, the interests and ideologies of some such groups are often in conflict (p.8).

These different groups, as proposed by Ernest (1991; 2014), are the Industrial Trainers, Technological Pragmatists, Old Humanist Mathematicians, Progressive Educators and the Public Educators. Table 1 expands on the aims of these five groups.

Table 1: Interest groups and aims for teaching mathematics (adapted from Ernest, 1991)

Interest Group	Aims for the teaching of mathematics
Industrial Trainer	Acquiring basic mathematical skills and numeracy, and social training in obedience (authoritarian, basic skills-centred view)
Technological Pragmatist	Learning basic skills, and learning to solve practical problems with mathematics (industry and work-centred view)
Old Humanist Mathematicians	Acquiring understanding and capability in advanced mathematics, with some appreciation of mathematics (pure mathematics-centred view)
Progressive Educators	Acquiring confidence, creativity and self-expression through mathematics (child-centred, progressivist view)
Public Educators	The empowerment of the learner as a highly numerate critical citizen (empowerment and social justice concerns).

The first four groups are more in line with an Absolutist view of mathematics and share beliefs such as viewing mathematics as a skill that one is born with and is fixed (Ernest, 2014). Of those four, all but the Progressive Educator believe that mathematics teaching should be varied according to one's inherited skills or future occupations (Ernest, 1991). Conversely, the Public Educator believes there should be a "humanized neutral maths for all" (Ernest, 1991, p. 138) and takes a Fallibilist perspective on mathematics education. Ernest (1991) explains that the Public Educators believe mathematics education should "deemphasize the uniqueness and correctness of answers and methods, and centre instead on humans as active makers of knowledge" (p. 287) and their aim is to "empower the working classes to participate in the democratic institutions of society, and to share more fully in the prosperity of modern industrial society" (p.126).

Askew, Brown, Rhodes, Johnson and, William (1997) also explore the purposes of teaching and learning mathematics and suggest three orientations that primary teachers exhibit towards teaching mathematics. These three orientations are outlined in Table 2

Table 2: Belief Orientation Towards Mathematics Teaching (adapted from Askew et al., 1997)

Orientation	Beliefs
Connectionist	Value students' methods, and teaching with emphasis on establishing connections in mathematics
Transmission	Emphasize the primacy of teaching, with a view of mathematics as a collection of separate routines and procedures
Discovery	Emphasize the primacy of learning, with a view of mathematics as being discovered by students

Askew and colleagues (1997) found that teachers with a connectionist orientation towards teaching mathematics had the greatest impact on student learning and that transmission and discovery beliefs were equally less effective. Ernest (2014) suggests that the connectionist orientation is most aligned with the Old Humanist Mathematicians interest group with some aims of the Public Educator interest group also represented.

The Old Humanist Mathematician, Progressive Educator, and the Public Educator interest groups best represent current views on the teaching and learning of mathematics. All students should acquire understanding, capability, and confidence in mathematics and become empowered as a critical and highly numerate citizen.

I present evidence from the U.S. based National Council of Teachers of Mathematics (NCTM) *Principles and Standards for School Mathematics* (2000), a seminal document that represents the current vision of mathematics education, and that supports my claim:

In this changing world, those who understand and can do mathematics will have significantly enhanced opportunities and options for shaping their futures. Mathematical competence opens doors to productive futures. A lack of mathematical competence keeps those doors closed. The NCTM challenges the assumption that

mathematics is for only the select few. On the contrary, everyone needs to understand mathematics. All students should have the opportunity and the support necessary to learn significant mathematics with depth and understanding. There is no conflict between equity and excellence. (NCTM, 2000, p. 5).

These views on teaching and learning mathematics are also reflected in position statements and curricula in a variety of jurisdictions in Canada. For instance, the Grade 1 to Grade 8 Ontario Mathematics Curriculum states that the curriculum is:

Based on the belief that all students can learn mathematics and deserve the opportunity to do so. It recognizes that all students do not necessarily learn mathematics in the same way, using the same resources, and within the same time frames. It supports equity by promoting the active participation of all students (OME, 2005, p. 3).

The Manitoba Ministry of Education (2013) states in the Kindergarten to Grade 8 curriculum that one of the main goals of mathematics education is “to prepare students to become mathematically literate citizens, using mathematics to contribute to society and to think critically about the world” (p. 5).

Changing Role of Teacher

This relatively new perspective on the aims for teaching mathematics and the stance that mathematics is for all students requires reconsidering the role of the teacher (Even & Ball, 2009). Cochran-Smith and Lytle (2009) argue that although there is a great reform underway in teaching and learning, historical assumptions about the role of teachers still hold true. These assumptions include that “teachers are primarily technicians; the goal of teacher learning initiatives is to make teachers more faithful implementers of received knowledge and curriculum; [and] subject matter is a more or less static object to be transmitted from teacher to students” (p. 2). Essentially, teachers historically have been required to transfer knowledge from themselves to their students following a protocol pre-determined for them.

Keeping the work of Askew and colleagues (1997) in mind, a transferring of knowledge, or a transmission orientation towards teaching mathematics, is not as effective as teaching for understanding and making connections. Rather than simply being technicians, perhaps teachers could be recognized as individuals “who can teach mathematics effectively and who can help prepare young people for successful adult lives and for participation in the development and progress of society” (Even & Ball, 2009, p. 1). This echoes the Public Educators interest group’s aims for teaching mathematics.

This evolution in the role of mathematics teachers from transmission to connectionist is due in part to the changing mathematical needs of citizens as they navigate a more technologically rich and connected society (Clarke, 1997). Mathematics is now seen not only as a set of necessary skills, but as a tool for empowering individuals to affect change and contribute to society (Ernest, 1991; Even & Ball, 2009; Cochran-Smith & Lytle, 2009; Ontario Ministry of Education, 2005). These perspectives and research on mathematics teaching and learning shifts the role of the teacher (Suurtamm, 2013).

Beginning in the 1990s we have seen a shift in thinking about mathematics teaching and learning from a traditional approach focused on practicing procedures of doing mathematics to a reform-oriented approach that focuses on developing both procedural and conceptual understanding through problem solving and inquiry into mathematical ideas. As such, the teacher’s role shifts from one of telling and explaining to a more complex one that includes appropriate task selection, facilitation of students actively engaging in mathematical activity, and listening and responding to students’ mathematical thinking (Suurtamm, 2013, p. 1).

LaChance & Confrey (2003) suggest this “shift in thinking” was prompted by the NCTM’s publication of *The Curriculum and Evaluation Standards for School Mathematics* (The Standards) in 1989. There have since been two follow-up documents, the *Principles and Standards for School Mathematics* in 2000 and more recently the *Principles to Action* in 2014. These documents encourage teachers to examine their

teaching and specifically *Principles to Action* suggest that several realities still exist in today's classrooms that are impeding the learning of mathematics for all students. These realities include:

- Too much focus is on learning procedures without any connection to meaning, understanding, or the applications that require these procedures.
- Too many students are limited by the lower expectations and narrower curricula of remedial tracks from which few ever emerge.
- Too many teachers have limited access to the instructional materials, tools, and technology that they need.
- Too much weight is placed on results from assessments—particularly large-scale, high-stakes assessments—that emphasize skills and fact recall and fail to give sufficient attention to problem solving and reasoning.
- Too many teachers of mathematics remain professionally isolated, without the benefits of collaborative structures and coaching, and with inadequate opportunities for professional development related to mathematics teaching and learning (NCTM, 2014, p. 3).

In this most recent publication, *Principles to Action*, the NCTM (2014) suggests that there is still a large focus on learning procedures, skill and memorizing facts in the mathematics classroom and less on understanding and problem solving. NCTM suggests higher expectations are required for all students, not only students bound for university and that limiting students' access to rich mathematics impacts their opportunities for success in the future. These realities impact the role of teachers and change the

expectations placed on teachers. These realities need to be considered if teachers are expected to shift their practice and the role of teacher is to be redefined.

Challenges Teachers Face in Teaching Mathematics

Principles to Action differs from NCTM's previous standards documents; the association realizes that a set of standards alone will not affect change to the profession of teaching. *Principles to Action* is a research-based set of actions that is intended for all levels of the educational system, including parents, teachers and administrators. The rationale of supporting the creation of these actions "is to fill [the] gap between the development and adoption of...standards and the enactment of practices, policies, programs, and actions required for their widespread and successful implementation" (NCTM, 2014, p. 4).

The NCTM *Standards* from 1989 were extremely influential (Wright, 2012) and many school jurisdictions around the world leaned on the NCTM *Standards* while developing their own curricula (O'Shea, 2003). The implementation of these curricula is not necessarily easy to do. Research suggests that there are many challenges facing teachers as they attempt to teach and gain the necessary knowledge to teach to these new standards. Darling-Hammond and Ball (1998) summarized the research on mathematics teacher learning and the challenges teachers face when they are expected to align their teaching with these new ideas:

1. Teachers' prior beliefs and experiences influence how they teach and what they learn from professional development activities designed to increase their learning
2. Shifting ones practice to align with new standards is complex, takes time and it is not easy

3. Teachers require both thorough content knowledge and deep understanding of how children learn mathematics in order to effectively teach mathematics
4. Knowledge of children, their ideas, and their ways of thinking is crucial to teaching for understanding
5. Opportunities for analysis and reflection are central to learning to teach

I subdivide these challenges into three groups and discuss them accordingly.

Challenges 1 and 2 relate to teachers' beliefs and practices and how a shift in beliefs is often required to teach to these new standards. Challenges 3 and 4 are related to the knowledge, both mathematical and pedagogical, that supports teaching to these new standards. Challenge number 5 relates to teacher learning and the necessary conditions that support teacher learning.

Teachers' beliefs and practices. Challenges 1 and 2 relate to teachers' beliefs and practices and how they affect one's teaching. A reformed curriculum will only be successful if teachers' practices align with the suggested reforms (Ernest, 1989). Simply implementing a new set of standards for teaching and learning mathematics does not result in an instantaneous shift in teachers' practice, teachers' own beliefs need to be considered (Ernest, 1989). "Teaching reforms cannot take place unless teachers' deeply held beliefs about mathematics and its teaching and learning change" (Ernest, 1989, p. 249).

Teachers' own experiences as learners of mathematics deeply affect their beliefs of teaching and learning mathematics (Darling-Hammond & Ball, 1998). Teachers tend to teach as they were taught, which for a majority of teachers follows the traditional model. Stigler and Hiebert (1997) suggest that in a traditional mathematics lesson the teacher:

1. Reviews or introduces a new procedure
2. Provides students with step-by-step instructions
3. Assigns students problems on which to practice the procedure

This model is in sharp contrast to reform-based lessons that involve more open-ended questions often in mixed-ability groupings (Boaler, 1998). Instead of practicing mathematics, reformed-based lessons allow students to actively engage in solving mathematical problems. For instance the Ontario mathematics curriculum stress the importance of not only mastering mathematical skills but engaging with mathematical processes they identify as; problem solving, reasoning and proving, reflecting, selecting tools and computational strategies, connecting, representing and communicating (OME, 2005).

If teachers have never experienced reform-based lessons perhaps they would find teaching in this way challenging. Research on teacher change has shown that several factors can help to support a shift in teachers' beliefs about the teaching and learning of mathematics. Cooney (2001) suggests that not only is it helpful to suggest to teachers that certain practices and activities positively affect student understanding of mathematics, it is helpful for teachers to witness and engage with these practices. It is possible that teachers may reevaluate their own beliefs if teachers themselves engage in mathematical activities that allow them to reflect on how specifically designed mathematical tasks can lead to greater understanding for their students (Cooney, 2001).

Teachers' knowledge for teaching. Challenges 3 and 4 relate to knowledge for teaching mathematics and researchers have attempted to define this. Shulman (1986, 1987) popularized three terms in relation to the knowledge required for teaching, these

are: subject matter knowledge (SMK), pedagogical content knowledge (PCK), and curriculum knowledge. He pays particular attention to PCK as he stresses the importance of marrying both pedagogical knowledge and content knowledge for teaching and most importantly “an understanding of what makes the learning of specific topics easy or difficult” (1986, p. 9). See Appendix A for Shulman’s full list of the necessary knowledge teachers needed for teaching-

Several researchers (Even, 1990; 1993; Ball, Hill & Bass, 2005) have used Shulman’s concept of SMK to develop an analytical framework for teaching mathematical concepts. Even (1990, 1993) suggests that the following seven aspects of teachers’ knowledge are in play when teaching mathematical concepts: understanding students’ images of a concept, different representations of the concepts, alternative approaches to the concept, the strength of the concept, powerful examples of the concept, knowledge and understanding of the concept, and knowledge about mathematics.

Ball, Hill, and Bass (2005) applied Shulman’s work on the necessary knowledge for teaching to mathematics education and coined the term mathematical knowledge for teaching (MKT). They define MKT as “the mathematical knowledge that teachers require in order to carry out their work as teachers of mathematics” (Ball, Thames & Phelps, 2008, p. 395). MKT includes the following six types of necessary knowledge: common content knowledge, knowledge at the mathematical horizon, specialized content knowledge, knowledge of content and students, knowledge of content and teaching, knowledge of curriculum. The connections between these different types of knowledge are illustrated in Appendix B

It becomes evident when considering the above researchers' work that teachers require a sound foundation in the major ideas of the disciplines of mathematics. Also, it appears that teaching mathematics calls for a deep understanding of how students come to learn the discipline (NRC, 1999). In order to successfully assess students' prior knowledge, process the big ideas of the curriculum content, and how best to teach their students this content a strong pedagogical content knowledge (PCK) is important (Shulman, 1987). PCK is necessary in order to respond to student thinking and to select appropriate tasks to help students connect the big ideas of the curriculum (Loucks-Horsley and Matsumoto, 1999). Research has shown that PCK can be developed several ways: through the work of teachers reviewing and planning lessons, viewing student work, and through the act of teaching (Loucks-Horsley and Matsumoto, 1999).

Analysis and reflection. A third challenge facing teachers is finding time to analyze and reflect on their own pedagogy in ways that enhance their practice, challenge number 5 as outlined by Darling-Hammond and Ball (1998). The work of teaching is often carried out in isolation; teachers receive minimal feedback from peers and few opportunities to collaborate (Hargreaves, 1994). Crespo (2006) suggests that significant conversations related to pedagogy and best practice between teachers are uncommon. Britton, Paine, Pimm & Raizen (2003) suggest that in North America it is understood by the majority of teachers that to be a good colleague suggests that you do not ask peers about their classroom practice. This idea appears in *Principles to Action* (NCTM, 2014). There it is stressed that still "too many teachers of mathematics remain professionally isolated, without the benefits of collaborative structures and coaching, with inadequate

opportunities for professional development related to mathematics teaching and learning” (p. 3).

Rosenholtz (1991) describes this challenge as learning-impoverished. Her research on different types of learning environments in schools found that there exist two very different environments of schools. She labels these two environments as either “learning-enriched” or “learning-impoverished” (p. 83). In learning-enriched schools teachers interacted frequently and worked closely together around issues of teaching and learning” (Loucks-Horsley and Matsumoto, 1999, p. 265). Understanding how to create a learning-enriched environment might potentially address the challenge many teachers face of finding opportunities to analyze and reflect on their own practice. If teachers are given “time, space, and encouragement to reflect in ways that facilitate their learning by talking with others, by keeping a journal, or by engaging in action research” (Darling-Hammond & Ball, 1998, p. 16) perhaps schools can become more in line with the learning-enriched model. Hargreaves (1994) suggests that teachers’ sense of efficacy can also be strengthened when they collectively share a common goal, such as improving student achievement in mathematics.

Professional Development for Mathematics Teachers

In the previous section I have reviewed literature relating to the challenges facing teachers as they teach mathematics, namely their beliefs and practices, knowledge for teaching, and opportunities to analyze and reflect on their teaching. In this section I review literature related to professional development that helps to support mathematics teachers as they face these challenges. Well-designed professional development provides

teachers with opportunities to examine their practice and enhance their knowledge for teaching mathematics (Borko, 2004).

There is no one-size-fits-all formula for designing professional development for mathematics teachers as each school or community of teachers has its own individual goals and exists in its own specific learning environment (Loucks-Horsley et al., 2010). However, there are some particular components that researchers have found to be effective, regardless of the setting (Loucks-Horsley and Matsumoto, 1999). These components suggest that professional development should be:

- Curriculum-based
- Focused on student thinking
- Takes place in a supportive environment in alignment with other elements of the system such as assessment and administrative support
- Goal-focused and collaborative (Loucks-Horsley and Matsumoto, 1999).

I break down these characteristics and discuss each of them individually and in terms of mathematics teaching and learning.

Curriculum-based. Using the mathematics curriculum (government document outlining the required expectations teachers must address during a course of study) as a point of focus for teachers' professional development allows teachers time to develop a deeper understanding of mathematics (Loucks-Horsley and Matsumoto, 1999). Teachers engaging in problem solving activities similar to those that their students engage in allows teachers to develop a deeper understanding of not only the mathematics content but also of how a learner would interact with this content. This provides teachers the opportunity to consider how best to teach the content (Schifter & Fosnot, 1993; Borko,

2004). When teachers engage in curriculum-based professional development they have an opportunity to develop a clearer understanding of how students learn, the difficulties and misunderstanding students may have, and how best to assist them with their learning of these concepts (Borko, 2004).

LaChance and Confrey (2003) explored what impact the exploration of mathematical content might have on a group of high school mathematics teachers. The original goal of their study was to enhance the teachers' knowledge of mathematical content by having the teachers engage in activities that their students would engage with. What the researchers discovered was that by exploring the mathematical content together as a group it gave the participants "a reason and purpose for interacting" (p. 120) around issues that were important to them. An unexpected result of this study was the beginnings of a PLC forming at the school.

Focused on student thinking and learning. A teacher's own understanding of mathematical concepts in a curriculum is important yet does not always lead to an ability to help students grasp these concepts (Kersting, Givvin, Sotelo & Stigler, 2010). Professional development that is focused on both student thinking and student learning offers teachers a different perspective on the mathematics curriculum (Loucks-Horsley & Matsumoto, 1999). When teachers assess student work, decipher students' level of understanding, and decide on the appropriate next steps to help students advance their mathematical understanding, teachers are presented with an opportunity to engage in rich mathematical dialogue (Shulman, 1987; Borko, 2004; Kersting et al, 2010). Professional development that is focused on student thinking allows teachers to develop this necessary mathematical knowledge for teaching and analyzing artifacts of student work is an

effective approach to focusing on student thinking (Ball, Hill & Bass, 2005). When teachers discuss student work together with colleagues they develop a deeper understanding of students' thinking and can work together to design plausible next steps for students in order to enhance students' mathematical understanding (Borko, 2004). In their review of studies looking at the impact of PLCs Vescio and colleagues (2008) found that communities that did not engage in work that was specifically focused on student learning were not as successful as PLCs that were.

Teachers can focus on student learning in several ways. One way is to analyze student assessment data, both formative and summative and student achievement on standards-based tests. A second way is to consider the day-to-day work of students in class such as their written and verbal responses to tasks, and reflective writing about their experiences in mathematics class. This focus on student learning data may bring to light any gaps in performance between different groups of students, different ethnic, gender or socio-economic groups for example, and may reveal inequitable learning trends that teachers were unaware of (Loucks-Horsley et al., 2010). Being made aware of these performance gaps could present an avenue for teachers to explore teaching practices together and perhaps pursue a different course of action that would address these inequities (Loucks-Horsley et al., 2010). Focusing on student thinking through the examination of their day-to-day work may reveal misunderstandings students have about specific mathematical content. These areas of struggle offer a point of focus for teachers to discuss student thinking Borko, 2004).

Supportive environment. Professional development can be most effective when it occurs within a supportive environment that aligns the interests of all stakeholders

towards a common goal of increasing student learning (Loucks-Horsley & Mastsumoto, 1999). These stakeholders include, but are not limited to, teachers, students, school and district administrators, and parents. A key component to a supportive environment is leadership, and strong leadership has a profound impact on student learning (Leithwood, Louis, Anderson, & Wahlstrom, 2004). Effective leaders not only create opportunities for teachers to engage in professional learning activities they also “ensur[e] that the entire range of conditions and incentives in districts and schools fully supports rather than inhibit teaching and learning (Leithwood et al., 2004, p.3).

Collaborative and goal-focused. Due to the evolving expectations for the teaching and learning of mathematics discussed earlier, teachers are often expected to teach and design learning experiences for their students that they themselves may not have experienced before (Darling-Hammond & McLaughlin, 1995). It has been suggested that the creation of well-developed professional learning communities (PLC) would allow teachers the opportunity to develop these new ways of teaching mathematics with their peers (Vescio, Ross & Adams, 2008). Collaboration alone does not guarantee that a professional development initiative will be successful (Fullan & Hargreaves, 1996; McLaughlin, 1993). Schools engaged in professional development that is focused on specific goals, rather than a transfer of specific skill or knowledge, such as long-term school improvement have proven to be more successful (Killion, 1998). As I continue to review the literature and place my study within the context of current educational research, I shift my focus specifically to PLCs.

Professional Learning Communities

PLCs are a “hot topic” in research literature and some could argue that they are simply the latest trend to infiltrate school culture (DuFour, 2004; Stoll, 2006). Hord and Sommers (2009) suggests that while many schools have implemented what they perceive is a PLC they have not considered current research, are not familiar with the definition of a PLC, and the requirements for establishing a PLC are misunderstood. DuFour (2004) fears that the term *professional learning community* “is used so ubiquitously that it is in danger of losing all it’s meaning” (p. 1). This confusion and these misunderstandings around the term can result in a school community being unsuccessful at implementing a PLC and might prevent them from pursuing further professional development for their teachers (Timperly & Robinson, 2000). As PLCs are a relatively new initiative in many schools, and research focused specifically on the PLCs is still being generated, I feel it is important to present a complete picture of this initiative in schools

In the following sections I present current research on PLCs, I discuss the following aspects of PLCs and use empirical studies as examples:

- Definition of a PLC
- Characteristics of a PLC
- Role of Key Stakeholders in a PLC
- Effect of PLCs on pedagogy
- Effect of PLCs on student achievement
- Challenges associated with establishing a PLC

Definition of a PLC

Many educational researchers credit Senge (1990) with disrupting the way that the education community views the structure of their institutions (Cormier & Olivier, 2009;

Roberts and Pruitt, 2009). In his publication, *The Fifth Discipline*, Senge suggests that if organizations are to survive they need to rethink how they communicate within their structure. Senge (1990) had intended the audience for his publication to be business organizations but the concept caught on within schools and educational stakeholders began to consider how to create schools that were learning organizations based on his model (Cormier & Olivier, 2009; Fullan, 2007; Roberts and Pruitt, 2009). Ultimately, Senge (1990) suggests that schools should focus primarily on student learning rather than the efficiency with which they produce graduates.

Senge (1990) defines five disciplines necessary for the survival of an organization including: personal mastery, mental models, team learning, building shared vision, and systems thinking. It is this fifth discipline, systems thinking, that had the biggest impact on the educational system (Cormier & Olivier, 2009). Systems thinking is described as one part of a system directly influencing another part of a system. In order for schools to function effectively Senge (1990) recommends considering how teachers can work more collaboratively (Roberts & Pruitt, 2009). As previously discussed schools have traditionally been organizations with individuals working in isolation and with limited discussions around practice. The teaching profession “typically [does] not encourage shared thinking. Teachers are generally free to make their own instructional decisions” (Roberts and Pruitt, 2009, p. 3).

Senge and his colleagues followed up his 1990 publication with *How Schools Learn* in 2000. This publication focused on educational systems and detailed how stakeholders within a school may possibly think about organizing themselves as a thinking system (Senge, Cambron-McCabe, Lucas, Smith, Dutton, & Kleiner, 2000). This wave of

rethinking how schools learn introduced the concepts of learning communities in schools, teachers as professionals and the importance of conversations amongst these professionals, all of which are the foundations of PLCs as they exist in schools today (Hargreaves, 1994; Roberts & Pruitt, 2009).

Reimagining schools as learning communities encourages conversations amongst all stakeholders, including principals, teachers, parents, and students (Speck, 1999). The definition of a PLC has evolved over the years since they were first considered as a viable option for organizing a school. The definition that I connect with the most, based on my previous experiences and through this study is a “group of people sharing and critically interrogating their practice in an ongoing, reflective, collaborative, inclusive, learning-oriented, growth-promoting way” (Stoll, et al., 2006).

The idea behind the PLC movement is that “building a more collaborative culture in schools can profoundly change the way both the staff and students in schools grow and learn” (Lieberman, 1988, p. vii). Vescio and colleagues (2008) explain that PLCs are based on two assumptions, the first being that the knowledge of teachers lives in the “day-to-day lived experiences of teachers and [is] best understood through critical reflection with others who share the same experience” (p. 81). The second assumption is that this knowledge is increased, and will enhance students’ learning, when teachers engage in a community of professional learning with their peers (Vescio, Ross & Adams, 2008). Morrissey (2000) suggests that a PLC is more than a professional development plan, “rather than becoming a reform initiative itself, a professional learning community becomes the supporting structure for schools to continuously transform themselves through their own internal capacity” (p. 10).

Characteristics of a PLC

As the amount of research on PLCs grows different frameworks for thinking about these communities have emerged. Table 3 presents three similar frameworks used by educational researchers and leaders of professional development for educators. Roberts and Pruitt (2009) suggest the framework defined by Kruse, Louis, and Bryk (1995) as suitable for schools to model their efforts after. This model defines a PLC as focused on “the cultivation of learning and interaction among teachers and administrators so as to improve teaching and learning outcomes for students and for the school community at large” (p.6). Cormier and Olivier (2009) reference DuFour and Eaker (1998) when discussing frameworks for PLCs and suggest that the framework defined by Hord (2004) has emerged as a classic framework for a school PLC. Hord (1997) defines a PLC as “a school staff investing its time and effort with student learning as the major goal” (p.22). Hord (1997, 2004) is credited with combining previous research, including that of McLaughlin & Talbert, 2001; Rosenholtz, 1991; and Senge, 2000 on PLCs to create the current accepted model for PLCs (Cormier & Olivier, 2009).

Table 3: Comparing Different Frameworks for PLC Characteristics

Kruse, Louis, & Bryk (1995)	DuFour & Eaker (1998)	Hord (2004)
Shared values and norms	Shared mission, vision and values	Shared beliefs, values, and visions
De-privatization of practice	Systemic process of action orientation and experimentation	Shared personal practice
Collective focus on student learning	Commitment to continuous improvement towards results	Shared and supportive leadership
Reflective dialogue	Collective inquiry by	Collective learning and its

	stakeholders	application
Collaboration	Application of collaborative teams	Supportive conditions

Although not identical in their characteristics, all three frameworks define PLCs as focused on improving student learning. The frameworks suggest that PLCs require members to have similar beliefs and values about teaching and learning and engage in collaborative dialogue and practice.

Louise, Kruse and Bryk (1995) do not limit their framework to these characteristics. They also suggest that the presence of certain structural conditions and human/social resources will help to support the framework they have developed. These structural conditions include:

- Time for teachers to meet and talk about their practice
- Teachers being physically situated close together to ensure ongoing conversations and the opportunity to observe each others practice
- Teacher empowerment and school autonomy
- Effective communication across the entire school structure and regularly scheduled opportunities to discuss teaching, learning and professional learning
- Opportunities to team-teach in order for teachers to share their practice with one another.

The human/social resources consist of:

- Ongoing support for teachers willing and eager to engage in new practices and that express a desire to improve
- Trust and respect for all members of the school community
- Social interactions beyond pedagogical interactions
- Support from those in leadership positions;
- Opportunities to seek out innovative practices, acquire knowledge and work on

expanding their skill set (as cited by Roberts and Pruitt, 2009, p. 7).

Importance of shared goals in a community. The important role of *shared values and goals* in a PLC is mentioned repeatedly throughout the research literature and I feel needs to be discussed in more detail. The importance of shared values and goals is highlighted specifically in an ethnographic study carried out by Westheimer (1999). Before discussing the study Westheimer describes the idea of community from a social theorist point of view. According to social theorists a community exists if it exhibits the following five characteristics:

1. Shared beliefs,
2. Interaction and participation,
3. Interdependence,
4. Concern for individual and minority views, and
5. Meaningful relationships (Westheimer, 1999).

In Westheimer's (1999) quest to describe two well-known and developed school communities he uncovered striking differences based on the goals, beliefs and processes used within these two communities. He describes how the two communities were driven by two very different identities, one he describes as a liberal community "emphasizing individual rights and responsibilities" and the other as a collective community where "members maintain shared goals". Westheimer stresses the importance of defining individual school communities and not simply labeling them all the same because they share the same five characteristics. The liberal community in this study chose to focus on individual teacher autonomy as a goal of the community. This led to a decrease in teacher involvement in collaboration. The collective community shared the goal of increasing

student learning, resulting in increased opportunities for collaboration (Westheimer, 1999). Westheimer (1999) suggests, “community is not built in and of itself – but is built over a set of substantive issues important to all participants” (as cited in LaChance and Confrey, 2003, p. 120).

Roles of Key Stakeholders

The characteristics, structural conditions and resources outlined above require the commitment and engagement from a wide cross-section of stakeholders in a school system (Speck, 1999). I limit my discussion of stakeholders to the two roles represented in my study, teachers and principals.

Lambert (2003) suggests that as a PLC is developed, and if it is to be sustainable, commitment from both principals and teachers are required. A shared leadership approach between principals and teachers is “one of the defining characteristics of PLCs...power, authority, and decision making are shared and encouraged” (Hord & Sommers, 2008, p. 10). Building leadership capacity refers to transferring the leadership from one individual, usually the principal, to the community as a whole, thus resulting in a shared leadership. The importance of shared leadership is highlighted by Wiley (2001) in her study focused on the types of relationships between staff members that have a positive influence on student achievement. She suggests that student achievement is only affected by the organization of teachers into a professional community when “teachers experience above average transformational leadership” (pg. 1).

Principals. The transfer of leadership from one individual to the collective community creates a new role for the principal, from one of “sole instructional leader to leader facilitator” (Roberts & Pruitt, 2009, p. 27). A second role of the principal is to act

as a cheerleader of sorts, “encouraging, nourishing, bolstering and reminding others within the school community of the shared vision and values that serve as motivation for the work of reform” (Copland, 2003, p. 388). Perhaps the most important role of the principal is to create opportunities, and encourage teachers, to meet and discuss teaching and learning strategies that will move a PLC towards their shared vision focused on student achievement (Eaker, DuFour & DuFour, 2002). This support from the principal will help to insure the sustainability of a school’s PLC (Schmoker, 1999). Shared leadership is made possible through the “collegial and facilitative participation of the principal who shares leadership - and thus, power and authority” (Hord, 2004, p. 7) with the teacher participants within the group. DuFour (1999) summarized the role of the principal as twofold, “principals must live with a paradox: They must have a sense of urgency about improving their school, balanced by the patience to sustain them for the long haul” (p. 12).

Teachers. The PLC model reimagines the role of teacher, moving “away from the traditional view of teachers as isolated practitioners, [and towards] the role as a participant in a collaborative, learning-central model” (InPraxis Group Inc., 2006, p. 9). The idea behind teacher collaboration is ultimately “no teacher can possibly possess all the knowledge, skills, time, and resources needed to ensure high levels of learning for all his or her students, educators at a PLC school work in collaborative teams” (Buffman, Mattos, & Weber, 2009, p. 51). As teachers engaged in a PLC the focus of their role shifts from teaching and towards active student engagement and learning (Eaker and DuFour, 1998).

Huffman (2003) found that as teachers participated in the collaborative work of PLCs their expertise grew and as a result their classroom instruction improved. Goddard, Hoy and Hoy (2004) similarly found that as teachers collaboration increased, their sense of efficacy also increased as well as their sense of collective efficacy for the group. Through the shared leadership model of PLCs Moller (2003) identified an increase in respect from peers within the school as teachers demonstrate their abilities through their gained confidence in their own practice. This increased respect leads back to one of the human/social conditions identified by Louise, Kruse and Bryk (1995) as being an important factor in establishing a PLC.

Effect of PLCs on Student Learning

Many researchers suggest that the focus of any PLC should always be on finding ways to positively impact student learning (Hord, 2004; Kruse, Louis, & Bryk, 1995; Roberts & Pruitt, 2009; Senge, 1990). As teachers participate in the collaborative process of examining their practice, developing new strategies for teaching and implementing these new strategies in the classroom one would hope that they have a positive impact on students (Roberts & Pruitt, 2009). Studies have sought to prove a link between engagement in a PLC model of teacher learning and positive affects on student learning. The challenge with using research data to prove or disprove that PLCs have a positive impact on student learning is that different studies measure student learning in different ways (Ancess, 2000). Schools identify different needs for their students based on the specific context of that setting and as a result practices may have varying results across these sites (Ancess, 2000).

Ancess (2000) studied three different high schools in the United States with very different profiles. One was predominantly white with nearly all students coming from working class homes, one was a “second chance school” for very diverse students in New York City and the third was predominantly immigrant students from over 54 different countries in Queens, New York. Results from this study showed that “there is a reciprocal relationship among teacher learning, teacher practice, restructuring, and student outcomes. It indicates that the interaction of these variables produces practitioner knowledge that teachers use to the benefit of student outcomes” (Ancess, 2000, p. 8). All three schools in this study experienced positive outcomes such as increased graduation rates, increase in the number of students attending post-secondary education institutions and an overall increase in student achievement (Ancess, 2000).

Roberts and Pruitt (2009) reported on a different study in New York City that involved the restructuring of a school as a PLC. This restructuring involved a slow and purposeful shift over an 8-year period. The outcome was the school “transformed from one of the poorest performing schools in New York City to a center of educational excellence” (Roberts & Pruitt, 2009, p. 15). In mathematics the student population improved from 13% of students meeting expectations in 1999 to 81% of students meeting expectations in 2007.

Effect of PLCs on Teachers

Roberts and Pruitt (2009) identified several ways that teachers are affected when a school adopts a PLC model, including; increase teacher collegiality, increase leadership roles, increased teacher learning and an increase focus on pedagogy.

Barth (2006) suggests that teacher collegiality has the greatest impact on student learning in a school. PLCs offer teachers the opportunity to: design and teach lessons together, discuss pedagogy and to learn from one another. Roberts and Pruitt (2009) explain that a “culture of sustained collegiality in which teachers talk about and share what they know and have opportunities to learn is essential for meaningful school change, for the building of community, and for the nurturing of teachers’ commitment to their schools” (p. 19). An effective PLC builds leadership capacity within a school and sees the teachers and principal both having a leadership role (Hord & Sommers, 2008). As discussed earlier strong leadership within a school has a profound impact on student learning (Leithwood et al., 2004). When teachers gather as a well-formed PLC and focus on teaching and learning they are able to learn from one another (Hord, 2007). The collaborative nature of a PLC can help to shift the focus way from individual teachers and towards the learning of the group, allowing the group to “capitalize on the diverse talents of individuals in a collective manner” (Cormier & Olivier, 2009). Through the combined activities of analyzing student learning and examining their own teaching strategies PLCs allow for an increased focus on pedagogy (Roberts & Pruitt, 2009). Roberts and Pruitt (2009) found that teachers participating in a PLC often “take on greater responsibility for student outcomes and for school improvement” (p. 19).

Challenges to Establishing a PLC

DuFour, Eaker and DuFour (2005) identified three challenges that schools face when attempting to implement a PLC model. The first of these challenges is creating and executing a plan that establishes these new norms for a school environment. Planning for a shared vision requires that all members “buy in” to this new vision and are on board

with the direction that the school has decided to go. The second challenge is creating a plan that is sustainable. Both of these challenges lead to the third and largest challenge, shifting the culture of a school (DuFour, Eaker and DuFour, 2005; Fullan, 2007). Eaker and Keating (2008) define culture as the “assumptions beliefs, expectations, and habits that constitute the norm for those working in it” (p. 15).

Establishing a PLC in a school requires a commitment to the characteristics, school structures and resources discussed previously. For many schools this requires a complete shift in the culture of a school (Fullan, 2007). This can often pose a challenge for institutions within the educational system as “resistance to a cultural shift is often powerful and persistent” (Roberts & Pruitt, 2009, p. 9). The shift towards a PLC model may ask teachers to reconsider everything they know and believe about teaching and learning and requires all members of a school community to participate in this shift in order to affect change (McLaughlin & Talbert, 2001). Fortunately, as pointed out by Vescio and colleagues (2006) in their review of the literature, collaboration amongst teachers can have a positive impact on the culture of the school. They explain how “culture is improved because the learning communities increase collaboration, a focus on student learning, teacher authority or empowerment, and continuous learning” (Vescio et al., 2006, p. 88). Similar to establishing a PLC, shifting a school culture requires time for teachers to meet, opportunities to collaborate and support from leaders within the school community (Roberts & Pruitt, 2009).

Gaps in Research

Through my review of the research literature I became aware of several areas that required further research. Crespo (2005) explains that although PLCs have become a

common method for professional development for teachers there is a lack of descriptions about what occurs when these groups meet as well as how these communities become effective at supporting teacher learning. She suggests that recent studies have begun to document how these communities are formed and sustained and it is my hope that this study contributes to that knowledge.

Summary

Through the review of the literature on both effective professional development and PLCs it becomes clear to me that PLCs are one way to establish effective professional development norms in a school (Sackney & Mitchell, 2001). Table 4 compares the characteristics of effective professional development as defined by Loucks-Horsley and Matsumoto (1999) with the characteristics of a PLC (Hord, 2004). The shared “beliefs, values and visions” characteristic of a PLC is represented several times in the model for effective professional development.

Table 4: Characteristics of Effective PD and PLCs

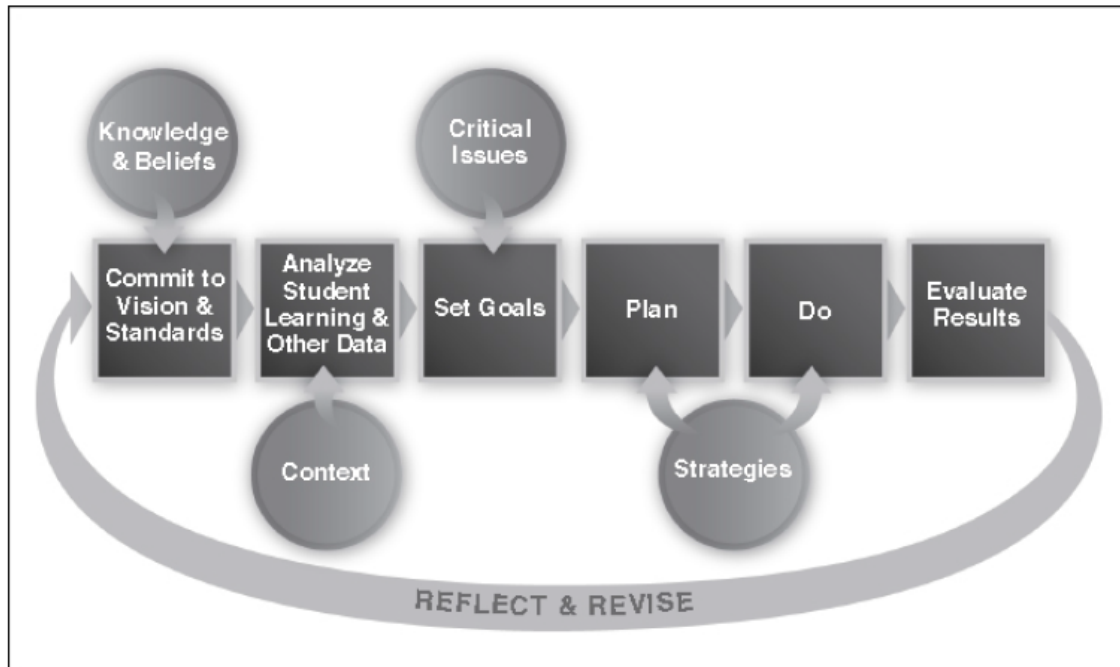
Characteristic of Effective PD (Loucks-Horsley & Matsumoto, 1999)	Characteristics of a PLC (Hord, 2004)
Curriculum-based	Shared beliefs, values and visions Collective learning and its application
Focused on student thinking	Shared beliefs, values and visions Collective learning and its application
Supportive environment/administrative support	Shared and supportive leadership Supportive conditions
Goal focused	Shared beliefs, values and visions
Collaborative	Shared personal practice Collective learning and its application

A well-formed PLC could help to alleviate teacher isolation and ideally contribute to teachers sharing their pedagogical expertise and experiences, which in turn would add to the collective knowledge of the community (Schmoker, 2004). By focusing on the curriculum and student thinking as teachers share their practice and collective learning the characteristics of effective professional development would completely overlap with the characteristics of a PLC suggesting that a PLC is an effective model for professional development.

Chapter 3: Conceptual Framework

A conceptual framework “explains, either graphically or in a narrative form, the main things to be studied – the key factors, concepts, or variables – and the presumed relationships among them” (Miles & Huberman, 1994, p. 18). This chapter introduces a conceptual framework that I use to examine the PLC in this case study and that helps explain the relationships among the different research based models and characteristics I have discussed previously. Darling-Hammond and Ball (1998) described the different challenges teacher face when attempting to teach to new standards of mathematics, Loucks-Horsley and Matsumoto (1999) outlined the characteristics of effective professional development for teachers of mathematics, and Hord (2004) describes the characteristics of PLCs. The research that I have previously discussed is represented in the following conceptual framework. It allows me to organize my ideas and observations from my data and helps me to uncover connections between the different components of the PLC. I examine this framework and relate it to current research on both professional development and PLCs in order to justify its use in this study.

Figure 1: Framework for Professional Development for Mathematics Teachers



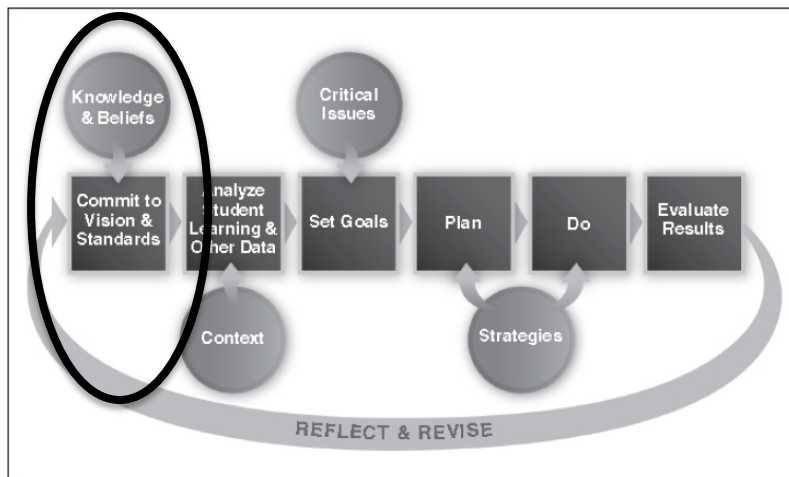
Reprinted from Loucks-Horsley, S., Stiles, K. E., Mundry, S., Love, N., & Hewson, P. W. (2010). *Designing professional development for teachers of science and mathematics*. (3rd ed.). Thousand Oaks, CA: Corwin Press. p. 18.

Loucks-Horsley and colleagues (2010) designed their approach to professional development using actions and inputs that they feel result in effective professional development for science and mathematics teachers, and represented their design in Figure 1. The actions are represented through the center of the framework in squares, and include; *commit to vision and standard; analyze student learning and other data; set goals, plan; do and evaluate results*. The large sweeping arrow, labeled *reflect and revise*, might appear to represent a process that occurs after the final action of *evaluate results*. However the process of reflecting and revising is an important element that happens throughout the entire process of designing and engaging in professional development (Loucks-Horsley et al., 2010).

The circles above and below the actions represent the second component of the framework. These circles identify *inputs* that influence the actions of a professional development initiative. The *knowledge and beliefs* of participants engaging in professional development will directly impact the vision and standard that they commit to. The *context* of a specific situation, the students they teach and the school culture for example, will have a direct impact on how teachers analyze student learning and other data. Any *critical issues* that are present in a school environment will have an impact on the goals they set and different *strategies* will impact the *planning* and *doing* stages of the professional development process. Loucks-Horsley and colleagues (2010) stress that these four inputs impact not only the actions they are assigned to but also all of the actions that follow. The researchers' intent on placing these inputs at specific spots in the framework was meant to represent where that input factors most in the process. These four inputs influence all phases of the design process but it is important to consider some before others. For example, it is perhaps helpful to consider the context of the setting before selecting strategies for that setting, as some strategies may not work in all settings.

This framework, as presented by Loucks-Horsley and colleagues (2010), appears to be linear with one action resulting in another action. It is important to note that the researchers themselves suggest that this framework is an "ideal to strive for" (2010, p. 21) rather than a step-by-step guide and that implementing professional development is "far from linear or lockstep...[it] is recursive and usually messy, demanding flexibility and continuous learning throughout the process" (2010, p. 43). I break down this framework into the different actions and discuss each as well as the inputs that may influence each phase in order to better describe how I examine the PLC in this case study.

Commit to Vision and Standards

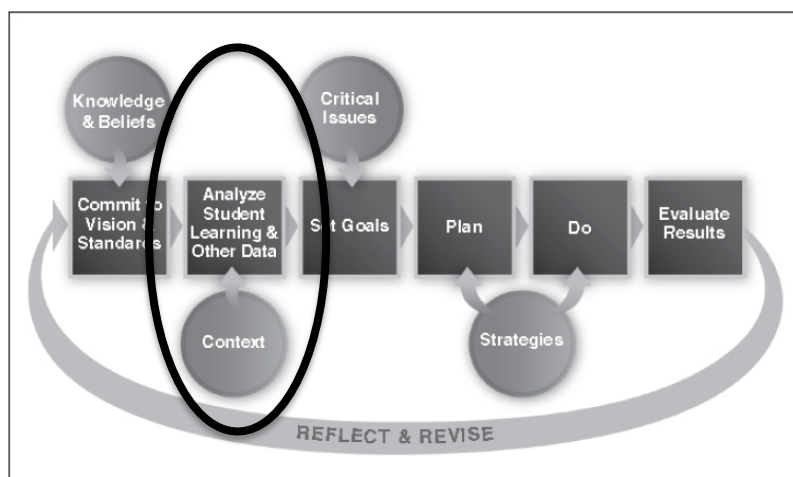


According to the framework, the first action in an effective professional development initiative is to *Commit to Vision & Standards*. “Effective professional development programs start with committing to a vision of quality teaching and learning” (Loucks-Horsley et al., 2010, p. 18) based on standards such as those developed by the NCTM (1989, 2000, 2014). These NCTM standards influenced many jurisdictions across North America, including Ontario, as different jurisdictions redesigned their mathematics curriculums to reflect new research based ideas on the teaching and learning of mathematics, such as those represented by the NCTM standards (O’Shea, 2003). As I discussed previously the NCTM standards stress the importance of all students being given the opportunity to engage in rich mathematical investigations that will help develop their mathematical literacy. A commitment to the vision and standards will hopefully bring the focus of a professional development plan to the core of what is most important in terms of teaching and learning mathematics as “standards set the course for professional development” (Loucks-Horsley et al., 2010, p.31).

Committing to a vision and standard will be influenced by the knowledge and beliefs of those involved in an initiative. When considering knowledge as an input in the design framework Loucks-Horsley and colleagues are referring to “information that is sure, solid, dependable, and supported by research” (2010, p. 52). As discussed in Chapter 2, teachers require both thorough content knowledge and a deep understanding of how children learn mathematics in order to effectively teach mathematics. As well teachers require knowledge of children, their ideas, and their ways of thinking. By accessing current research in the area of mathematics teaching and learning teachers are able to align their beliefs with what is considered best practices and have the confidence to pursue a certain course for their professional development.

In my review of Ernest’s (1991, 2014) research on the different interest groups informing the teaching and learning of mathematics, I described how individuals’ own experiences shape their beliefs. These beliefs are an important input into the design process of professional development for mathematics teachers and may impact a participants’ ability to commit to the vision and standards. Beliefs refer to what we believe to be true and “powerfully affect the ways in which individuals make sense of new ideas” (Ball, 2009, p. 40). Teachers’ beliefs about teaching and learning affect what they gain from participating in a professional development initiative (Wilson & Berne, 1999).

Analyze Student Learning and Other Data



The analyze phase of the professional development process allows participants to “take stock of their reality as they explore the gap between the current and the desired state—based on the vision and standards—and set targets for improvement” (Loucks-Horsley et al., 2010, p. 21). When analyzing student data and other learning it is important to consider the specific context of a school setting (Loucks-Horsley et al., 2010). One model that proved successful in one school may fail in another simply due to different contexts (DuFour, 2001). It is often seen as the role of the Principal to have a solid understanding of the context of their institution in order to guide the school towards the most effective model for professional development (Marzano, Waters, & McNulty, 2005). Loucks-Horsley and colleagues (2010) have identified different context factors that could impact a professional development initiative; these are outlined in Table 5.

Table 5: Context Factors Affecting PD Initiatives (adapted from Loucks-Horsley et al., 2010)

Context Factor	Impact
Students and Teachers learning needs	Impacts the goals selected for a professional development initiative
Leadership and local policies	Impacts the level of support a professional

	development initiative might receive
Available resources	Impacts the time or support available for teachers to meet and engage in professional development initiatives
Families and communities	Impacts the support teachers receive for different initiatives and may influence teachers participation

Of all of the context factors to consider when designing professional development, student learning is deemed the most important and analyzing the following subsets of student learning and related data may prove to be helpful:

- Demographic data about students and teachers
- Multiple measures of students' achievement of standards
- Data about classroom practice and students' opportunity to learn
- Data about professional development, the school culture, and leadership (Loucks-Horsley et al., 2010, p. 21)

I discuss each of these context factors in more detail in the following section.

Demographic data. Analyzing learning data related to different demographic groups may reveal issues, such as inequitable teaching practices, that teachers did not realize existed. Different demographic identifiers may include race, ethnicity, economic status, English language learners, students with special needs, and gender. When teachers examine data through this lens they may consider the need of focusing on teaching practices that address these issues.

Student achievement data. In Ontario, the most accessible data on student achievement is publicly available through the Education Quality and Accountability Office (EQAO). Student data from these large-scale, standards-based tests, given in

mathematics in Grades 3, 6 and 9 across Ontario, are available to the public and are accessible through the EQAO website. The data for each school is presented in a report that compares the school's achievement results against both the school district and the rest of the Province. Individual reports for each student are also made available to the student and to their school. These individual reports are not available to the public. These tests are intended to measure "how well Ontario's public education system is developing students' reading, writing and math skills...as well as contextual, attitudinal and behavioural information from questionnaires" (EQAO, n.d.).

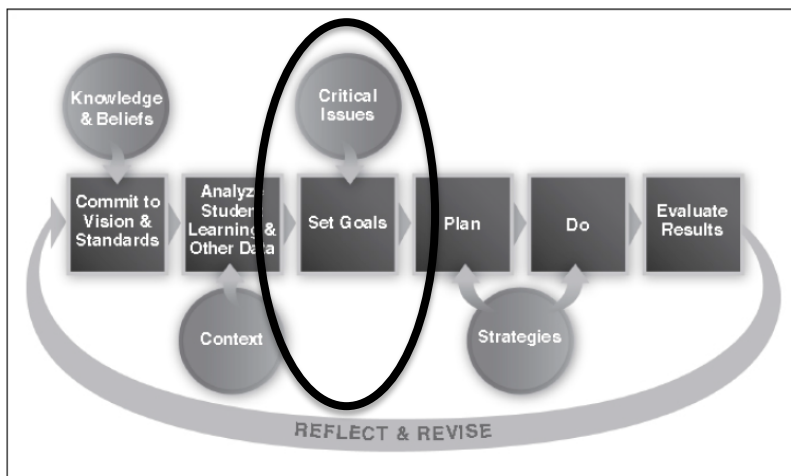
Such large-scale assessments alone do not offer a complete representation of student learning. It is possible for teachers to assess students using their own methods in class. These methods could include activity-based tasks and written tests or summative activities that are intended to showcase the summation of a student's learning over the semester. The final record of students' achievement is generally documented in a report card.

Classroom practice and opportunities to learn. The daily work carried out in the mathematics classroom is an important source of data that helps teachers analyze student learning. Examining student work may highlight misconceptions that need to be revisited. For instance, student exit cards offer teachers insight into the ideas behind students' work. Other ways to collect this type of information include observation of students in class, interviews with students, and artifacts of student work (Loucks-Horsley et al., 2010). This phase of the framework is supported by research on professional development that encourages focusing on student work and student thinking. Research has shown that when teachers focus on student thinking an opportunity for teachers to

engage in rich mathematical dialogue is created (Shulman, 1987; Borko, 2004; Kersting et al., 2010).

Professional development, school culture and leadership. Data related to previous professional development, school culture and leadership is useful when designing a professional development initiative (Loucks-Horsley et al., 2010). Knowing what different professional development projects and initiatives a school has engaged with in the past, how successful these have been in terms of student and teacher learning, as well as teacher engagement, could help to inform any new initiative being designed (DuFour, 2004).

Set Goals



The importance of setting goals is highlighted by several researchers and is another key component in the framework,

Of all the variables related to effective professional development, goal clarity is perhaps the most important. It is essential that we be explicit about the goals of professional development, especially in terms of the classroom or school practices

that we hope to see implemented and the results that we would like to attain in terms of students (Guskey, 2000, p. 17).

When considering the goals of a PLC dedicated to improving the performance of students in Grade 9 Applied Mathematics one might assume that the goal is obvious, improve the learning of students in Grade 9 Applied Mathematics. According to Loucks-Horsley et al. (2010) it is not that simple. In their framework the researchers break down this phase into four components; goals for student learning, goals for teacher learning, goals for teaching practice, and goals for the organization. At this phase of the conceptual framework the critical issues that exist within a school setting also directly impact the action of setting goals and it is important to be mindful of them (Loucks-Horsley et al., 2010). First I discuss the seven types of critical issues identified by Loucks-Horsley and colleagues (2010) then I discuss the different components of setting goals.

Table 6 outlines seven different critical issues that need to be considered and that may impact the success of professional development initiatives and the goals that have been set:

Table 6: Critical Issues That May Affect PD (adapted from Loucks-Horsley et al., 2010)

Critical Issue	Description
Building capacity for sustainability	Rather than focusing on individual teacher learning an initiative that focuses on school wide sustainability may be more successful. Understanding the areas of a particular school environment that would support learning and designing professional development for those areas could be the most beneficial approach to ensuring sustainability for professional development.
Making time for professional development	Making time for professional development is crucial to supporting teacher and student

	learning and using this time effectively is paramount to achieving success in schools (Guskey, 1999).
Developing leadership	Strong administrative leadership helps to establish effective professional development programs and teacher leadership. Through increased teacher leadership more effective PLCs are established and teacher learning is increased and results in increased student achievement (Waters, Marzano, & McNulty, 2003).
Ensuring equity	Creating opportunities for all students to be successful in mathematics is the focus of new reforms in education. Traditional teaching approaches have not created these opportunities and professional development is needed to allow teachers time to reconsider how best to teach all students. Focusing of equity is one way to achieve this.
Building a professional learning culture	De-privatizing teaching allows a school community to create opportunities for continuous learning amongst its staff. This culture of professional learning can increase the sustainability of professional development programs
Garnering public support	Funding for professional development for teachers is directly related to the support of the public. It is important for the community beyond the school to understand that professional development for teachers ensures quality-learning opportunities for the students.
Scaling up	Early adopters of new pedagogical methods are important to the success of professional development initiatives. It is also important to convince resistors of the effectiveness of these new methods. In order to ensure mathematics for all, the engagement of all teachers is essential.

In summary, Table 6 outlines the critical issues that may impact the goals that are set within a school setting. It is important to consider the sustainability of a professional development initiative. The support of participants involved in an initiative is imperative, without their support an initiative will not be sustained. Similarly, making time for professional development is critical. Teachers need time during their school day to meet and discuss their own learning and that of their students. Both of these issues fall under the responsibility of the administration at a school. The administration plays an important role in supporting teacher learning. Strong leadership at the administrative level can help to foster leadership amongst the teachers, which in turn increases support of professional development, building capacity for sustainability. Examining the issue of equity in a school is a critical step in creating opportunities for all students to engage in rich mathematical learning. Focusing on ways to reach all students allows teachers to consider alternative methods for teaching mathematics. These alternative methods may create opportunities for students that are not successful in traditional mathematics classrooms and can help to ensure equity. When teaching moves from a private practice to a shared practice more opportunities for teacher learning are created and help to sustain professional development initiatives within a school. A professional development initiative that has the support of the public is more likely to achieve the goals they set for themselves and to receive the adequate support and funding from the stakeholders beyond the school walls. Lastly, it is important to reach beyond those within a school that are likely to embrace change. By influencing those that are resistant ensures that all students of mathematics have access to the new ideas generated by a professional development

initiative. If all students are to be reached, all teachers should share in the learning of the community.

As I mentioned previously these critical issues impact the success of a professional development initiative and the goals they have set. I now discuss the four different components of goals identified in the framework of Loucks-Horsley and colleagues (2010).

Goals for student learning. “Goals based on analysis of student learning needs not only give coherence and focus to the plan, but they set the stage for ongoing monitoring and evaluation, which rely on clear targets” (Loucks-Horsley et al., 2010, p. (84). Schmoker (2002) suggests that the goals of a professional development initiative should focus on the lowest performing students and attempt to close the achievement gaps that exist between the weakest and strongest students. Setting goals for student learning based on gaps in student achievement requires an analysis of the current state of student achievement and presents an opportunity to dissect where in the curriculum students are struggling or perhaps if a certain demographic of the student population is struggling. This type of analysis of student learning could help to address any inequity that exists amongst the student population thus addressing the critical issue of ensuring equity (Loucks-Horsley et al., 2010).

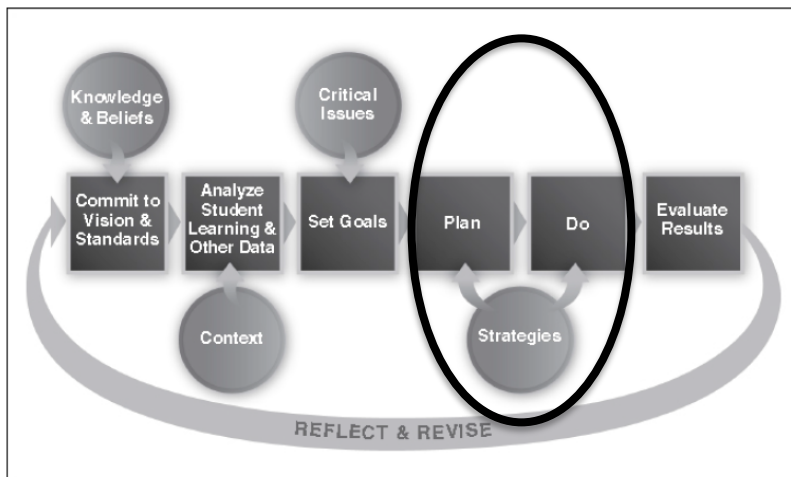
Goals for teacher learning. Loucks-Horsley and colleagues (2010) explain that setting goals for teacher learning emerges directly from the established goals for student learning. By setting goals for student learning teachers may be able to reflect on the required knowledge and skills they themselves require to assist their students in meeting student goals. Goals for teacher learning are focused on both content knowledge and

pedagogical content knowledge (Loucks-Horsley et al., 2010). Goals for teacher learning should also be in line with the committed vision and standards from the earlier phase of the framework.

Goals for teaching practice. Stemming from the goals for teacher learning are goals for teaching practice. Essentially this goal defines how teachers will use their new knowledge and how it will be enacted in the classroom with students (Loucks-Horsley et al., 2010). The goals for teaching practice help participants visualize how their own learning will be translated into pedagogical approaches that will allow their students to achieve the defined goals for student learning (Loucks-Horsley et al., 2010).

Goals for the organization. Loucks-Horsey and colleagues (2010) suggest that goals for the organization can include “the development of leadership or the strengthening of the professional learning community... [and to] establish a core of teacher leaders who will support other teachers’ growth” (p. 40). Through well-defined goals for an organization several critical issues can be addressed, perhaps most importantly sustainability and developing leadership capacity. Loucks-Horsley and colleagues (2010) stress “that having explicit goals for leadership development and for building a professional learning community are essential for sustaining any changes in practice that the professional development program designed to bring about” (p. 40).

Plan and Do



At this phase in the conceptual framework, the planning and doing phases, one needs to revisit all other actions that have preceded this one. Through reviewing previous phases, including; commit to vision and standards, analyze student learning and other data, and set goals, a school community can better determine the plan and delivery for professional development that will best fit their needs (Loucks-Horsley et al., 2010). During the plan and do phase, the professional development strategies chosen will impact the plan and delivery of a professional development initiative. As previously discussed, all prior phases of this framework influence each latter phase. In this case the strategies are impacted by previous inputs such as knowledge and beliefs, context of a school setting and critical issues at play in specific settings. A thorough understanding of different strategies for professional development, and the research they are based on, will help to insure that the strategies are properly implemented. Loucks-Horsley and colleagues describe how planning effective professional learning for mathematics teachers is more than implementing “the latest strategy, [such as PLCs]” (p. 158).

Good teacher learning programs require a lot more thinking and design than simply grabbing and implementing the latest strategy. We have seen this playing out recently with the wave of interest in professional learning communities (PLCs).

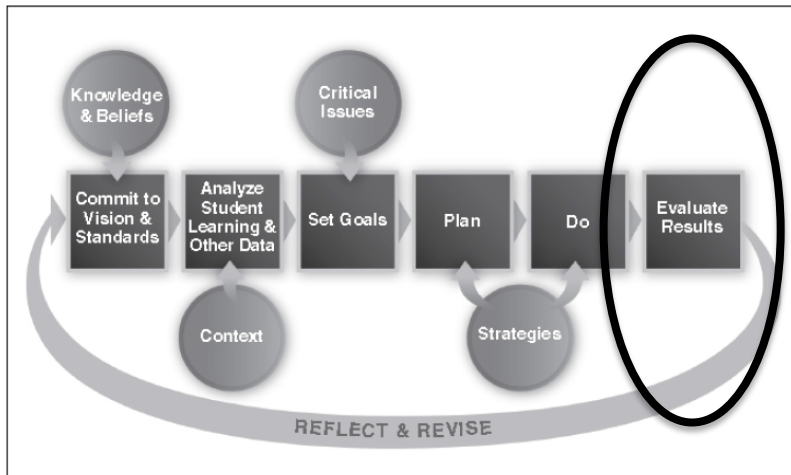
Principals and teachers tell us they are “doing PLCs this year.” In some cases, little thought has gone into what the goals are for the PLC, and the context has not been primed for this strategy (Loucks-Horsley et al., 2010, p. 158).

Strategies. Deciding on strategies that lead to accomplishing goals is a difficult process and one that requires a great deal of thought. Loucks-Horsley and colleagues have identified “four interconnected outcomes [that] support the goal of enhanced student learning and can form the basis for most professional development plans” (p. 161). These outcomes are:

1. Enhancing teachers’ knowledge, including their knowledge of mathematical content, how students interact with the content and the most effective methods of teaching this content.
2. Enhancing quality teaching. Providing opportunities for teachers to practice teaching and incorporating their newly enhanced knowledge for teaching.
3. Developing leadership capacity. As discussed in Chapter 2, developing leadership capacity refers to the sharing of leadership amongst teachers and administrators within a school.
4. Building professional learning communities. PLCs offer sustained, long-term learning for teachers within their own school (Loucks-Horsley et al., 2010, p. 161).

In order to achieve these four outcomes it may be necessary to incorporate various strategies that best support specific settings. Considering the entire framework and each phase allows participants to consider all the factors that affect a school environment and how best to approach designing a professional development plan that will be effective.

Evaluate Results



The evaluating results phase appears to occur at the end of the professional development process. In reality this phase occurs throughout the entire process, results of each phase are evaluated to inform the next phase. Loucks-Horsley and colleagues (2010) suggest determining what acceptable results would look like before commencing a professional development plan, “being clear about desired outcomes and articulating what they would look like if they were present not only lays important groundwork for evaluation but also results in a more focused and purposeful program” (p. 45). When evaluating the results of a professional development initiative it is important to consider many aspects of results. Focusing on a single outcome, such as participant satisfaction or student achievement, does not provide a clear definitive answer to whether or not a plan was successful. Professional development for mathematics teachers is a long-term process and different areas should be considered. Student achievement and participant satisfaction are important but not one without the other.

Summary

The above framework was designed with both science and mathematics teachers in mind. I found it to be an effective lens for examining the PLC at Fields High School in terms of the work the mathematic teacher members were engaged in. It was created by Loucks-Horsley and colleagues (2010) through their own research in the area of professional development and is supported by other current literature. I use it as a framework, to organize my thoughts and observations of the PLC knowing that it is in line with my own ideas of professional development as well as that of the greater research community. The framework speaks to the evolution of a PLC, which is very much in line with my research, specifically looking at how PLCs are formed, sustained, and how they evolve.

In Chapter 6 I discuss my findings using this framework as my guide. I connect and compare the actions and inputs of each phase of this framework with the actions and inputs present at my research site. I do not use this framework to critique the PLC but rather as a tool to organize my observations and structure my discussion of my findings.

Chapter 4: Research Design

This chapter provides an overview of the research design including a rationale for choosing a qualitative approach. I also describe my role as the researcher, my recruitment strategies, the school, and the participants themselves. I outline my data collection methods and instruments as well as describe my data construction, data analysis, and data interpretation methods. I finish with a discussion on my data credibility and verification.

Overview of the Research

In order to investigate and describe the experiences of a practicing PLC where teachers focus on enhancing their teaching of mathematics, a qualitative approach has been selected. Qualitative research involves the researcher gathering multiple forms of data in a natural setting, in this case as part of a PLC, as the researcher attempts to learn “the meaning that the participants hold about the issue” (Creswell, 2013, p. 47). The research design provided for emergence of the meaning the participants hold in the sense that the process evolved after I engaged with the participants and gained a better understanding of the PLC and how it operates (Creswell, 2013). I have selected a single case study approach as the PLC exists within a bounded system and I explored, over time, the current, real-life case that is in progress (Stake, 2005; Yin, 2005). This specific case study allowed me to better understand how this community operates and to present an in-depth understanding of the case (Yin, 2005).

As required with a case study, data collection was extensive and drew from multiple sources (Eisenhardt, 1989) including audio recordings of PLC meetings and individual interviews, classroom artifacts that participants shared, and my own observations. I attended a total of 11 PLC meetings but due to delays in approval to conduct research

from the school board I was only able to collect data at 8 of these meetings. I also conducted 5 individual interviews with members of the PLC and attended the final one-day OAME Project session. This final one-day session included the 9 other school teams involved in the project and it was held at the end of the 2014-2015 school year.

Rationale for Qualitative Case Study

Swann and Pratt (2004) believe that educational research “is aimed at informing educational judgments and decisions in order to improve educational action. The focus is on what happens in learning situations – that is, educational action – and on value orientation towards improvement of that action” (p. 111). With this in mind I suggest that my research draws attention to what is happening in a specific school and within a specific professional learning community. My goal for this research is to investigate and describe the experiences of a practicing PLC as participants worked collectively to examine and enhance their own practice. I also hoped to gain a better understanding of the challenges teachers face as they engage in this professional learning. In order to achieve this goal I selected a qualitative case study method to guide this research. Denzin and Lincoln (2011) suggest that a qualitative approach helps “make sense of, or interpret, phenomena in terms of the meanings people bring to them” (p. 3). In this case study the phenomena was the act of engaging in professional development by a high school mathematics professional learning community.

A qualitative case study has been defined by Yin (2003) as “an empirical inquiry that investigates a contemporary phenomenon within its real-life context; when the boundaries between phenomenon and context are not clearly evident; and in which multiple sources of evidence are used” (p. 23). One of the goals of a case study, as

suggested by Swann and Pratt (2004), is to provide a description of the phenomena and to offer “something significant to someone (teacher manager, policy-maker, parent, learner etc.) thereby informing her or his work and potentially helping to improve it” (p. 116).

My Role as a Researcher

My role as a researcher, in terms of this case study, varies slightly from my role as a RA in the OAME project, however both place me in the natural setting (Creswell, 2013) of this PLC and allow me the ability to observe the natural progression of the work that teachers do as they engage with one another and examine their practice. My role as a RA for the OAME project was to attend monthly meetings held at the participants’ school, to document their process of professional development and to support the members of the PLC throughout the project as they request support. My role was explained to the members of the PLC at the launch for this project held in early October 2014. I feel the PLC members understood that I was there to assist them and not merely “study” them and this helped to establish a comfortable relationship between the participants and myself. My role as a researcher for this qualitative case study was an extension of my role as an RA. As a researcher for this case study my interests overlapped with those of the OAME project. I was able to document the PLC’s strategies for implementing and teaching the Grade 9 Applied Mathematics curriculum and at the same time I was able to drill down and ask additional questions that helped me specifically address my research questions. I was able to tailor the data collection process in order to meet the needs of both the OAME project and my own study without adding any extra demands on the PLC.

My own experience as a high school mathematics teacher as well as a part-time instructor at the University of Ottawa provided me common ground with the members of

the PLC. They, perhaps, were able to think of me as not only a researcher but as a teacher as well. Ultimately being a mathematics educator allowed me to develop an easy rapport with the group and my familiarity with one of the members outside of the PLC added a level of ease to my integration into the group.

Recruitment Strategies

Because of the involvement of this particular PLC in the OAME project, this study did not require any additional recruitment strategies. By applying to participate in this project school teams agreed to participate in the professional development component of the project. Once approval to carry out research at school sites was received from the various school boards the school teams were invited to participate in the research component of the project. This case study falls under the research component of the OAME project therefore when this particular PLC agreed to participate in the research component of the OAME project they were also agreeing to participate in this case study.

Participation in the Study

Through participation in this research study the participants were asked to share their views on teaching and learning. As teaching is a personal experience it is possible that some participants may feel vulnerable when asked certain questions. It was outlined in the teacher consent form, and verbally by me; that every effort would be made to reduce the amount of stress related to participation in the project. I made it very clear that opinions and comments made by the participants would be held in confidence by the researcher. The teachers were given assurance that all the information gathered during the research study would remain confidential and that the contents used only for research purposes and for improving the implementation of the Grade 9 Applied Mathematics

Curriculum. The names of all participants and their schools were kept confidential and pseudonyms are used when referring to individual teachers in this study.

It was made clear to the participants that participation in the research study was completely voluntary and that they could withdraw from the project at anytime. They could also choose not answer any question at any time. Any teacher that decided to withdraw from the project could choose to have their individual logbook destroyed but since the focus group and observational data are highly dependent on the overall group discussion these data sources would not be destroyed. A teacher that had decided to withdraw would not be quoted directly and would be omitted from any excerpts of data quoted. All PLC meetings and individual interviews were scheduled according to participants' own schedules and needs.

Through participation in this research study participants were given the opportunity to reflect on their own teaching and information gathered during this research study may possibly help other teachers as they implement the Grade 9 Applied Mathematics Curriculum.

Data Collection and Instruments

A qualitative case study requires multiple sources of data to insure a thorough representation of the phenomena (Eisenhardt, 1989). For this particular study the participants were asked specifically to:

- Take part in a focus group interview for 30 – 45 minutes during each monthly team meeting.
- Allow portions of their monthly team meeting to be audio-recorded (the team had control over which portions)

- Provide copies of artifacts that were relevant to the monthly school team meeting (but not student work)
- Record significant events, reflections, activities as were relevant to the focus of the school team initiative in a logbook as they see fit

Focus group and individual interviews. As the PLC meetings unfolded it became clear that it was not appropriate for me to conduct focus group interviews during each meeting. The meetings for the OAME project generally merged with a second professional development initiative the school was participating in. This second initiative was cross-curricular, teachers from different subject areas including Mathematics, Science and Geography were present. Although this other initiative was also focused on students in various Grade 9 Applied subjects, asking questions that centred only on mathematics and the OAME project was not suitable and would have been disruptive to the flow of the conversations. It did happen that many of the focus group interview questions were answered through the dialogue of the PLC. To address the questions that were not answered I sought an alternative method. With the approval of my supervisor, Dr. Suurtamm, I requested an individual interview with each of the OAME participants. During these individual interviews I was able to ask the questions originally intended to be asked during the focus group interviews, Appendix C, at each monthly meeting as part of the data collection.

These individual interviews provided me the opportunity to ask additional questions that differed from the protocol of the OAME focus group interviews. The OAME project was focused on the PLC's identified problem of practice and different strategies the team was using to address these problems. For my own study I also wanted to gather additional data that would offer insight into a teacher's personal journey as mathematics teachers

and how their practice has evolved. Together with my supervisor I developed two different individual interview protocols, one for the Principal, Appendix D and one for the mathematics teachers, Appendix E.

These interviews took place near the end of the school year after I had spent a significant amount of time with the PLC. I had developed a good rapport with the members and the interviews were not overly structured as a result of this. There were five individual interviews conducted and the average duration was roughly 30 minutes. The interviews were with the five members of the OAME project, Dolores, Wayne, William, Tasha and Rachel.

Monthly PLC meetings. As I mentioned previously, I was present for a total of 11 PLC meetings and collected data at 8 of these meetings. On average the meetings were 2.5 hours and took one of three forms during my time with the PLC, they included:

- Specific PLC planning related to the overall goals of the PLC
- Lesson planning for a specific teacher's classroom
- Debriefing after observing a lesson planned by the PLC and taught by a specific teacher.

My role at these meetings was simply to observe and offer any support that the PLC requested of me. A full list of the PLC meetings and the data collected is presented in .

Table 7.

Table 7: Summary of Data Collected

Date	Activities	Participants Present	Data Collected
Oct. 6 & 7, 2015		No data collected – waiting on school board approval	
Nov 17, 2015			

No data collected – waiting on school board approval			
Dec 4, 2015	No data collected – waiting on school board approval		
Dec 11, 2015	No data collected – waiting on school board approval		
Jan 30, 2015	Finalize student beliefs and attitudes survey	Dolores, Wayne, Tasha, William	Audio recording, field notes
Feb 12, 2015	PLC meeting, start of new term	Dolores, Wayne, Tasha, William, Rachel, Larry, Shirley, Anna	Audio recording, interview transcript, teacher artifacts, field notes
Apr 2, 2015	Lesson planning session	Wayne, Tasha, William, Rachel, Larry, Shirley, Anna	Audio recording, interview transcript, field notes
Apr 9, 2015	Lesson observation and debrief session	Dolores, Wayne, Tasha, William, Rachel, Larry, Shirley, Anna	Audio recording, interview transcript, teacher artifacts, field notes
Apr 14, 2015	Lesson planning session	Dolores, Wayne, Tasha, William, Rachel, Larry, Shirley	Audio recording, interview transcript, field notes
Apr 22, 2015	Lesson observation and debriefing session	Wayne, Tasha, William, Rachel, Larry, Shirley, Anna,	Audio recording, interview transcript, teacher artifacts, field notes
Apr 22, 2015	Individual interview	Tasha	Audio recording, interview transcript
Apr 22, 2015	Individual interview	Wayne	Audio recording, interview transcript
Apr 22, 2015	Individual interview	William	Audio recording, interview transcript
Apr 27, 2015	Individual interview	Dolores	Audio recording, interview transcript
Apr 30, 2015	Lesson planning session	Wayne, Tasha, William, Rachel, Larry, Shirley, Anna	Audio recording, interview transcript, field notes
May 4, 2015	Lesson observation and debriefing session	Wayne, Tasha, William, Rachel, Larry, Shirley	Audio recording, interview transcript, teacher artifacts, field notes
May 21, 2015	Research project wide wrap	Dolores, Wayne, Tasha, William, Rachel, Larry, Shirley, Anna,	Audio recording, interview transcript, teacher artifacts,

	session	Linda	field notes
May 26, 2015	Student Success Teacher Individual Interview	Rachel	Audio recording, interview transcript

Artifacts and logbooks. Four different participants provided me with artifacts that were relevant to the monthly meetings; these are outlined in Table 8. At this site all participants agreed to all the activities listed, however, it is apparent that no logbooks were used and none were returned to me at the end of the 2014-2015 school year.

Table 8: Summary of Artifacts Collected

Participant	Artifact	Appendix
Wayne	Lesson plan designed during April 2, 2015 meeting	Appendix G
William	Lesson plan designed during April 14, 2015 meeting	Appendix H
Tasha	Lesson plan designed during April 30, 2015 meeting	Appendix I

The data was kept in a secure manner with all electronic copies of data stored on a password protected hard drive and all hard copies of data in a locked file cabinet. Both the hard drive and locked file cabinet are in the Pi Lab, a secure research facility at the University of Ottawa.

Data Construction Analysis and Interpretation

For this research study I used both selective and complete transcriptions. The PLC meetings were on average 2.5 hours and often the team would discuss topics such as personal details about students that were not appropriate for me to transcribe due to reasons of confidentiality. At other times the PLC members would get off topic and speak about personal topics that were not relevant to the work of the PLC so I chose to

transcribe only the sections of the audiotape recording that I deemed relevant to the research. The personal, friendly banter between members is important to note though as I feel it helps to define the PLC and offer insight into the dynamics of the phenomena. For this reason I chose to use my observational notes and summarize these sections of the audio recording. The individual interviews were transcribed in their entirety as I had more input into the direction of the interview and although the interview protocol was only loosely structured I did adhere to the questions I had listed and had shared with the participant upon commencing the interview.

Having been present for all the meetings and then transcribing the data myself allowed me to know the data very thoroughly. Schram (2006) suggests that the act of transcribing is not as simple as typing what you hear a participant speak "even a transcript is the product of ongoing interpretive and ethical decisions about the significance you give to what other people convey as meaningful" (p. 12). By deciding what I deemed significant I am imposing my own beliefs and interpretations on the data and this needs to be taken into consideration when discussing the credibility of the data in the following chapters.

The protocol for the individual interviews was created through a combination of research literature and my own observations of the PLC leading up to these interviews. Knowing that the research suggested a lack of data in the area of describing how teachers had previously taught (Vescio, Adams and Ross, 2008) I was more attuned to listening for comments that pertained to this type of description. As I was present more as an observer at the PLC meetings, I was hesitant to interrupt often to ask for more clarification on things that the teachers said and insinuated. I instead made note of these

comments in my research journal. The individual interviews allowed me to go back to these comments and ask for more clarification and dig a little deeper into what the individual had meant.

The collected data from each PLC meeting and individual interview was organized, managed and securely stored on a computer. As the volume of data collected was quite large it was imperative I follow a structured chronological approach to data management. Interviews were transcribed by myself and then read several times to become intimately familiar with the data and memoing took place during each read through. Memoing took place in the form of margin notes; I would add observations about the tone and interactions that I recalled from the meeting that were not picked up by the written words.

After all the data had been collected, transcribed and read through several times, I began coding and grouping the data into themes that represent an overall description of the PLC (Creswell, 2013). I began coding the PLC meeting transcripts first. My process involved “chunking” the data into “buckets” with a shared theme such as “improving mindset”, “focus on students needs” and “connection to research”.

After this initial coding of the PLC meeting transcripts into themes I sent my work to my supervisor for a review to confirm that I was on the right track. The feedback that I received suggested focusing more on my research questions and considering my themes under that umbrella; essentially my “buckets” were too specific. This feedback proved to be very helpful, I used this new focus as I began coding the individual interviews. I found the coding of the individual interviews to be much more straightforward, upon reflection I determined that this was because I was able to tailor the interview questions directly to my study and I was able to ask questions that directly related to my research questions.

Once both the PLC meetings and the individual interviews were coded I immediately consulted my research questions again. This allowed me to clarify the level of importance I assigned to the different themes I had pulled from the transcripts based on how closely they addressed my research questions. Further to that, I broke down the research questions into smaller parts and because the data was so fresh in my mind I was able to make connections between the data and these different parts. My research questions had now become four discrete questions as follows:

1. How is a PLC formed?
2. How does a PLC evolve?
3. How is a PLC sustained?
4. What happens when teachers come together to examine their practice?

With these four questions as a guide I began to gather “like terms” so to speak. I rearranged my coded data under one of the four headings until I had sorted through both the PLC meeting transcripts and the individual interview transcripts. It was at this stage in my data analysis that I decided I would interpret my data in two separate ways. The first method of interpretation would be to discuss the data in terms of my research questions. I would attempt to answer the questions I originally intended to address with this study. The second interpretation would be in relation to the conceptual framework that had also been consulted when designing this study. I consider my data in terms of each phase of the framework, Figure 1. I report on the actions of the PLC in this study using the actions and inputs described in Chapter 3 as a guide for the analysis. Both the research questions and the conceptual framework guided me throughout the data collection and analysis process. The research questions were instrumental in terms of sorting through my data

and designing the individual interview protocol while the conceptual framework guided my observations during PLC meetings. In Chapter 6 I present my findings using the research questions as a guide and in Chapter 7 I discuss the findings using the conceptual framework as a lens through which to view the actions and observations of the PLC.

Credibility and Verification

For this study my main source of verification was triangulation (Creswell, 2013). I used different data sources to corroborate evidence of a theme or category of data. Different data sources could include audio recordings of PLC meetings, individual interviews, and classroom artifacts that participants share with me. I did not rely on member checking to verify data as the quantity of transcriptions and researcher notes was vast and would require a great deal of time for participants to review. I offered participants the opportunity to review all audio recording transcriptions but it was with the understanding that it is purely voluntary. After one meeting the Principal, Dolores, requested a copy of the transcript, as she had been absent. I shared this data with her but I am unaware if she read it and she did not contact me with questions or comments.

Chapter 5: Case Study

In this Chapter I describe the OAME project, the school setting and the participants involved in this case study. I begin by describing the OAME project in greater detail. I then describe the school, the PLC, the PLC members, the PLC meetings, and activities that occur during these meetings to provide a complete picture of this study.

Description of the OAME Project

The OAME project is a collaborative inquiry project funded by the Ontario Ministry of Education and managed by the Ontario Association for Mathematics Teachers (OAME). The project was initiated to address an identified need to support students in Grade 9 Applied Mathematics. Both school data and large-scale provincial assessments have highlighted that many students are not meeting the expectations of the Grade 9 Applied Mathematics course. This project helps to address this need by providing funding for 10 school teams of teachers and administrators from across Ontario. The intent is to provide opportunities for teachers to focus on enhancing their own, and students' understanding, of the Grade 9 Applied Mathematics curriculum, and to focus on implementing the curriculum in ways that best meet the needs of their students.

The funding provided for the school teams covers release time for the participants one day a month as well as some additional funding for supplies that the school team might request. This collaborative inquiry project has two components, the professional development component and the research component. The professional development component of this project focuses on: supporting a school team of teachers and administrators as they work on increasing student achievement in Grade 9 Applied Mathematics; increasing teacher knowledge of the curriculum, both in terms of mathematics content knowledge and

mathematics knowledge for teaching; identifying effective teaching and learning strategies; sharing implementation strategies with stakeholders; and fostering teacher leadership in mathematics. The research component focuses primarily on documenting and supporting the work of school teams to learn more about ways to support both students and teachers in the teaching and learning of Grade 9 Applied Mathematics across Ontario. The research component examines how teachers enhance their understanding of the interactions between curriculum, pedagogy, and student needs and also seeks to understand the role of teacher collaboration in professional learning.

Each school team is assigned a research assistant to act as a resource for the team and offer assistance such as providing research literature related to school teams' areas of focus. The research assistants also collect, transcribe, code and analyze various forms of data, write case reports for their assigned schools and contribute to the writing of the final report for the project.

Description of School

Fields High School (pseudonym) is a large, older school in an urban setting in a medium sized city. The student body is composed of a wide range of ethnic, cultural, religious and socioeconomic backgrounds. Thirty percent of the student population is English language learners and 20% of the student population has identified learning needs that are supported with individual education plans (IEPs). Fields High School has a student population of 1400. Fifteen percent of the Grade 9 students are enrolled in the Grade 9 Applied mathematic course with the remaining 85% enrolled in Grade 9 Academic Mathematics. The average Ontario high school sees 28% of their Grade 9

population enrolled in Grade 9 Applied Mathematics and 72% enrolled in Academic Mathematics.

At Fields High School the focus of the PLC is on students in Grade 9 Applied Mathematics. Table 9 compares certain aspects of the students in both the Grade 9 Applied and Academic classes and suggests that more students in Grade 9 Applied require greater support and consideration when learning mathematics.

Table 9: Comparing Grade 9 Applied and Academic Demographics at Fields High School

2014-2015 EQAO data	% of Students in Grade 9 Applied Mathematics	% of Student in Grade 9 Academic Mathematics
English language learners	34%	20%
With Special Education needs	52%	17%
Who received one or more accommodation during completion of the EQAO assessment	56%	17%

Historically Fields High School students in Grade 9 Applied Mathematics have not performed well on the Ontario Education Quality and Accountability Office standards-based tests (EQAO). Averaging the data from the last five years shows that 66% of Fields High School students have scored below the provincial standard in Grade 9 Applied Mathematics (level 3) on EQAO, with approximately 10% of students scoring below level 1. Data for the school board for the same time period show that 59% of students in Grade 9 Applied Mathematics score below a level 3. Data for the province show that 65% of students in Grade 9 Applied are scoring below a level 3.

Description of the Participants

Table 10 lists the members of the PLC and their role at Fields High School.

Table 10: Members of the Fields High School PLC

Name (Pseudonym)	Role
Dolores	Principal
Wayne	Department Head/Grade 9 Mathematics Teacher
William	Teacher of Grade 10 Applied Mathematics
Tasha	Teacher of Grade 9 mathematics/Special Education Teacher
Rachel	Student Success Teacher
Larry	Teacher of Grade 9 Applied Science
Shirley	Teacher of Grade 9 Applied Science
Anna	Teacher of Grade 9 Applied Geography

Dolores. Dolores has been as administrator for 15 years and the Principal at Fields High School for the past three years. She was trained as a French immersion teacher but describes herself as a self-taught geography teacher as that was the position she was first hired for at the beginning of her career. Dolores shared with me that she does not feel comfortable in the mathematics and science domain. Instead she described her role within the PLC as that of a “mosquito”, buzzing ideas into people ears rather than dominating or directing the flow of discussions during PLC meetings. She feels there is a risk of a principal becoming too overbearing in a PLC and chooses instead stay on the periphery.

Wayne. Wayne is a veteran mathematics teacher who has been teaching mathematics for 25 years, the last seven of which have been at Fields High School as the Mathematics Department Head. Fields High School has been experimenting with a “split” Grade 9

classroom in which both applied and academic students are taught in the same class and the same curriculum. Wayne is one of two teachers that teach the split class at the school.

Wayne explained that he struggled through high school for various reason and never really understood mathematics. Wayne enrolled in university and his course selection was extremely varied, he studied mathematics but also meteorology, chemistry, philosophy and fine arts. After several years in university he left to accept a job as an educational aide helping students in Grades 9 through 12 with mathematics. It was during this work that he discovered he understood mathematics for the first time. He returned to university, finished a degree in mathematics and then applied to teacher's college to become a high school mathematics teacher. Interestingly enough, at the time, he thought that a job in teaching would be a good short-term job and he planned to move on to the next thing, possibly a Masters degree, after five years of teaching.

Wayne, and his colleague William, are very active outside of Fields High School and are fairly well known leaders in the local mathematics education community. They are frequently invited to lead professional development for other elementary and high school mathematics teachers and they have presented their work at national and international education conferences. Wayne is a strong presence in the PLC and others often turn to him for words of wisdom during planning meetings when the meetings lose momentum or the PLC is unsure how to proceed.

William. William is a veteran mathematics teacher who has been teaching for 25 years. Fields High School is the third school that he has taught at. Similar to Wayne, he did not originally intend to become a mathematics teacher. He describes himself as being a strong mathematics student in high school and claimed that mathematics was the only

subject he enjoyed in school and the only one for which he would complete his homework. He studied mathematics in university and chose to apply to teacher's college simply for lack of another career option.

William currently teaches Grade 10 Applied Mathematics as well as several Grade 11 and 12 academic mathematics courses. He, along with Wayne, is active in the mathematics education community; he has a very strong presence online through both a personal blog about teaching mathematics and on the social media platform twitter. He explained to me that he is frequently away from his school as he is invited to speak to other mathematics educators about professional development and pedagogy. He presents at national and international conferences about the work he and his colleagues at Fields High School are engaged in. William has a strong voice in the PLC and sometimes worries that he intimidates the other members.

Tasha. Tasha has been teaching mathematics for 12 years and she is both a Grade 9 mathematics teacher and a special education teacher. She, along with Wayne, teaches the split Grade 9 mathematics classes. Tasha explained that she struggled through high school mathematics and often tells her students that she had to repeat Grade 9 mathematics several times. She claims that she relied on the memorization of algorithms and never understood mathematics as a student. This experience has affected the way she teaches her students.

In university Tasha struggled to find a degree program that she connected with. She started university in a pre-med program but found the students too competitive; she found the same when she next enrolled in biochemistry and then business. She enjoyed her courses in computer science but did not see a future for herself in that industry. At the

end of her four years of university in various programs she discovered she had enough mathematics courses to earn a degree in mathematics.

After university she had several part-time jobs, one of which was tutoring K-12 mathematics students. Through tutoring she gained an understanding of mathematics that she had not had up until that point. She also was able to understand where and why students were making mistakes due to her own struggles with mathematics. This experience of tutoring led to her enrolling and obtaining a Bachelor of Education degree in secondary mathematics and soon after she began teaching high school mathematics.

Prior to teaching at Fields High School Tasha taught at a different high school where Wayne was also the mathematics department head. It was at this school that they began to collaborate and share ideas about teaching Grade 9 Applied Mathematics students.

Rachel. Rachel's current role at Fields High School is Co-Headship of Student Services, which encompasses both learning support and special education for the school. Rachel is a Student Success Teacher; she monitors and supports approximately 340 students who have been assigned an individual education plan (IEP). Student Success Teachers assist with students who have been identified as requiring additional support at school. Rachel is involved in such programs as "Credit Rescue and Recovery classes that support students when they have fallen behind in their studies. Rachel is familiar with many of the students in Grade 9 Applied Mathematics classrooms as they are involved in the Student Success Program.

Rachel has been teaching for 18 years and is a science, mathematics and guidance specialist. She has been involved with the special education component of the school system for the last 10 years and before that she was a classroom teacher teaching a

variety of subjects including secondary mathematics and English and middle school technology and design. She informed me that Fields High School is the ninth school that she has taught in during her career and she is currently in her sixth year at Fields High School

Larry. Larry is a high school teacher with over 20 years of experience. He currently teaches science and physics courses at Fields High School including Grade 9 Applied Science. This is his first year as a member of the PLC. My interactions with Larry were limited to my participation in the lesson planning and debriefing session related to the mathematics lessons.

Shirley. Shirley is in her 18th year of teaching, all of which have been at Fields High School. She currently teaches science courses including Grade 9 Applied Science. My interactions with Shirley were limited to my participation in the lesson planning and debriefing session related to the mathematics lessons.

Anna. Anna has been teaching for 18 years and is currently in her 15th year at Fields High School. She teaches geography courses and my interactions with Anna were limited to my participation in the lesson planning and debriefing session related to the mathematics lessons.

Description of the PLC

The focus of this research is on the PLC involved in the OAME Project at Fields High School. However it is important to describe how this PLC came to exist in its current configuration to fully understand how it operates. Informal collaborations between several members of the PLC including Wayne and William at their current school and Wayne and Tasha at a previous school contributed to these individual teachers

collaborating on more formally defined projects currently underway at the school. One of these formal projects, the Student Success School Support Initiative (4SI), commenced three years earlier (during the 2012-2013 school year). The 4SI project is a spin-off of the Student Success/Learning to 18 Strategy that the Ontario Ministry of Education commenced in 2003. The focus of the 4SI project was on creating success for students in Grade 9 and 10 applied courses in mathematics, English, history, geography and science. At the time that Fields High School first began the 4SI project Dolores, Field High School's Principal, decided the focus of their work would be primarily on mathematics and English. She felt numeracy and literacy were key to improving student's success "it just seemed like numeracy and literacy would be a logical place to start. I liked the idea of a cross subject [PLC] and as luck would have it, Wayne and William had already done a lesson study" (Dolores, Interview, April 27, 2015). Two English teachers were invited to participate and Dolores made up the fifth member of the PLC.

During the second year (2013-2014 school year) of Fields High School's participation in the 4SI project Wayne and Dolores extended an invitation to Tasha to join. It would appear that Wayne's previous experience working and collaborating with Tasha led him to suggest that she join the PLC. At the end of the second year of the 4SI project the English teachers decided that they would no longer continue and three new teachers were invited to join. After consultation with both Wayne and William, Dolores invited Larry, Shirley and Anna to join the PLC. The third year (2014-2015) of the school's participation in the 4SI project was also the year that Fields High School applied for, and was selected to participate in, the Grade 9 Applied Mathematics Collaborative

Inquiry Project coordinated by the Ontario Association of Mathematics Educators (OAME).

One of the OAME project criteria is the creation of a School Implementation Team (SIT). This SIT should include up to three Grade 9 (or Grade 10) Applied Mathematics Teachers, the Student Success Teacher, the Special Education Resource Teacher, the Mathematics Department Head/Chair, an Administrator and a Board Mathematics Lead.

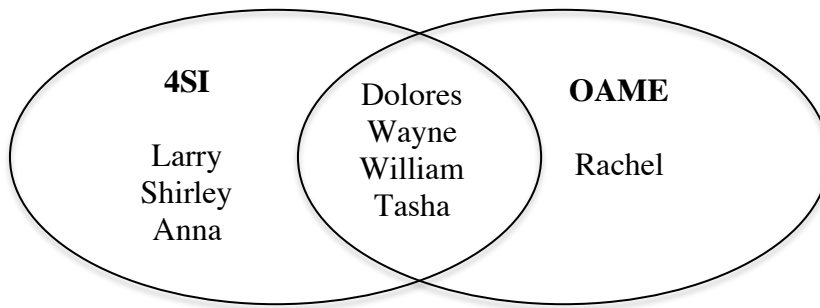
Fields High School identified the following individuals to fulfill this requirement:

- Wayne – Mathematics Department Head
- William and Tasha – Applied Mathematics Teachers
- Dolores – Administrator
- Rachel – Special Education Teacher

Other individuals were identified on the application form but were not present at the meetings and therefore did not sign consent forms for the project. Their names are not included in this research.

As the 2014-2015 school year began, the members of the OAME project soon realized that the time expectations for both the OAME and 4SI projects were very high. Teachers felt they were already pulled out of their classrooms too much and adding another full day each month would be too great a stress on both them and their students. It was decided early in the school year that the 4SI and the OAME project meetings would merge. The OAME project members, Dolores, Wayne, William, Tasha, and Rachel, felt that the goals of the two projects were similar and could be accomplished simultaneously. The result was a PLC that merged members from both the OAME project and the 4SI initiative. The overlapping of these two PLCs is represented in Figure 2.

Figure 2: OAME and 4SI Member Overlap



Description of PLC Meetings and Activities

The PLC meetings are held according to a schedule that was decided upon at the beginning of the 2014-2015 school year. Meetings generally serve one of two purposes, planning a lesson or observing and debriefing about a lesson. A planning meeting revolves around one teacher and a concept that the teacher has decided they would like the team to address and design a lesson for. Different teachers bring different levels of pre-planning to the meeting. For instance one teacher knew only that he wanted to teach a lesson focused on ratio and proportion. During the course of the meeting even that focus gave way to an entirely different focus and the team ended up designing a lesson focusing entirely on meta-cognition and the factors that influence how students make decisions in a mathematics class. During a different meeting a teacher brought a semi-planned lesson and asked for help determining the more minute details of the lesson. A typical planning meeting generally runs 2.5-3 hours.

An observation and debriefing meeting generally follows closely after a planning meeting. The entire team is present in the classroom to observe and take notes while one teacher teaches the lesson the PLC designed together. Following the observation of the

lesson the PLC meets to discuss the observed lesson, to talk about what worked and what didn't and to make suggestions about alternative forms of delivery, assessment, flow, etc. Like the planning meeting, these observation and debriefing meetings run between 2.5 and 3 hours.

PLC Initiatives

When I first began attending the PLC meetings at Fields High School I became aware of several approaches to teaching that the group had been exploring. These different approaches include the Split Grade 9 classroom and the re-organization, or spiraling, of the curriculum.

Split Grade 9 classrooms. For the last few years all students registered in Grade 9 Applied Mathematics at Fields High School are placed in a split Grade 9 Applied/Academic classroom. There are no longer any straight Grade 9 Applied classes at Fields High School. Students in these split classrooms are unaware of what other student's course designation is. All students are given the same lessons, assignments, and assessments. If a student is achieving the expectations of the academic credit then they will have their course designation switched to academic, and vice-versa. The goal is to have no student fail Grade 9 mathematics and to have each student placed in the correct course designation before the end of the term. Wayne explained that their students have responded positively to this reorganization of students. Wayne feels this reclassification for the students in Grade 9 Applied Mathematics class has helped to improve student mindset towards their own abilities in mathematics. His goal is to one day have only a common Grade 9 mathematics course at Fields High School and to eliminate the labels of

applied and academic that often become attached to students in these different classrooms.

Spiraling. This approach to rearranging the curriculum was first initiated by Wayne and William. William explained that after several unsuccessful years of teaching students in Grade 10 Applied Mathematics he decided to switch his approach to teaching. He explained how his traditional teaching was not helping his students achieve adequate results and they lacked enthusiasm for the course. He also was losing his motivation for teaching and stated that he either needed to completely change the way he taught, or leave teaching. Through discussion with Wayne they decided to let the students “play” for the first month of school. They implemented an activity-based approach to teaching and they found that their students were more engaged in class. As they continued to locate existing activities and create their own they found that many activities were covering multiple strands of the curriculum simultaneously allowing different strands to be explored more than once. This revisiting of the curriculum concepts appeared to be having a positive impact on the students. All three mathematics teachers now use the spiraling approach to teaching Grade 9 and 10 Mathematics students at Fields High School. Dolores shared that the students in Grade 10 Applied Mathematics are experiencing much higher rates of success over the last few years on a board wide summative exam. She credits William and the PLC with this improvement.

Summary

This Chapter provided an overview of the PLC, the members of the PLC and the different ways that the school has decided to approach the teaching and learning of students in Grade 9 Applied Mathematics classes at Fields High School. The following

two Chapters will provide a closer look at how this PLC operates and how the members of the PLC interact as they explore ways to best meet the needs of their students.

Chapter 6: Findings

My interest in pursuing a Masters in Education has always been to explore further the issues that relate to professional development for mathematics teachers. While the cross-curricular nature of this PLC does play an interesting role in the planning of the mathematics lessons I have decided to focus my attention primarily on the three mathematics teachers, Wayne, William and Tasha and the Principal, Dolores. By doing this I am best able to address the research questions that guided this study. These guiding questions are:

1. How is a PLC formed and sustained, and how does it evolve throughout the process of examining practice?
2. What happens when a professional community of learners comes together to discuss, dissect and reflect on their own practice with the intention of broadening their understanding of teaching mathematics?

During the analysis of the data I found it helpful to break down the first research questions into three more discrete parts:

1. How is a PLC formed?
2. How does a PLC evolve throughout the process of examining practice?
3. How is a PLC sustained?

I first discuss these three parts of the first research question focusing primarily on the individual interviews with Wayne, William, Tasha and Dolores. Following that I discuss the second research question drawing from both the individual interviews and the PLC meetings.

Addressing Research Question One: How is a PLC Formed?

In the previous chapter I discussed how, out of necessity and practicality, this particular PLC was created when Fields High School merged two initiatives, the 4SI project and the OAME collaborative inquiry project. In this section I describe, in more detail, the history of this PLC, how it was formed and the role that the professional relationships amongst the participants played in shaping it.

The paths that led the teachers; Wayne, William and Tasha to this PLC are different yet connected. Their teaching careers have intertwined in such specific ways that it is clear it is not a coincidence that they ended up participating in a PLC that is examining the teaching and learning of applied level mathematics at their school. I describe each participant's experience as both a student and a teacher and how that has influenced their beliefs and attitudes about teaching and learning mathematics. I also describe how the four participants came to be at Fields High School together, their professional relationships and how that shaped the PLC.

Wayne. As a student Wayne felt that he “stumbled in high school” (Wayne, Interview, April 22, 2015) due to situations at home. After high school he was unclear of a path to follow and tried his hand at various odd jobs and different courses in university. One of these jobs was as an instructional aid at a high school. His job required him to answer mathematics questions from students across Grades 9 through 12, and through this experience he gained a clearer understanding of mathematics.

I realized suddenly...for the first time in my life I understood high school math and I realized it wasn't that complicated so I decided...this would be a good thing to do. Go back and have a better experience than I did in high school. The other mitigating factor was I could get a math degree in only one year of study left in my degree (Wayne, Interview, April 22, 2015).

Following the completion of his mathematics degree he pursued and completed his teaching degree and began teaching high school mathematics and computer science. It was through teaching these different courses that he was exposed to two different methods of teaching.

There was the computer science branch which was filled with all kinds of problem solving and it was all very ‘guide on the side’ stuff with comp sci[ence] because they were...all working on their stuff and you would just help them along. If they hit a snag and then you work it through, help them and work it through. Then there was the math side, which was a little bit more ‘stand and deliver’. I thought if I could lead them to understanding, if [they] did this step this step this step I could lead them to understanding (Wayne, Interview, April 22, 2015).

Before his work with the PLC he had wanted to introduce more activities in his mathematics classes yet he still tended to teach using a traditional method:

More of a stand and deliver sort of approach...I was still trying to introduce things but I was still trying to tell them what to think and I had the agenda and I wanted to get through it and we had timelines and we were working hard to make sure that I was going to cover everything in that textbook (Wayne, Interview, April 22, 2015).

Wayne credits his colleagues at Fields High School with pushing him to try new methods of teaching.

In the last 5 years [my teaching] really [has] been buffered by my colleagues who have also gone that direction... it’s a whole lot easier to go that direction when you’ve got people that value that and think it’s important and that sort of becoming best practices (Wayne, Interview, April 22, 2015).

Tasha. Similar to Wayne, Tasha struggled as a student, “mathematics in high school was not a treat for me. I memorized my way through everything...I memorized the algorithm and that’s how I got through math” (Tasha, Interview, April 22, 2015). This experience affected her beliefs about the teaching and learning of mathematics and resulted in her taking a different, non-traditional approach to teaching.

I knew as a kid that’s how they taught me and I knew that didn’t work. Because when I finished high school I couldn’t remember a single thing. Even when I finished my

math degree I couldn't remember a single thing. So I knew that that is definitely not the way kids learn...they need to understand it and even through tutoring I learned that and so when I started teaching math that's the way I started teaching... I always knew it was important to address the kid's thinking and how they came up with their ideas and work off of that so I've always done that. My teaching style is for the kids to discover stuff on their own, like share each other's work and then examine each other's work (Tasha, Interview, April 22, 2015).

Tasha described how she first met Wayne during her early years of teaching when he was the head of the mathematics department at her previous school. Tasha shared that she was always given the classes that no one else wanted; these classes were the Grade 9 Applied Mathematics classes.

I always had to teach the classes that no one else really wanted to teach...so it's like 9 credit courses and applied level courses so I was usually the only teacher teaching those so I could do stuff independently...when I switched schools I was the only teacher teaching applied (Tasha, Interview, April 22, 2015).

When the enrollment in Grade 9 Applied Mathematics increased at her previous school Wayne began to teach the course as well. It was at this time that they first started to collaborate, "he saw what I was doing so he kind of tagged along and used the same resources and...that developed the inquiry-based learning" (Tasha, Interview, April 22, 2015). This collaboration continued when they both moved to Fields High School, Tasha in 2007 and Wayne in 2008. It is clear through observation of the PLC meetings that Wayne and Tasha have a strong working relationship. Wayne has a high level of respect for Tasha and values what she says. At one point during a planning meeting he tells the group, while pointing to her down the table, "I have been influenced by this woman down here" (Wayne, PLC meeting, April 2). He again asks her opinion later on in the meeting. Tasha is generally one of the more reserved members of the PLC and Wayne often asks her to speak to what the group is talking about. It would appear that he feels she has an opinion on whatever the topic is but may not voice it. Tasha corroborates this during our

individual interview when she tells me “I’m an introverted thinker so I have to think through and understand the process before I give my input” (Tasha, Interview, April 22, 2015).

William. Unlike Wayne and Tasha, William excelled in mathematics in high school; in fact it was the only subject that he worked hard in, “math was definitely my best subject in high school. It came to me. I definitely worked at it. I always did my homework in math. I never did my homework in any other subject” (William, Interview, April 22, 2015). Following high school William studied mathematics in university and obtained his teaching degree the following year. He has now been teaching mathematics for 25 years, the last 14 years at Fields High School.

When I asked William if his teaching style has remained the same throughout his career he described how, about 18 years ago, he had a moment during one particular class that changed how he thought about teaching.

I was teaching a lesson to a Calculus and Vectors class on Friday afternoon and I’m standing at the board lecturing, kind of what I always did. There was some math activities thrown into it but it was always very teacher directed, and I can remember the day where it was coming out of my mouth, I was writing it on the board and I was not in the room, mentally at all. And if it was like that for me, imagine what it was like for those kids in my class? It was very lecture format, some classes 75 minutes of me talking, very structured that way (William, Interview, April 22, 2015).

He decided around this time that either he needed to leave teaching and try a different career or try a different approach to teaching because as he says “I was losing classes, I was teaching applied level classes and completely losing them, having zero success with them so a lot of things happened that made me think about changing” (William, Interview, April 22, 2015). He credits Wayne with pushing him to rethink his teaching strategies. Several of the teachers in the PLC have described Wayne as calm, thoughtful

and wise. William described a conversation he had with Wayne that affected him greatly. William was having a lot of challenges teaching the Grade 10 Applied level mathematics course and discussed this with Wayne.

It's my third semester in a row teaching the applied level kids and I'm just like ok Wayne it's someone else's turn. I did this for you, you asked me to do it. I've tried three different things, three different semesters. I really did try to do different things and Wayne there with his hands crossed, you know the gentle giant, kind of looking and listening, let's me vent for a bit then kind of gives me the '*Yeah well ah, maybe you need to change*', you know he put it on me (William, Interview, April 22, 2015).

This appears to be a turning point for these two teachers and it began the collaboration between the two of them that would eventually spread to include Tasha as well as the rest of the PLC. Their collaboration is centered on how best to teach the school's students in applied level mathematics. A common struggle brought these teachers together around a shared goal. The relationships that the three mathematics teachers had developed, over many years and several schools, centered on developing strategies that would enhance the learning of the schools most vulnerable students. Tasha believed very strongly, based on her own experience as a student, that traditional methods were not effective. Wayne believed that a guide on the side approach would be most effective, as he had seen through teaching computer science. William believed that the way he was taught, and the method that was effective for him was not working with the students he was teaching in applied mathematics.

Lots of the kids could learn that way, lots of them could sit there, like lots of academic classes I think you can get, I'm going to say get away with it. But there is still a bunch of kids in those classes who you are talking over their heads and that's the reality of it and I think anyone who tells you that's the way to go is deceiving themselves a little bit, that they are trying to reach every kid, because they are not (William, Interview, April 22, 2015).

All three teachers share similar beliefs about the teaching and learning of mathematics. They took different routes to get to the same understanding but now they are united in pursuing what Wayne describes as best practices. This common goal appears to be the foundation of the PLC.

Dolores and the importance of leadership. The fourth member of the PLC that I focus on is Dolores. The 2014-2015 school year was Dolores' third year at Fields High school and she has played a key role in the formation of the PLC. Her first year at Fields High School was also the first year that the school participated in the 4SI project. The other four members were Wayne, William and two English teachers. Dolores chose Wayne and William to participate because of the extensive collaboration they were already engaged in that focused on the applied mathematics courses and exploring different methods of teaching the students in these courses. Wayne and William were already seeking out opportunities to engage in professional development that would help them to address the identified needs of their students. "As luck would have it, Wayne and William had already done a lesson study with a TTLP [Teacher Learning Leadership Program]; which is a funding from the Province and so [they] could make a case for lesson study" (Dolores, Interview, April 27, 2015).

Dolores' engagement with 4SI was only one of her contributions to the PLC, all of the teachers I interviewed credit Dolores with being one of the key elements to their perceived success as a collaborative environment. When Dolores first arrived at Fields High School she embraced the lesson study model "when Dolores came along, the PLC and the lesson study idea, she encouraged it" (Tasha, Interview, April 22, 2015). Others shared similar sentiments about what it means to have the support of the Principal as you

engage in professional development that explores the idea of shifting your practice and stepping away from more traditional teaching practices.

If you are looking at doing things differently and changing the way you teach [she] will support you right... she's totally willing to let you, if you think it's good. Well I think she is proud of what has happened here, right? She should be proud of what's happened here it's been, it's probably one of the most collaborative environments you can work in if you choose to collaborate, if you choose to jump in (William, Interview, April 22, 2015).

Another big thing about [our open door policy] is the support of the Principal and she is all about supporting us and allowing us to take chances and take risks and it's a huge deal and more of us are willing knowing we are not going to get burned (Wayne, Interview, April 22, 2015).

I personally think that she is a fabulous leader. She's one of the best Principals I've ever had and I've been in a lot of schools. And she's the best I'd say in many ways because she's so encouraging and willing to support you in what you want to do and I think that's just phenomenal... like I don't think she's pushy about it either. And this is the best thing to do and you can only move forward (Rachel, Interview, May 26, 2015).

Dolores herself demonstrates a desire to learn and to expand her understanding of teaching and learning at the applied level. She appreciates that the PLC has provided her with an opportunity to improve as an administrator.

For me it's been the biggest learning curve in my entire career. It's been the most impactful thing I've ever done as a Principal... This is our third year and I've been a Principal, I've been an administrator since 99 so I've been around for a while. This has been the most powerful thing for me in my practice ever (Dolores, Interview, April 27, 2015).

The shared goal of improving their practice is very much at the core of the PLC and again would appear to be the primary reason that the PLC was formed. The desire of the teachers to examine their practice combined with the support of the Principal resulted in the formation of this PLC.

We all had something to bring and we all knew that education was changing rapidly and the way we do things is changing and it just has grown right and I think it's a pretty cool group to be involved in (William interview, April 22, 2015).

Addressing Research Question One: How Does a PLC Evolve?

In a physical sense the PLC evolves when new members join, new lessons are planned, observed and debriefed, and new areas of pedagogy are explored. When the Science teachers, Shirley and Larry, joined the group at the beginning of the 2014-2015 school year they brought a different dynamic to the group. Larry and William would often engage in debate over issues of scaffolding lessons and direct instructions. Even though they sometimes disagreed William welcomed the different point of view, “I do think he has some slightly different opinions than I do about certain things, and that’s good, we bring those different things to the table” (William, Interview, April 22, 2015).

The shared knowledge of the PLC also evolves when teachers participate in professional development outside of their own school. Many of the teachers are involved in other collaborative environments outside of the school, whether online or through professional organizations such as their local branch of OAME. Wayne and William share their experiences from attending national and international conferences with the group. For instance a conference they attended several years ago introduced them to the research of Dr. Peter Liljedahl and his work on non-permanent vertical surfaces, otherwise known as whiteboards. This work was shared with the PLC and had a direct impact on the PLC members. Most, if not all members have now installed whiteboards in their classrooms and often speak about the positive impact it is having on teaching and learning. Tasha shared with me that when Liljedahl “showed his research and data on [non-permanent vertical surfaces]... Wayne and William were so excited about the idea that on Monday they came in and got these whiteboards and just started implementing it and it’s been wonderful” (Tasha, Interview, April 22, 2015).

The members of the PLC are very familiar with current research in many areas of education and this allows the PLC to evolve. Wayne jokes that instead of getting a few photocopied sheets in his mail box at school now there are whole articles or books for him to read. The PLC members often arrive at the PLC meetings with the latest book study book stacked with their pile of work and at every meeting I attended I heard different research articles or books referenced to back up a method or idea they wanted to implement. During the launch of the second semester of the 2014-2015 school year the team was re-evaluating their goals for the semester and Dolores suggested that they focus on students' metacognition. Prior to the meeting Dolores had attended a two-day conference led by John Hattie and provided his book for each member of the staff. Throughout this meeting the PLC members also discussed the work of Boaler and Dweck and how this was informing their own practice.

Addressing Research Question One: How is a PLC Sustained?

Through out the analysis of the data a recurring theme appeared, the theme I dubbed, "work with the willing" and it appears that this is one of the key factors that sustains this PLC. Not only do the PLC members share the common goal of working through the challenges associated with teaching students in applied level classes, they share the willingness to do this work. When I spoke with Dolores about challenges associated with the PLC she spoke to the negative impact that non-willing participants can have on the group.

The biggest challenge for PLC is the naysayer. I know a lot of my colleagues in the other 4SI schools had naysayers and they just submarined the whole thing. I don't do that. I don't spend a lot of energy on people who are pushing back (Dolores, Interview, April 27, 2015).

The original members of the PLC were Wayne and William along with Dolores and two English teachers. For reasons not shared with me the two English teachers decided to leave the PLC after the second year. William speaks to this during our interview but he is unclear of their reasons for leaving. When Dolores addresses their departure she turns their leaving into a positive opportunity to bring in new, willing members to the PLC.

They wanted to do it differently and they wanted to go back to their regular things and that was fine and that was a great opportunity for me to bring in other people who were keen (Dolores, Interview, April 27, 2015).

It seems that through this change of members the PLC is able to sustain itself. To keep negative minded members in the PLC would not be beneficial according to Dolores “there has to be a dynamic of willingness to be there” (Dolores, Interview, April 27, 2015).

Rachel, who is the Student Success Teacher, describes the excitement that the teachers bring to the PLC and her eagerness to be involved.

I ended up becoming involved actually, because...the OAME project stated that you needed a LST [learning support teacher] but also it was my colleague Tasha that included my name...Which actually I’m really happy about because it was something that I wanted to do. I was very excited about hearing about the other professional learning communities going on in the school and because I’m not actually in a classroom teaching. I didn’t know if that was even a possibility for me to be able to get involved with it but I’m really happy that I had the chance to be able to do that (Rachel, Interview, May 26, 2015).

It would seem that it is this excitement that sustains the group, which was evident when the group was making plans for continuing the OAME project into the second year. The PLC members were trying to sort out the best way to maximize the benefits from both the 4SI and OAME projects. They saw the continuation of the OAME project as an opportunity to expand the group and to involve more willing teachers by perhaps creating two groups instead of one. Some of the teachers were reluctant to split up their group

Everyone is so excited to be a part of it...the plan is to sort of separate into two groups. But it's interesting how everybody wants to stay involved and they kind of feel like [they] don't want to be separated into another group. [They] want to stay with the group that we're in and we want to keep that positive rolling (Rachel, Interview, May 26, 2015).

As discussed previously, Dolores played a key role in forming the PLC. The same can be said about her role in sustaining the PLC. Wayne and William also appear to be very important in terms of sustaining the group. Wayne and William have both been teaching for 25 years and have been collaborating together, both within the PLC and outside the PLC since Wayne arrived at Fields High School in 2008. Their collaboration has led to the creation of a model of teaching mathematics that is becoming well known outside of Fields High School. The two teachers regularly present their work at local conferences in Ontario and have begun to present internationally as well. William especially is very active on social media and influences many teachers through his twitter account and blog. Wayne feels that they are affecting change in the way that people teach and this influence carries over into the PLC and helps to sustain it.

To go to a presentation and sort of lay out what we are doing and have people who change because of that, because of the contact we have with them, is exciting. William has single-handedly changed the way the [anonymous] Board is approaching mathematics teaching. I think that's the best feeling (William, Interview, April 22, 2015).

The PLC also is sustained through the teachers' belief that the process they engage in is powerful and is important. All the teachers I spoke with describe their lesson study process as very powerful and effective professional development, "it was just the most incredible PD to sit around for a day and talk about teaching with other teachers" (Wayne interview, April 22, 2015). They also speak a lot about respect and describe the lessons they design as "our" lessons, they don't attribute the success, or lack of success, of a

lesson to an individual teacher, it is a collaborative process that results in lessons for all the teachers.

It's a very respectful group and what's powerful about it is it's all about ideas. There's nothing personal about any of this and that's the force of the lesson study, is that we are not looking at the teacher; we are looking at the kids. Was "our" lesson impacting those kids? It's not about you (Dolores interview, April 27, 2015).

Summary of Addressing Research Question One

When considering the data that was collected I can summarize that this particular PLC was formed through a shared belief that the needs of students in applied level mathematics classes were not being met. These teachers came together around the common interest of improving both their own teaching and the learning of their students. Lastly, the support and leadership of their Principal allowed teachers the time, opportunity, and support to establish this PLC.

The PLC at Fields High School evolves in several ways. The introduction of new pedagogical challenges that arise through the introduction of new participants and new professional development opportunities, such as the OAME project is one way that the PLC evolves. PLC members attending and presenting at national and international conferences allow for new knowledge to percolate through the PLC and keeps the PLC connected to current educational research and best practices. Dolores once again plays an important role and her careful selection of new members for the PLC offers the opportunity for the PLC to evolve as well.

Lastly, the PLC is sustained by the willingness of members to continually challenge themselves to examine their pedagogy and effective ways to enhance the learning of their students. The teachers' belief that the PLC is an effective method of enhancing their practice also sustains the PLC. Ultimately, their belief that what they are doing is

working drives them to continually work on improving both the teaching and learning of mathematics at Fields High School.

Addressing Research Question Two: What Happens When a PLC Comes Together?

When I consider how to address the second research question it becomes clear that there are two separate aspects involved. The first aspect is literally what happens at a PLC meeting, I refer to this as the actions of the PLC. When analyzing the data using this interpretation the themes that emerged included; the role of the Principal in the PLC and the different areas of teaching and learning the PLC focused on during these meetings. Different areas of focus included; students' well being, pedagogy and mathematical concepts. The second aspect of the question is what happens because of the PLC coming together to discuss, dissect and reflect on their own practice. I refer to this as the results of the actions of the PLC. The themes that emerged when using this lens are; the impact on student learning, the impact on pedagogy, the impact on the school and the challenges associated with participating in the PLC. In this section I discuss these two different aspects of the research question and the related themes that emerged.

The actions of the PLC. The February 2015 PLC meeting was unlike previous meetings I had attended. This meeting was not a planning or debriefing meeting. Instead Dolores led the meeting and she hoped to refocus the PLC and establish some goals for the semester. Generally at meetings Dolores listens more than she speaks. At this meeting she introduced some new concepts related to teaching and learning to the PLC and suggested that this is where they might want to focus their work. She leaves it up to the teachers to decide if this is the direction they would like to go.

Are we interested in just doing what we did before? Which was working on accountable talk and higher order questioning or do we want to go a little bit deeper

and a little bit more explicitly and institutionalize these aspects that we talked about before? Around mindset, around criteria, the success criteria and the anchor charts, possibility of journaling as one of the, everybody's not doing that, as one of the tools to get them to do the metacognition. I don't know, do we want to do that way? What's your feeling? (Dolores, PLC meeting Feb 12, 2015).

Dolores describes herself as a “mosquito” a voice in everyone's ear offering advice and suggestions but not determining the direction that the PLC or individual teachers take when designing a lesson. She is mindful of several factors: she feels the teachers know more than she does about each individual subject areas, she sees her role as bringing new ideas to the table and she feels that she can't be overbearing at these meetings.

So the dynamic has been one of each of the teachers bringing their subject to the table. I kind of see my role as kind of being the mosquito... I do feel that that's part of my role. That is try to just throw in a new thing you know like, I do...I also feel that there is a certain danger, if you want to call it that. There is a certain challenge for the Principal not to be overbearing; to be able to maintain your relationships of trust but still bring the group along in a way that you see is important. Respecting all the while that they know way more than I do. But it's also handy because I'll be in a, the science [planning meeting] and I'll be able to say you know what I remember learning electricity and not getting it. And you're doing it, you're doing exactly what they did when I was in school. That doesn't work (Dolores, Interview, April 27, 2015).

At this planning session Dolores focused a great deal of energy on student metacognition. She brought back information from the Dr. Hattie conference to share with the teachers at this meeting. They used this information to consider different strategies that teachers could use to explicitly teach metacognition. Over the course of the three-hour meeting there was much back and forth about how to teach students metacognition. Not all teachers were sure about how to teach students this. It seemed at the time that not all of the team was completely on board with this approach to the second semester of the school year. Interestingly enough, at every planning session after this meeting the teachers always came back to metacognition. It became a very important

piece in the PLC's planning sessions and they spent a great deal of time planning lessons that would help students reflect on how they think, what factors affect them when making decisions, and the importance of having confidence in their own thinking. Dolores had planted a seed that really took root.

Dolores is not afraid to push back against teachers and have them justify their thinking when they are making decisions or statements about a lesson or concepts related to teaching and learning. One particular instance with William highlights this

Dolores: Is this worth the time you are spending on it?

William: I don't know

Dolores: Is it rich enough?

William: Well I don't know

Dolores: I'm just sort of afraid that it's just kind of like meh...so you're going to talk about, what did you think about, you're going to talk about their strategies for figuring out how TEACHER NAME got all these t-shirts, you know it's irrelevant (PLC meeting, Feb 12, 2015).

This conversation continues with William really focusing in on what it is he wants students to know and how he will structure the lesson so that they arrive at this understanding.

Rachel describes Dolores's role similar to how I observed her and she suggests that the teachers respect her opinion and appreciate her role in the group.

[Dolores] sits in with the lesson planning and yet I feel will contribute now and then but doesn't override it and I don't think anyone feels like they have to impress her where as I think there are some situations where that might be a different dynamic. So to have the right personality in an admin[istration] role might further it in some of the schools where that wasn't the case where they had that positive experience (Rachel, Interview, May 26, 2015).

Focus on students well being. Apart from this first meeting of the semester the PLC meetings are generally one of two formats: to plan a lesson or debrief a lesson that the PLC members have just observed. During the planning of a lesson many different things can happen but generally they follow a similar pattern. I break down these meetings and discuss what happens when the PLC discusses, dissects and reflects on their own practice with the intention of broadening their understanding of teaching mathematics?

An important part of every lesson planning PLC meeting is an in depth discussion of the individual students in a particular teacher's class. The PLC spends a minimum of 45 minutes at each planning meeting discussing the students. Each participant in the meeting is given a class list with photographs of each student and any pertinent information such as whether or not that student has an IEP or any emotional or physical challenges they are dealing with. Often the dynamics of a class will dictate the tone of a lesson. For instance when the PLC was designing a lesson for Wayne's Grade 9 mathematics class he stipulated that because of the high number of males in the class he would like something physical and hands-on for the students to engage with.

The cross-curricular nature of this PLC was intentional, and the objective is to meet the needs of students in applied level classes across all their subject areas. The teachers have the opportunity to observe students in all subject areas allowing them insight into how the students react to different teaching styles and subject matter. Teachers often share different experiences they have had and share information about students, such as, if a parent is absent from a child's life or if the student's home life is disrupting their learning due to divorce or illness. Rachel's role, as the special education teacher, is an important one. She is very familiar with details about the students' lives outside of

school. She is in contact with family members, health professionals and the previous schools students have attended. She is also well versed in different learning difficulties and the reasons behind many behavioural difficulties the students may have.

The teachers realize that the students they are planning lessons for are a unique group with needs that might be different from the majority of the school population. In one lesson planning meeting the teachers discuss the impact that different types of praise can have on students. The teachers talk about Dr. Carol Dweck and her research that compares praising effort versus praising intelligence. Shirley shares her concern that the students they have are not used to being praised at all and that teachers are hesitant to withhold praise for that reason.

Often we are dealing with a segment of our student population that doesn't have that unconditional sort of, at home Mom or Dad, that consistent sort of 'you're the best no matter what happens. And it has its place in a different realm and so we know that we are lacking that. And so I think sometimes when people are resistant to withhold that, for obviously the right reasons and proven research, it just doesn't feel right because you know there's that need (Shirley, PLC meeting, Feb 12, 2015).

The specific needs, both emotionally and in terms of learning, of the students they are designing lessons for are the primary focus of this PLC. As discussed earlier, it was the shared experiences of the teachers and the challenges they faced when teaching applied level mathematics that began their collaboration and it is this challenge that continues to be the focus. When the teachers meet to discuss, dissect and reflect on their own practice, both during planning and lesson debriefing, much of their conversation is focused on the well-being and needs of their students. During the lesson planning meeting for Wayne's class the teachers focused part of their conversation on one particular student and how important this lesson could be for her. They describe this student as lacking confidence and following the group rather than trusting her own mathematical instinct.

Larry: think about how important this will be for STUDENT NAME, if in this lesson she suddenly realizes this is stupid, or whatever her modus operandi is...it will be for her, her little epiphany, this is the whole point.

Wayne: this is STUDENT NAME's lesson in fact, right? (PLC meeting, April 2 2015)

Often after a lesson is observed the teachers dissect the actions of a particular student. They attempt to assess what a student's actions mean in terms of her or his mathematical understandings but also how that student is doing emotionally.

I'm not so sure, she might have figured it out. She put numbers down for her group strategy...and she put down an answer...I actually think she may have done some work today but would not work in a group. Um I don't know what's going on with her (William, PLC meeting, April 22, 2015).

After Wayne's lesson one particular student, who had been very vocal throughout the whole class but actually had an incorrect solution, was very discouraged. Tasha was concerned about his well-being. Tasha proceeded to talk about the student's solution and how even though it was incorrect he did demonstrate some strong mathematical thinking. The conversation then focused on the best way to assess this student and Tasha felt that their assessment strategies might need to be reconsidered in light of this particular student.

You saw STUDENT NAME's reaction to when the right answer came up. He was so deflated after that. He didn't want to fill in the reflection sheet. He wrote very little on the reflection sheet, so I think about that reaction... What does that mean to this student when they see oh I got this wrong or their thinking was actually valid. So our methods of assessment, this goes to show you that our methods of assessment aren't.... (Tasha, PLC meeting, April 9 2015).

The PLC continued to discuss possible ways to address the misunderstanding of this particular student and to help Wayne plan his follow up lesson the next day. The reactions and actions in one lesson directly impact the direction of the next lesson. The entire process of the PLC appears to be driven by the need to address the students and

their understandings or misunderstandings. Often in follow-up meetings the PLC members will inquire about certain students and how they reacted to subsequent lessons.

Focus on pedagogy. In each meeting after the PLC has discussed the different students, their needs and different challenges they move on to discussing the lesson. This often takes a great amount of time. Teachers go off on tangents but they always come back to the lesson and the teacher that will be delivering the planned lesson leaves with a nearly fully formed plan. The teachers at Fields High School have developed a method of teaching mathematics that doesn't necessarily teach the curriculum as linear nor focuses on individual expectations. Instead they use an activity-based approach that allows several areas, or strands, of the curriculum to be addressed at once. Different activities often address similar strands of the curriculum and the teachers feel that this revisiting, or interleaving (Rohrer, Derrick and Burgess, 2014) is a more effective way for students to learn. By using activity-based teaching the teachers feel that the students are more engaged. They are up and moving around, which they believe is better for students. Another important component to their teaching method is student collaboration on whiteboards as "it allows the exposure of fundamental problems" (Larry, PLC meeting April 22, 2015).

Throughout the planning process teachers share teaching strategies that have worked for them in the past or ask for help from their colleagues about how best to approach a specific teaching idea or concept.

I'm curious about what other strategies you're using to get their behaviour to change, other than just telling them to change their behaviour. Like what strategies make them change? What other things are we doing? (William, PLC meeting, Feb 12, 2015)

The debrief meetings allow teachers to discuss what worked and what didn't work during the lesson. The PLC members help the teacher decide what their next steps are and what possible follow-up they could plan

Wayne: They really can't articulate their strategy, they really struggle with that and then when they get into doing that, executing their strategy, they can't explain what they are doing, they can't articulate [that] this is why this works.

Shirley: So is the goal then more lessons like this where they are focusing on strategy?

William: Yeah, I think I need to do the strategies, I do lots of lessons like this that are hands on, but I think I'm going to get to the flesh of their strategies more before they get any data and get them better at articulating their strategies (PLC meeting April 22, 2015).

Focus on mathematical concepts. The cross-curricular nature of the PLC has had an interesting effect on how the mathematics teachers approach the mathematical concepts that they teach during a lesson. Wayne's lesson was the first mathematics lesson to be planned by the PLC and it clearly set the tone for the others. He began by sharing with the PLC that he wanted to address the concept of ratio and proportion.

Next week my students are doing some kind of lesson on ratio and proportion and maybe, the emphasis will probably be on volume, the fact that 3 dimensions...if you double the number of the dimensions you end up with a volume that is 8 times as big (Wayne, PLC meeting April 2, 2015).

The group takes this idea and begins to share ideas about how they could approach this concept. After a while Wayne stops the meeting and decides to change the focus of the lesson based on the reaction of Anna, the geography teacher.

Wayne: what has just occurred to me...I'm looking around the room like I'm just leaving Anna in the dust here

Anna: no kidding [laughter]

Wayne: and so maybe we just throw it all... maybe we just forget about the ratio and proportion and maybe we just go with, I mean some of the things we tried to get the idea of, the power of the group or the decision process, maybe we do something very non-math. I mean I'm happy to do that (PLC meeting April 2, 2015).

From this point on in the meeting the focus switches to designing a lesson that will reveal to students how others influence them in the classroom. The idea of metacognition that Dolores introduced during the Feb 12 meeting appeared to really have taken root with the teachers. During the PLC meeting on April 30, when the team is designing a lesson for Tasha's class, Wayne describes the role that mathematical concepts play in the lessons they plan.

There is that aspect of our lesson studies, it's almost like we take a break from the curriculum ...and then we learn about students learning and teaching the curriculum is secondary (Wayne, PLC meeting, April 30, 2015).

This appears to be true in the two mathematics lessons that follow Wayne's. The lessons focus primarily on student thinking and students justifying their thinking rather than on the mathematical concepts that are being addressed.

Impact on student learning. The teachers mentioned several instances where the work carried out by the PLC have had an impact on student learning. As mentioned earlier, Tasha was encouraged to use whiteboards in her class after Wayne and William returned from a conference and shared the research about the vertical, non-permanent surfaces. This idea has spread through the PLC and other teachers are noticing the impact this has on student learning. The teachers have shared that the students are more likely to write something down on a whiteboard because it is non-permanent. Also, having students' work visible to the rest of the class helps to dispel misconceptions about mathematical concepts.

Wayne explains how mistakes are valuable and the whiteboards make them more visible and easier to address and share with the students in his class. “The whiteboard does a nice job of [exposing mistakes]. You’ve got all this stuff all over the walls and that really helps you... change that approach in the classroom” (Wayne, PLC meeting, Feb 12, 2015). William shares that he believes the vertical surfaces increases the quality of the work that he gets from his students “it really makes a massive difference in the quality of stuff you get and the connections they make and the different representations you get from them. Like just everything you get more and better quality” (William, PLC meeting April 9, 2015). Larry also described how whiteboards and “snowballing”, a process that has students rotate to another group’s whiteboard to see their work, affected the student learning. “We watched last week in a physics lesson, conceptual change occurred in the class in less than 5 minutes and it was just as soon as they got to rotate once and the snow ball was when everything changed” (Larry, PLC meeting April 9, 2015). The participants observed that when students are encouraged to share their ideas with one another they learn from each other, either through their mistakes or through their correct solution.

Dolores also has noticed a change in the students’ learning. “It’s made a huge difference for kids, pursuing what they really know and therefore it’s really much more valid” (Dolores, Interview, April 27, 2015). By focusing on the needs of the students the participants are designing lessons that directly relate to the students and may be of interest to them. Dolores explains that “kids are talking about what they are learning, not just what they are memorizing” (Dolores, Interview, April 27, 2015) and this to her is evidence that the PLC is impacting student learning.

Tasha believes that giving the students multiple opportunities to demonstrate their learning and extended periods of time to write tests helps to decrease their anxiety about mathematics. For instance when Tasha gives students a test she gives them as long as they need to work on it, even if they require several days. “I’ll say it could take you one day it could take you three days. You can take as long as you need to write it. So kids will go home and get answers, I don’t care” (Tasha, Interview, April 22, 2015). She explained that if students are getting answers from home then they are talking to others about mathematics, which is a good thing. They still need to come back the next day and be able to communicate what they have learned at home. She also interviews students after they have handed in their tests to give them an opportunity to explain their thinking to her. The students know that they have multiple opportunities to demonstrate their understanding of a concept and Tasha believes this reassures them and leads to greater success. She explained to me “that one on one contact with them [gives them] reassurance and boosts their confidence a little bit” (Tasha, Interview, April 22, 2015).

Impact on pedagogy. The PLC’s primary focus is always the students and their well-being and this focus has had an impact on how the teachers interact with students and how they deliver their lessons. During a lesson planning session on April 30, 2015 there was a conversation between four members of the PLC that highlights this.

Larry: The whole point of this for me was to create classrooms where kids would become resilient and the only way we do it is, it’s like going to the swimming pool and I’m holding a pole and then I slowly pull it away when you are ready from you. I’m not throwing you into the swimming pool.

Shirley: Just let them be on the periphery for as long as they need to be.

Larry: Periphery yeah, and then you are starting to make, you know, whatever small steps you need to feel better about it.

Wayne: We've seen plenty of cases where the students are just hanging out for a couple of weeks before they even dip their toe in, you know. And you've seen plenty of those [speaking to William].

William: Months, I'll say months...I think that's what these types of lessons are doing though. Because how we used to teach we didn't even give them an opportunity to hang around until they were ready to get on the ladder right. We just said get on the ladder (PLC meeting, April 30, 2015).

During our individual interviews I had the opportunity to ask each of the three mathematics teachers how being part of the PLC has impacted or influenced how they teach. All three expressed the power of observing each other teach and the importance of collaboration and how it opens your mind to other possibilities. William feels he has learned to give up a bit of control.

That's a hard thing to do, you now, to let it go, to let the kids go where they want to go, give them opportunities and to value their thoughts. And I've learned that through our PLC for sure... I think I was always good at making relationships with kids but more so now that I really do value what they have to say and I don't think I did that as well for a long time (William, Interview, April 22, 2015).

William continued to tell me how the PLC has influenced the way he teaches and how the lessons they have designed as a PLC are now regular lessons he teaches in his classroom. The lessons the PLC have designed revealed to him areas that the students need to work on. "I'm now implementing the strategies that I'm learning about in the PLC in my everyday teaching so that would be the biggest positive thing for me is I now teach this way, right, it's the way I teach" (William, Interview, April 22, 2015).

Wayne expressed how being part of the PLC has impacted how he teaches and why. The PLC designed lessons were focused more on student thinking than on the mathematical concept and Wayne sees this as being very important.

One of the big things is where the math has become secondary. We always, for years we've always focused too much on the curriculum. Curriculum is supposed to be a guideline rather than a...we tend to sort of take it literally. It's got a lot of good stuff

in there but at the same time it's the big ideas that we need to focus on. So we've moved away from the minutia and focus on the big ideas in the curriculum. And now we are moving away from the math to the bigger ideas in thinking and communication in life. And I think as math teachers, I think we are moving away from thinking that we are teaching the next great rocket scientist and realizing that we have citizens in front of us and we have responsibilities to them and if they happen to become rocket scientists it probably won't be because of us (Wayne, Interview, April 22, 2015).

Impact on school. The participants believe that the PLC has impacted Fields High School in various ways. Dolores believes strongly in the lesson study model and she now structures her teacher performance appraisals using a similar model. She explained to me how she feels that observing teachers then evaluating them does not offer that teacher the best opportunity for growth.

I also do my TPA with this model. We do a lesson study together the teacher and I. We'll look at that class, we'll look at those kids...we're doing it together, and that's exactly it, it's growth. The conversations we have about these things, they are much richer than sitting at the back and watching some class that they've prepared that you know nothing...It's just boring for me as the watcher. They love it. I love it (Dolores, Interview, April 27, 2015).

Other teachers outside of this PLC are expressing interest in starting a lesson study for their department. Dolores supports this and makes a point of including funding for lesson studies in the school budget. Dolores makes this form of professional development a priority for Fields High School.

The successes in this building have been phenomenal, I mean the amount of engagement by the teachers has been unpredictable, fabulous, very deeply enriching. And what it's done as well because I brought it back to the heads table, and in our budget we built in funding to create other PLCs, lesson studies. And you talk about Fullan and the lateral growth, that's exactly what we've been doing as of the second year (Dolores, Interview, April 27, 2015).

William also shared that the school as a whole is changing because of the impact that PLCs have on teachers and their teaching. He describes it as an evolution:

There was a bit of an evolution if you want to look at the school in total. People got wind of [our lesson study process] and then department heads were talking about it. Wayne and Dolores would be saying oh yeah, the 4SI lesson study we've been doing these types of things. People would be really interest[ed]. So then subject areas started requesting money to have lesson studies in their subject areas. So Dolores was finding money for that and then there were these other lesson studies going on in the school were subject based by department and then that started spreading. And then even Dolores is doing her TPA she started mini-lesson studying that. So if she was doing your teacher evaluation she would meet with you one-on-one like not just say ok what lesson are you doing. It would be like ok how can we make this, how can we get you to push yourself here a little bit? (William, interview, April 22, 2015).

Wayne feels that the collaboration aspect of the PLC affected the whole school; the collaborative nature of the process was beginning to change teachers' mindset about the school and being involved. Wayne described to me how there are "people in departments stepping up to do things, to lead groups within the school on issues like attendance, whatever, this whole collaboration thing really started to show up in everything we were doing" (Interview, April 22, 2015). Wayne suggests that the collaborative, open door-philosophy of the school has evolved over the last seven years. He credits the different PLCs and their participation in lesson studies for opening teachers up to having other people observe them teach.

I think that is a big hurdle for a lot of teachers is having other people in the classroom observing them. So I think that has been a huge change in the seven years I've been [here]. I think it was last semester, I was kind of interested in what everyone else was doing and there was this whole flood and said come drop into my class anytime (Wayne Interview April 27, 2015).

Challenges associated with the PLC. The teachers describe many of the successes they feel the PLC is evoking at Fields High School but they also shared with me some of the challenges associated with participating in the PLC. Wayne and William both have explained similar regrets about the impact their absence from their classes have on their students. William told me "that's a big struggle, move teaching forward, move instruction

forward but at the expense of the kids that are really right in front of me this semester”

(William, Interview, April 22, 2015). For Wayne the situation is similar:

I feel like I’m short changing my students...That’s hard to accept because here you are doing all this work to try to improve things and your kids are suffering... So here I’m doing this work for the good of education so to speak and yet I’m ignoring my students. So that’s interesting because all these programs, 4SI the OAME they are all about our most vulnerable kids and yet we are not in the room right. So that for me would be the toughest part of the whole business (Wayne, Interview, April 22, 2015).

Wayne and William’s absence from Fields High School also impacts the other teachers and the PLC. Tasha is unable to collaborate with Wayne as much as they used to because Wayne’s busy schedule interferes with this. “We haven’t [been able to collaborate] just because Wayne is so busy with other projects” (Tasha, Interview, April 22, 2015). William feels this strain as well:

I think we are a little bit ahead of the curve [but] we are still trying to learn and we’re still trying to get better but we are also trying to help other teachers, and other schools and other boards get better. And all that pulling, I think that’s the biggest struggle for me personally the biggest struggle for the PLC I think (William, Interview, April 22, 2015).

Summary of Findings

Using the findings from the data I collected during both the PLC meetings and individual interviews at Fields High School I feel confident in summarizing these findings to answer my two research questions. The PLC at Fields High School that I observed was a snap shot in the evolution of teachers collaborating at that school. The OAME project that allowed me access to this particular setting was another means of supporting a group of teachers that were already engaged in professional development and used different professional opportunities to support and grow their work. The collaboration that is at the heart of this PLC began through relationships developed when teachers shared a common struggle: how to better approach the teaching of the applied

mathematics courses in their school. These teachers' shared beliefs about the teaching and learning of mathematics created a bond that helped them explore and develop their pedagogy. The shared desire to improve their teaching brought them together.

The support and leadership of Dolores is a crucial factor in the creation, evolution and sustainability of this PLC. Dolores is strategic in her use of funding from initiatives such as the OAME and 4SI projects. Through these different initiatives, approved and supported by Dolores, teachers are able to receive release time during the school day to work together to examine their practice. Dolores shared that through the use of the lesson study model throughout the school for different subject areas and teacher performance appraisals she feels the lessons learned through this particular PLC have spread throughout the building and are influencing others.

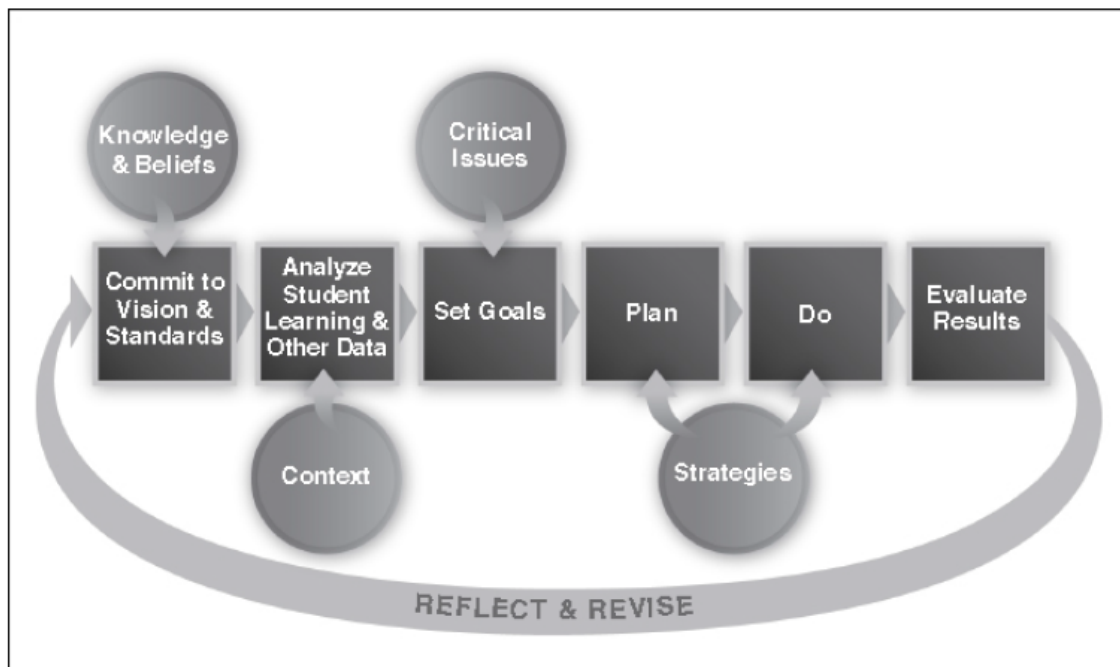
The participants shared with me this PLC has had a positive impact on the students and teachers at Fields High School and on the school culture itself. The participants that I interviewed all spoke of the positive impact that collaborating together at PLC meetings has had on their practice. Many shared with me that it has been the most powerful professional development they have experienced. The participants also feel this type of collaboration has spread beyond the PLC and is influencing others in the school. Wayne explained that other staff members are stepping up and getting involved and there seems to be more of an open-door policy than before. Of course Dolores feels that there are staff at the school that do not support the changes that have come about through the collaborative spirit but she does not concern herself with these naysayers; she chooses instead to focus on the willing members of her staff.

The participants in this study also shared with me that they believe the PLC collaboration is having a positive impact on the students. The teachers feel that several initiatives such as the split Grade 9 classrooms and the spiraling of activity-based lessons that have been developed and enhanced through the PLC are improving students' mindsets about their abilities to be successful in mathematics and student engagement has increased.

Chapter 7: Discussion of Findings

To further discuss and summarize the main findings of this study I once again draw on the conceptual framework I discussed in Chapter 3. This framework guided me throughout the study; it focused my attention on specific attributes, activities and behaviours of the group as well as guided my questions during the individual interviews. These attributes became my “look fors” throughout the data collection and analysis process. For example, when observing meetings I made note of instances when the PLC members spoke about their goals, vision and the purpose of engaging in this professional development, when they would analyze student learning, follow through on the plans they had made for teaching mathematics and when they would refer to research that supported their beliefs and knowledge of teaching mathematics.

Figure 3: Framework for Professional Development for Mathematics Teachers



As discussed previously in Chapter 3, this framework, as presented by Loucks-Horsley et al. (2010), appears to be linear. The researchers stress that it is not a step-by-

step guide but rather an ideal to strive for and for this study I use it as an outline for discussing my findings. I compare my findings to each phase of the framework.

Commit to Vision and Standards

As previously discussed, the action of committing to a vision and standards is informed by the knowledge and beliefs of the participants (Loucks-Horsley et al., 2010). Through my observation of the PLC at Fields High School I was able to gain a better understanding of the knowledge and beliefs the PLC shares and how it influenced their commitment to vision and standards. This PLC appears to share common beliefs about the teaching and learning of mathematics and has put much effort into aligning their beliefs with the current research on effective teaching of mathematics. During most meetings different PLC members demonstrated their knowledge of different academic sources that support their beliefs and inform their commitment to vision and standards, Table 11.

Wayne, William and Tasha all subscribe to a similar, activity-based approach to teaching mathematics. They chose this approach either through their own experiences as learners or after several years of witnessing a lack of engagement from their students and felt that something had to change. The teachers shared with me some of the benefits of activity-based teaching they have observed. These include: repeated opportunities for assessment, retention of curriculum, grasping mathematical concepts, multiple entry points for all students, natural opportunities for differentiated instruction, collaborative learning environment, increased engagement and fewer discipline issues. Most of these beliefs align with the Ontario mathematics curriculum and represent processes that support the effective learning of mathematics.

In addition to teaching through activities Wayne, William and Tasha have structured their delivery of these activities to reflect current research on students' retention of knowledge. These mathematics teachers believe in cycling through the curriculum numerous times throughout a course to allow students the opportunity to revisit different mathematical concepts. They refer to this process as spiraling the curriculum. This process borrows from the concept of interleaving. Essentially interleaving is a process that places breaks in between the learning of different mathematical concepts. A concept is revisited multiple times in order to increase the effort required to retrieve the information. This leads to a deeper understanding of the concept (Pyc & Rawson, 2009; Rohrer, Derrick, & Burgess 2014). It would appear that this spiraling of mathematics concepts works well in conjunction with the activity-based learning the teachers at Fields High School implement. Most of the activities they use require the implementation of multiple mathematical concepts to solve. This requires the students to recall concepts throughout the course on an as needed basis. As the students engage in different activities requiring comprehension of multiple mathematical concepts they must draw on prior knowledge of these concepts several times throughout a course. Rohrer, Derrick and Burgess (2014) describe how this "interleaving improves mathematics learning not only by improving discrimination between different kinds of problems, but also by strengthening the association between each kind of problem and its corresponding strategy" (p. 1).

All three mathematics teachers in the PLC share the belief that learning should be visible and accessible to every student in their class. As discussed previously, the work of Liljedahl has impacted the teachers' beliefs about how students work in classrooms. Two

changes that William, Wayne and Tasha implemented because of Liljedahl's research were the use of visible random groupings and vertical non-permanent surfaces.

Visible random groupings involve grouping students without the use of a strategy on the teacher's part. Liljedahl's (2014) research found that grouping students randomly helps to break down social barriers within the classroom, allows knowledge to transfer more quickly between students, students rely less on the teacher for guidance, and student engagement is increased. These benefits align with the results that the mathematics teachers at Fields High School experienced.

Students collaboratively working on vertical, non-permanent surfaces has had a similar effect in their classrooms. Students use white boards for the majority of the work they do in Wayne, William and Tasha's classes. The description the participants shared with me regarding the impact of these types of surfaces were similar to what Liljedahl describes in his research. Students persist at problems for a greater length of time, teachers witnessed higher levels of engagement and greater collaboration amongst students was observed (Liljedahl, in press).

There is a strong belief amongst the PLC members that mathematics at the Grade 9 level should be a common course for all students of all abilities. They feel the streaming of students into applied or academic has a negative affect on students' own beliefs about their abilities in mathematics and has a negative impact on their confidence and therefore their performance in mathematics. The work of such researchers as Boaler (2000) Boaler, William and Brown (2013) and Oakes (1990, 2005) support this belief.

Table 11: Knowledge and Beliefs of PLC Members

BELIEFS	KNOWLEDGE SOURCE
Activity-based learning/best practices	Dweck, Gini-Newman, Meyer, Small
Interleaving (Spiraling)	Rohrer & Taylor (2007) Rohrer, Derrick, & Burgess (2014)
Visible learning	Hattie (2012)
Visible random groupings & vertical non-permanent surfaces	Liljedahl (in press, 2014)
Split applied and academic classrooms	Boaler (2000, 2013)

The beliefs of the teachers at Fields High School align with current research in education, shown in Table 11, and these beliefs have had a direct impact on their commitment to vision and standards as outlined in the Ontario mathematics curriculum. All the lessons that I observed were designed with a focus on the mathematical processes outlined in the Ontario mathematics curriculum. These processes include: problem solving, reasoning and proving, reflecting, selecting tools and computational strategies, connecting, representing, and communicating. The teachers' commitment to aligning their lessons with the Ontario curriculum represents a commitment to the vision and standards set forth by the Ministry of Education here in Ontario and that borrows from the vision and standards that were set forth by the NCTM (1989, 2000, 2014).

Individuals' beliefs appear to be inline with other members of the PLC. Each member obviously has their own particular beliefs and their experiences as learners and teachers have shaped these. It was evident through both the PLC meetings and individual interviews that teachers feel confident in their own beliefs and feel comfortable approaching teaching in their own ways. There were several occasions where teachers

disagreed about different pedagogical approaches, William shared that he feels these differences make the PLC better. They create discussions that strengthen the PLC and challenge the members to discuss and reflect on individuals' points of view. Tasha shared with me that she doesn't always agree with the approach that the PLC takes when designing a lesson and that her focus is not always in line with that of the PLC. This does not deter her from participating in the PLC as her observations during others' lessons and the response from students does affect how she plans and delivers her own lessons.

Committing to a vision and standard in a sense happened before I began to gather data and I have doubts that it was even a formal discussion that occurred. Possibly this group of individuals sought each other out because of their commitment to a certain vision. The partnerships amongst Wayne, William and Tasha were formed based on their knowledge and beliefs about teaching and learning mathematics. This partnership led to these teachers engaging in informal professional development that focused on a lesson study style collaboration with a goal of improving the teaching and learning of applied mathematics. This informal collaboration led to Dolores inviting them to participate in the 4SI group and the group seeking out other professional development opportunities such as the OAME collaborative inquiry project, attending and presenting at educational conferences, and engaging in book studies as a staff.

As discussed previously, beliefs are shaped by teachers' own experiences learning and teaching mathematics. This was evident through data collected from the three mathematics teachers in this study. Wayne and Tasha struggled when learning mathematics and this influenced their beliefs about teaching and learning. They are committed to teaching in a style that is in contrast to what they experienced as students.

William excelled in mathematics as a student but realized that not all students learn the same way. His struggles teaching applied Mathematics caused a shift in his beliefs about how students learn and resulted in him seeking out alternative methods to reach the students he feels he was letting down. It is this shared belief about how students learn that allows these three teachers to commit to a specific vision and standard of teaching. This vision is informed by the teachers' beliefs and knowledge of teaching mathematics.

It would appear that through their participation in such initiatives as 4SI and the OAME project these teachers are committed to improving their practice dedicated to a certain demographic of the student population. Both of these initiatives are focused on students in applied Mathematics and the activities of the PLC, namely lesson study, are focused on improving not only student achievement but to increase their knowledge for teaching applied Mathematics.

Analyze Student Learning and Other Data

As previously mentioned, this phase of the professional development process allows participants to become familiar with the current state of a situation in a school environment. Loucks-Horsley and colleagues (2010) identified four context factors to consider during this phase:

- Student and teacher learning needs
- Leadership and local policies
- Available resources
- Families and communities.

Loucks-Horsley and colleagues (2010) also identified four sources of data that are

recommended when analyzing student learning and other data:

- Demographic data about students and teachers
- Multiple measures of students' achievement of standards
- Data about classroom practice and students' opportunity to learn
- Data about professional development, the school culture, and leadership

(Loucks-Horsley et al., 2014, p. 21).

I discuss these context factors and sources of data in terms of the situation at Fields High School and how the analysis of the data impacted the professional development of the PLC members.

Student and teacher learning needs. The learning needs of the students targeted by this PLC are specific to a subset of the Grade 9 population at Fields High School. The teachers identified a need for an increase in student engagement and a solution to some students' lack of consistent attendance in class. The introduction and continuation of activity-based learning was planned to increase student engagement. The reorganization of the curriculum was planned to allow students multiple opportunities to learn certain mathematical concepts. The poor attendance of some students resulted in them missing entire units of the curriculum. By engaging in the interleaving process students who were absent during the introduction of a certain concept would have several more opportunities to learn this concept.

The teachers identified their learning requirements as the need for a document library that would outline effective strategies and resources that assisted them as they implemented new strategies, activities and alternative approaches to assessment. They described how they required opportunities to discuss lesson planning and observing each

other teach in order to assist in the building of this resources library for teachers.

Leadership and local policies. In the context of Fields High School I have already discussed the high level of supportive leadership within the Fields High School building. Dolores also described to me the high level of support she feels they receive from the School Board. The involvement of the Ministry of Education and the OAME demonstrates support at all levels of the education system for this PLC and the work that they engage in.

Available resources. The importance of providing time and financial support to collaborate, plan lessons together and to observe one another teach has been discussed previously. The resources available to Fields High School through the OAME project include: release time to meet for a full day once a month, financial support to arrange substitute teachers to teach their classes during that time as well as financial support to allow for travel to provincial conferences and all team meeting and planning events for the OAME project. All of these resources provide teachers with time and opportunities to engage in professional development initiatives.

Families and communities. Different members of the PLC discussed the families of their students occasionally but it was difficult for me to gauge the level of support they receive. Wayne discussed both negative and positive interactions with parents of students and Larry discussed positive and negative experiences with the greater school community. Larry was often frustrated by negative feedback he would receive from other members of Fields High School staff. Not all teachers at this school support the direction that the PLC, and others in the school, were taking teaching and learning.

Through my own connections to the mathematics education community in the

province I am aware that other teachers speak of the work that the teachers at Fields High School are doing. I have been witness to occasions where William and Wayne have reached out to their feeder schools to offer collaborative partnership. As I discussed previously several teachers at Fields High School are very active in the online mathematics education community such as the #MTBoS (Math Twitter Blogosphere) and through blogs. Both Wayne and William are members in several lesson study groups that extend beyond their school community.

Demographic data. The members of the PLC at Fields High School are very familiar with the population they teach. I did not observe the analysis of specific demographic data at any PLC meetings I attended but I did observe thorough discussions of each student in particular classes and their individual needs. Teachers discussed such areas as challenges students face at home, challenges of English language learners and the individual education plans (IEPs) of students. IEPs are an important source of data for the Fields High School PLC. At one meeting William explained to me that 50% of his students have IEPs and this factors greatly into how he designs strategies for teaching mathematics to his students. Rachel, being the Student Success Teacher and Tasha, a Special Education Teacher, plays an important role in this aspect of the PLC. They are familiar with students' special needs through access to their individual education plans and guidance counselors at the students' previous schools.

The intent of both the OAME collaborative inquiry project and the 4SI initiative is to improve the success of students in Grade 9 Applied. As described previously the demographics of the Grade 9 Applied courses differ greatly from the Grade 9 Academic students. As this is the third year that Fields High School has participated in the 4SI

initiative I can only assume that examination of the demographics of these students and their needs were part of the initial process of the PLC. However I do not know this for a fact.

Student achievement data. The Province wide, standards-based assessment carried out by EQAO did not factor greatly into discussions at any PLC meeting that I attended. During the February 12, 2015 PLC meeting Dolores discussed how she has spent a great amount of time arranging for the compilation of student data and tracking student achievement during their time at Fields High School. She makes sure that teachers are provided with any data from previous schools that relate to the students needs and areas of struggle. It was her intention to compile records for all of the students targeted through both the 4SI and OAME projects that would detail their achievement through all of the EQAO test years, Grade 3, 6, and 9 as well as any other board wide assessments they participated in.

Classroom practice and opportunities to learn. At Fields High School the daily work carried out by students in the classroom informs many of the actions taken by the PLC members. Through the lesson study model the PLC employs they are continuously analyzing classroom practice, students' opportunities to learn, and student thinking. When teachers co-create lessons together and observe one another teaching they are able to critique teaching practices in a constructive way that focuses on the practice rather than the teacher. Several teaching practices that have been analyzed by the PLC and that they have found effective are the vertical non-permanent surfaces and the use of activity-based lessons. As previously discussed the teachers believe the use of students collaborating on vertical non-permanent surfaces help to highlight student learning in a way that allows

the teachers to more easily address misconceptions and gain a better understanding of how students are thinking about a problem. Teachers shared with me that the use of these vertical surfaces has changed the way they teach mathematics and the way that students are learning in their classrooms. Students' learning is impacted when they can observe others thinking. Students learn not only through the direction of the teacher but from each other as well.

The use of activities has also increased the engagement in the mathematics classrooms at Fields High School. Through observing these activities in each other's classrooms the PLC members have determined that activity-based teaching is the best approach for the students they are targeting in the applied level mathematics courses.

Professional development, school culture and leadership. At Fields High School the PLC is not at the beginning phases of designing their professional development but through the strong leadership of Dolores it is always evolving. Dolores is familiar with the school culture and how the staff at Fields High School interacts with one another. She informed me that she is always considering the next steps for the PLC, who might be a complementary addition to this particular PLC and how lessons learned through this initiative could benefit other PLCs in the school.

Set Goals

As previously discussed, Loucks-Horsley and colleagues (2010) break down the *set goals* phase into four components: goals for student learning, goals for teacher learning, goals for teaching practice and goals for the organization. They also discuss the importance of addressing critical issues that may exist when setting goals for a school. These critical issues include: building capacity for sustainability, making time for

professional development, developing leadership, ensuring equity, building a professional learning culture, garnering public support and scaling up. I first discuss how the PLC at Fields High school addresses these critical issues and then discuss how they sets goals for their professional development.

Building capacity for sustainability. Although this PLC at Fields High School represents a small group of the staff it is evident that sustainability is vital to Dolores, she stressed this to me during her individual interview. The success of this particular PLC has spread and other members of her staff are approaching her for support in starting other PLCs for different subject areas and grade levels. Several times throughout her individual interview she described how important sustainability is to her and how she is “training” the other administrators and department heads on how to support collaborative professional development at the school. She understands that as a Principal she will not always be at Fields High School.

I’ve had very explicit conversations about sustainability with my heads, because I’m not going to be here forever and they are not going to be here forever. Every teacher’s nightmare is that the Principal that’s doing things that they like will disappear and next will come in, you know? It will be what’s his name, the Hun, coming in and wrecking havoc and slashing and burning all that went before (Dolores, Interview, April 27, 2015).

Making time for professional development. The PLC at Fields High School drives their professional development by seeking out opportunities to receive funding to support their collaborative work. Their involvement in both the 4SI and the OAME project are evidence of this. Wayne explained that although every time a teacher agrees to participate in a new initiative it means adding to their workload he sees this type of professional learning as imperative to helping both teachers and students learn and therefore worth the effort it requires. The benefit of organized professional development is the support it

offers schools and teachers in terms of both time and financial. Without the financial support to acquire release time in order to meet it would be difficult to engage in the level of professional development that the PLC at Fields High School does. Making time for professional development does present its own challenges, as discussed in Chapter 6.

Developing leadership. The leadership of the Principal, Dolores, combined with the established leadership capacity amongst the members of this PLC, contributes to the level of engagement that I witnessed. The members of the PLC explained that their goal is to bring in new, interested participants, such as Larry, Shirley and Anna during the 2014-2015 school year, in order to develop leadership within the school. These new PLC members are able to bring their new learning to their departments, for example both the science and geography departments, and continue the work in a similar style.

Ensuring equity. Both the 4SI and the OAME project are geared towards a specific student demographic, those enrolled in Grade 9 Applied subjects. Traditionally students in the Grade 9 Applied Mathematics level have not been as successful as those students at the academic level. The most recent five-year data from the EQAO reveals that 47% of all students in applied level mathematics across the Province achieved at or above the Provincial standard compared to 85% of academic students (EQAO, 2015). The results at Fields High School are very much in line with these results. The implementation of a split Grade 9 classroom is one way that the Grade 9 mathematics teachers at Fields High School are addressing the critical issue of ensuring equity. Wayne and Tasha explained that they believe students feel they are being labeled as the “dummy” kids when they are put into a Grade 9 Applied classroom. By removing this perceived label they believe students’ attitudes about their own abilities have improved. In order to test this hypothesis

the PLC requested my help in creating a survey, Appendix J, which would provide an overview of their students' attitudes and beliefs about mathematics. They had the students complete the survey at the beginning of the second semester of the 2014-2015 school year and at the end of the semester. The teachers hoped to see a shift in the students' beliefs about mathematics and their abilities as learners of mathematics. Overall the teachers described to me that they observed a noticeable shift in students' beliefs about what mathematics is and their abilities to do mathematics as well as students' comfort level in the classroom.

Building a professional learning culture. The lesson study model that the PLC uses helps to de-privatize teaching and this helps to build a professional learning culture at Fields High School (Kruse, Louis, & Bryk, 1995; Loucks-Horsey et al., 2010). When teachers design lessons together I noticed they had a tendency to refer to lessons as “our” lesson rather than belonging to an individual teacher. Observing each other teach may also have contributed to the more open door policy that Wayne described. Wayne feels that the collaborative nature of the work the PLC engages in has increased teachers' engagement in the school community. As previously discussed Wayne believes that more teachers are willing to step up and volunteer for initiatives at the school and to invite one another into their classroom.

Garnering public support. The teachers at Fields High School invite parents and guardians to a “follow my timetable” event at the beginning of each semester. Those who attend can visit student's classrooms, hear teachers speak about their teaching methods and learner expectations, and ask any questions they have about teachers' program of study in each class. Wayne explained that some in attendance come with concerns about

different things they have heard from other members of the parent community. Their concerns include the method of spiraling the curriculum or the activity-based approach that the teachers use in mathematics. This event allows the teachers to explain their reasons for teaching in this way and Dolores is on hand to offer support to the teachers in answering any questions they receive. Wayne explained that this is an opportunity to help parents understand their methods and possibly gain their support.

Scaling up. As mentioned previously the participants in this PLC at Fields High School change slightly each year. As Loucks-Horsley and colleagues (2010) explained the early adopters are important to the success of a professional development initiative but helping the resisters understand the benefits is just as important. In order to shift the culture of a school all members of the staff need to be on board. Dolores does not worry about the resisters, she feels that the schools approach to growing the PLC model allows those that are more hesitant to take their time, to observe and engage when they feel more comfortable. As she told me, “you let the resisters resist for now and you let the critical mass build and eventually, you know, resistance is futile” (Interview, April 22, 2015).

Goals for student learning. The members of the PLC at Fields High School identified the specific goals for student learning as part of their participation in the OAME project. Specifically they would like to build student confidence and engagement, increase the level of responsibility students have in their own learning and increase the level of success for all of their students in Grade 9 Applied. These goals targeting the students in applied level classes at Fields High School are in line with current research in professional development (Schmoker, 2002). Focusing on the students that are having

less success could help to decrease the gap that exists between the applied and academic mathematic students.

Goals for teacher learning. Through my observations at PLC meetings it is apparent that the mathematics teachers at Fields High School have a high level of mathematical content knowledge, curriculum knowledge and mathematical knowledge for teaching. They are well versed in the curriculum and the differences that exist between the expectations for applied and academic mathematics. Perhaps this is why PLC meetings did not dedicate much time to discussing specific content knowledge. Their primary focus, in terms of teacher learning, was on their pedagogical knowledge and increasing their understanding of how to make content accessible to their students. They planned to create a resource for teachers that would compile rich tasks, teacher moves, and assessment strategies that would help them accomplish their goals for student learning. During my time with the PLC, goals for teacher learning were not explicitly discussed. However, their commitment to the lesson study model to help create appropriate activities suggests they feel this is the most effective way of increasing their own learning.

Goals for teaching practice. As the members of the PLC at Fields High School focused on designing lessons that would engage Grade 9 Applied students they made a point of discussing and focusing on teacher moves they found effective in the classroom. The teachers spent a great deal of time discussing past experiences that impacted their students' behaviours in class. For example the teachers spoke about how best to praise students and referenced the work of Dweck and other authors that have written about motivating students. The PLC members shared stories related to the negative impact that

praising students' intelligence has had on the students' engagement in class compared to praising the student efforts, which had a positive impact on students' engagement.

Dolores played a key role in establishing goals for teacher practice in the PLC. As discussed previously her guidance during the February 2015 meeting set the tone for the remainder of the school year. During this meeting the PLC established the goal of focusing on students' metacognition and many conversations in subsequent meetings revolved around how best to integrate opportunities for metacognition into lessons. Previous goals for teacher practice focused on developing pedagogy that would create accountable talk amongst the students and establishing practices in the classroom that helped students to understand and ask good questions.

Goals for the organization. The overall goals for Fields High School are very much in line with the conceptual framework. Loucks-Horsey and colleagues (2010) suggest that goals for the organization can include “the development of leadership or the strengthening of the professional learning community... [and to] establish a core of teacher leaders who will support other teachers' growth”. This goal was evident to me during my individual interview with Dolores as well as PLC meetings. Dolores explained at the February 2015 meeting that she considers this group of teachers to be an example of effective professional development for the rest of the school. The lesson study model that this PLC employs has spilled over and impacted other groups in the school. Different teachers are approaching Dolores and asking for funding and support to engage in their own lesson study. Dolores uses the lesson study model to engage with individual teachers when she performs her mandated evaluation of the teachers at Fields High School. Again,

this goal was not explicitly discussed at the meetings that I attended but it was evident that the results of this PLC have had a positive impact on the school as a whole.

Plan and Do

My observation of the PLC at Fields High School began after the PLC had already experienced the initial phases of planning and doing. The teachers did describe to me some challenges they faced when implementing certain strategies such as student collaboration however I did not observe this. When I began my data collection for this study the PLC had already tested and established a particular method of professional development referred to as lesson study. Essentially every PLC meeting at Fields High School alternated between a *planning* meeting and a *doing* meeting. As I have described previously, at a planning meeting, a teacher chooses a goal for a lesson they would like to teach and the following meeting the teacher delivers the lesson that the PLC planned together. This model has been in place at Fields High School for several years and I cannot speak to how this specific model came to be adopted. I have learned from the individual interviews and the PLC meetings that this model of professional development has evolved over the last few years. The PLC members themselves and external factors such as their participation in different initiatives have influenced the evolution of the PLC.

Evaluate Results

Similar to the different levels of goals there are different levels of results for the PLC to evaluate. I was present when the PLC evaluated the results of the work the PLC had done up to the mid point of the 2014-2015 school year. This meeting differed from the meetings when the PLC evaluated the results of a lesson study for one teacher. During the

February 2015 meeting Dolores led the meeting and focused the PLCs discussions on evaluating their success in implementing accountable talk and asking good questions. Dolores wanted to know how the teachers felt about their success at these previous goals and whether or not the PLC wanted to move forward and consider metacognition as a new goal for the group. The PLC spent a great deal of time considering if they had been successful at the previous goal and how to go about implementing a focus on metacognition.

At other meetings the PLC focused on discussing the outcomes of lessons that they planned together. Often the team would reflect on these lessons and consider what worked and what didn't and use this information to guide the next lesson, this process occurs within the planning and doing phase continually throughout the school year as well as on a larger scale once or twice throughout the school year.

Summary of Discussion

The conceptual framework of Loucks-Horsley et al. (2010) defines different actions and inputs present in effective professional development for mathematics teachers. When discussing the data I collected and analyzed it is evident that the PLC at Fields High school operates using similar actions and inputs to the conceptual framework. Through my observation I feel it is clear that the PLC has committed to the vision and standards defined by both the Ontario mathematics curriculum and influential documents published by the NCTM. This commitment to vision and standards is influenced by the PLC members' knowledge and beliefs and supported by their connection to current research on best practices for mathematics teaching and learning.

An important aspect to the PLC at Fields High School is their dedication to the subset of students they are teaching, the applied level mathematics students. Wayne feels these students are the schools most vulnerable of the student population at Fields High School. Through careful and thorough analysis of these students' learning and relevant data they have a solid grasp on the context in which these students exist. By learning as much as they can about how these students learn and factors that affect these students on a daily basis the teachers are able to set realistic goals for their students. The goals that are set take into account the critical issues affecting these students, issues such as learning difficulties and unique situations such as those that English language learners face.

The experience of the PLC at Fields High School is rich and through several years of collaborating together the PLC members have settled on strategies for professional development that they believe are most effective. The process of lesson study and planning lessons collaboratively has had a positive impact on the teachers, the Principal and the school as a whole. Several members of the PLC have become leaders in the mathematics education community outside of the school. Wayne, William and Tasha have presented their approach to teaching and learning mathematics at different conferences in North America. Different PLC members have been invited by different school boards to share their knowledge with mathematics teachers and both Wayne and William have worked with teacher candidates at the local university.

The PLC at Fields High School demonstrates a commitment to ongoing evaluation, reflection and revision of their professional development. The PLC will enter it's fourth year during the 2015-2016 school year and it will continue to evolve as it attempts to meet the needs of both the teachers and students at Fields High School.

Chapter 8: Concluding Comments

The last two decades have witnessed many debates and discussions about how best to teach mathematics (Schoenfeld, 2004; Wright, 2012). Instead of weighing in on this debate I instead focus on how teachers, if they choose to, can begin to shift their practice to align with the current vision of mathematics teaching and learning as outlined by the accepted standards. These standards, as I discussed throughout this study, are shaped in part by professional associations in the mathematics education community such as the NCTM in the United States and policy makers such as Ministries of Education in Canada. These research based standards all suggest that mathematics is a discipline that should be accessible to all students, regardless of race, gender or socio-economic standing (Manitoba Education, 2013; NCTM, 1989, 2000, 2014; OME, 2005).

This shift in thinking, towards mathematics for all, creates the need for discussion on how best to teach mathematics to all students. Historically mathematics was a discipline intended for only those individuals destined for university (Schoenfeld, 2004). In these traditional classes, for the university bound student, lessons followed a traditional script of first reviewing or introducing a new procedure followed by step-by-step instructions on how to perform the procedure and lastly by assigning students problems on which to practice the procedure (Stigler and Hiebert, 1997). Askew and colleagues (1997) refer to this as a transmission method of teaching and their research suggests that it is not the most effective method of teaching mathematics. Many teachers today were once students in these traditional classrooms and have little experience with mathematics being taught in any other way and also consequently have only a procedural understanding of mathematics (Darling-Hammond & Ball, 1998). Again, the current standards for

mathematics education clearly state that the subject should be accessible for *all* students. Not all students learn using the same method or in the same timeframe; therefore various approaches to teaching mathematics should be available in order to reach all students (OME, 2005). It stands to reason that teachers who are unfamiliar with alternative approaches to teaching mathematics might benefit from the opportunity to explore these different approaches (Cooney, 2001).

The focus of this study has been on the experiences of the members of a PLC as they engage in professional development designed to help them reflect on and respond to areas of their practice they would like to shift or enhance. This PLC was focused on exploring the needs of a particular subset of mathematics students at their school, the students in Grade 9 Applied mathematics. The data has suggested that these students are at the greatest risk of not achieving success in mathematics. Helping students be successful in Grade 9 Applied Mathematics was the motivation behind the OAME collaborative inquiry project as well as the goal of the PLC that I studied at Fields High School.

Contributions of this Study

I have discussed the findings of this study in detail in both Chapter 6 and Chapter 7. In Chapter 6 I used the data to address my two research questions. In Chapter 7 I analyzed the data using the conceptual framework developed by Loucks-Horsley and colleagues (2010). Here I summarize these findings in terms of the contributions of this study.

This study contributes to research in the field of mathematics professional development in several ways. First it provides insight into the experiences, successes and challenges of several high school mathematics teachers and a Principal as they consider

best practices for teaching Grade 9 Applied Mathematics. It also offers insight into how a professional learning community is formed and sustained and how it evolves throughout the process of teachers examining their practice. This study describes what happens when a professional community of learners comes together to discuss, dissect and reflect on their own practice with the intention of broadening their understanding of teaching mathematics. The PLC at Fields High School demonstrates effective collaboration amongst teachers and how the role of strong leadership creates opportunities that positively affect teachers' practice.

In Chapter 4 I described the lack of description in the research literature about what occurs when PLCs meet and how these communities support teacher learning (Crespo, 2005). Furthermore descriptions of how teachers' practice shifts when they take part in intentional collaboration are missing from the literature. As previously discussed researchers over the past two decades have concerned themselves with the definition of school communities and the overuse of the term community to label any gathering of teachers as a PLC (DuFour, 2004; Stoll, 2006). Others mention that more empirically based research describing these communities is needed (Westheimer, 1998; Crespo, 2005; Vescio, Adams and Ross, 2008). Grossman, Wineburg, and Woolworth (2001) stress that educational research is lacking in understanding of professional learning communities, particularly that

Studies of community typically examine already-formed groups. We have little sense of how teachers forge the bonds of community, struggle to maintain them, work through the inevitable conflicts of social relationships, and form the structures needed to sustain relationships over time. Without understanding such processes, we have little to guide us as we try to create community...in settings where it doesn't exist already (p. 4).

This study directly addresses this concern. It presents a detailed description of how the PLC was formed and how the teachers involved forged the bonds that created this PLC. The study also describes how the PLC is sustained and how it evolves over time. It also offers a description of how the teachers have shifted their practice over time as well as the issues they are currently concerned with. This study contributes to the body of research related to PLCs.

While my purpose in conducting this research was not to evaluate this PLC, my observations and conversations with the PLC members, and those in the larger mathematical community, lead me to suspect that this PLC is an exemplary model. Using the conceptual framework as a lens, my data analysis makes it clear that this PLC fits the model of effective professional development for mathematics teachers. However, the PLC at Fields High School did not intentionally follow the framework created by Loucks-Horsley and colleagues (2010). Rather their methods of engaging in professional development evolved over time as they addressed different areas of their practice they felt required attention.

Exemplary Model of a PLC

In order to go a bit further into components that made this PLC effective or to be able to go so far as to say it is exemplary I would like to draw on another framework to further explore characteristics that support my claim of the effectiveness of the PLC. The framework of Kruse, Louis, and Bryk's (1995), and later adapted by Roberts and Pruitt (2009). The framework has two parts, the first describes the key elements of an effective PLC and the second describes the necessary social conditions and human/social resources necessary for an effective PLC.

In their book *Professionalism and Community: Perspectives on Reforming Urban Schools* Kruse, Louis, and Bryk (1995) draw on years of research to outline the elements necessary to form a PLC and they are as follows:

1. Shared values and norms
2. De-privatization of practice
3. Collective focus on student learning
4. Reflective dialogue
5. Collaboration

I discuss each of these elements in terms of my observations at Fields High School and offer them as evidence that this PLC contributes to the research literature as an exemplary model.

Shared values and norms. This element refers to “the idea that the members of the professional community have reached agreement about the mission of their school and the values and norms that are to shape their behaviors as professionals” (Roberts & Pruitt, 2009, p. 8). At Fields High School the driving force of their PLC is their shared values and norms for the students they teach. In particular they have agreed that traditional methods for teaching mathematics are not effective for students, particularly those in Applied Mathematics classrooms. Wayne, William, and Tasha’s norms for teaching mathematics include lessons that are activity-based, collaborative, visible, and provide opportunities for students to revisit concepts multiple times throughout a course. The PLC members turned to activity-based lessons after many years of frustration with their students’ lack of engagement.

A shared value amongst the PLC members is the vision that Grade 9 mathematics should be taught as a common course for all students, insuring equity for all students. Wayne described that through removing the label of Applied or Academic from the class the students feel there is no longer a “dummy” class at the school and that all Grade 9 students are engaged in the same mathematics. Dolores herself mentions during a PLC meeting that the students that have come out of the split Grade 9 classes have a different approach to learning mathematics, “they seem to approach learning much more openly and with less angst” (Dolores, PLC meeting Feb 12, 2015).

De-privatization of practice. Kruse, Louis, and Bryk (1994) explain the de-privatization of practice as follows: “Teachers share, observe, and discuss each other’s teaching methods and philosophies...By sharing practice ‘in public’ teachers learn new ways to talk about what they do, and the discussions kindle new relationships between the participants” (p. 2). At Fields High School the PLC members de-privatize their practice by engaging in a lesson study model of professional development. Co-designing, observing and critiquing lessons as a community of professionals ensures that teaching is de-privatized and creates opportunities to discuss teaching methods and philosophies amongst the PLC members. The PLC members refer to their co-designed lessons as “our lessons”, signaling relationships are forming between the members.

The lesson study model has spread throughout the school and Wayne describes how teachers are free to visit one another’s classrooms: “it was like drop in you know, who knows what you’ll see, but drop in. Not that we have a lot of time for it but that kind of open door policy has changed a great deal” (Wayne, Interview, April 22, 2015).

Collective focus on student learning. Roberts and Pruitt (2009) suggest “the purpose of all actions in a professional community should be the growth and development of all the students. This element is characterized by ongoing conversations and decision making about curriculum, teaching, and learning that concentrate on student outcomes” (p. 7). This was evident at the Fields High School, the first step of every PLC lesson planning meeting was spent describing the students and their specific individual learning needs. The inclusion of the Student Success Teacher, Rachel, ensured that the PLC was focused on the specific learning needs of their students:

This isn't like the old days. We are not turning over the yellow page “we are on chapter 23” it's our teachers responding to that class and where they are and what their needs are and what their interests are so that teacher isn't going to be able to predict for you where they are going to be on a given day (Rachel, PLC meeting Feb 12, 2015).

Again several elements of the PLC at Fields High School come into play when discussing how they collectively focus on student learning. The decision to remove the labels of *Applied* and *Academic* from some Grade 9 classrooms was done so in order to improve students' mindset and outcome in the crucial first year of high school. The activity-based lessons and use of vertical surfaces were incorporated because the teachers decided these had a positive impact on student learning. The decision to revisit curriculum expectations multiple times throughout the year was also a direct result of concentrating on student learning and they described it having a positive impact on students in their classrooms.

Reflective dialogue. This element of a PLC “is described as those conversations that focus on teaching behaviours and learning outcomes to encourage teachers to discuss their teaching practices and collaborate on how they can be improved” (Roberts and

Pruitt, 2009, p. 7). The reflective dialogue that I observed at Fields High School occurred often during lesson study meetings, both in planning and debriefing the lessons the team co-created. As the PLC designed lessons together they discussed, in great detail, pedagogy that they felt would best serve the needs of their students. Occasionally they would also discuss teacher practices that had not been successful for them in the past. Through this iterative process of designing, teaching and critiquing lessons together the teachers engage in reflective dialogue that focuses on the teacher moves they designed as a team, to reflect on what worked and what didn't, and to discuss ways to improve the lesson.

One of the strengths of the PLC at Fields High School is their reflective dialogue and the way that they apply what they learned through the lesson study process to their own pedagogy. During a lesson debrief William shared with the PLC something that he had learned through the lesson study process:

My big take away is doing this more often. Getting the students to write down what their strategy is before you give them numbers, like how would you solve this problem and getting them to get better at doing that. Because they really can't articulate their strategy, they really struggle with that and then when they get into doing that, executing their strategy, they can't explain what they are doing, they can't articulate (William, PLC meeting April 22, 2015).

A second example is from Rachel and her contribution to the debriefing process after a lesson study observation:

That's one of my notes too is on communication...If that is actually something we should specifically design a lesson around to point out the importance of it somehow like maybe trip them up on some sort of question or... create that question in their own mind, like what is [that] and how come I don't understand it? Just to kind of force that a little bit. I think that would be neat to do (Rachel, PLC meeting May 29, 2015).

Collaboration. The last element of a PLC, as defined by Kruse, Louis, and Bryk (1994) is collaboration. They describe collaboration as follows:

A strong professional community encourages teachers to work together, not only to develop shared understandings of students, curriculum, and instructional policy, but also to produce materials and activities that improve instruction, curriculum and assessment for students, and to produce new and different approaches to staff development for the teachers themselves (p. 4).

The members of the PLC at Fields High School are supported and encouraged to work together to share their understanding of the students and the curriculum in Grade 9 Applied mathematics as well as to discuss effective pedagogy. They continually work together to design activities that they believe improve the teaching and learning of Grade 9 Applied mathematics. Their lesson study meetings are self-directed and self-designed and are only possible through collaboration. These meetings lead to teachers challenging themselves and each other in terms of creating new and different approaches to teaching their students.

In summary, the PLC at Fields High School is an exemplary model of collaboration. Their use of the lesson study model encourages the de-privatization of their practice, focuses the meetings on student learning and encourages reflective dialogue. Without the shared values and norms the PLC would not be as effective as they are.

Structural conditions and human/social resources. In addition to the elements of a PLC Louise, Kruse, and Bryk (1995), and later Roberts and Pruitt (2009), describe the structural conditions and human/social resources necessary for an effective PLC. Louise, Kruse, and Bryk (1994) found in their research that although both the structural conditions and the human/social resources are important it is the human/social resources that are essential. “Structural conditions...are important, to be sure. But if a school lacks

the social and human resources to make use of those structural conditions, it's unlikely that a strong professional community can develop" (p. 6). I compare these conditions and resources to the situation at Fields High School and present the checklist in Table 12 as a summary and claim that all of these conditions were present at Fields High School. As noted, the human/social resources are essential to the creation and maintenance of an effective PLC and these are not only present at Fields High School but they are one of the key factors to its success.

Table 12: Structural Conditions & Human/Social Resources Necessary for a PLC (adapted from Louise, Kruse, and Bryk, 1995 & Roberts and Pruitt, 2009)

Structural Conditions	Observed at Fields High School?
Time for teachers to meet and talk about their practice.	✓
Teachers being physically situated close together to ensure ongoing conversations and the opportunity to observe each others practice.	✓
Teacher empowerment and school autonomy.	✓
Effective communication across the entire school structure and regularly scheduled opportunities to discuss teaching, learning and professional learning.	✓
Opportunities to team-teach in order for teachers to share their practice with one another.	✓
Human/Social Resources	
Ongoing support for teachers willing and eager to engage in new practices and that express a desire to improve.	✓
Trust and respect for all members of the school community.	✓
Social interactions beyond pedagogical interactions.	✓
Support from those in leadership positions.	✓
Opportunities to seek out innovative practices, acquire knowledge and work on expanding their skill set	✓

By discussing the PLC at Fields High School using the five elements of a PLC as defined by Louise, Kruse and Bryk (1995) as well as the essential structural conditions and human/social resources I feel I have evidence for my claim of this PLC being an exemplary model. Its description and examination will help to fill the gap in the literature identified by Crespo (2005).

Implications of This Study

There are several conclusions that can be drawn from this study particularly related to teacher learning, professional development and research. I discuss each of these implications and how this study may influence each.

Implications for teachers. Two implications from this study for teachers are the important role that collaboration plays in shifting or enhancing teacher learning and the importance of a Principal who supports teachers as they attempt to shift or enhance their practice.

This study offers a snapshot of effective teacher learning that could benefit both pre-service and in-service teachers. The collaborative nature of the community provides a model of how teachers can examine their own practice and at the same time design learning opportunities for their students as a community. William describes how he is a better teacher because of the collaboration he has sought out and engaged in:

I think we are better together, if there is a motto and like I would even extend this to my online professional learning community that I have, I'm way better with them...I can ask a question online and get answers" (William, Interview, April 22, 2015).

Dolores echoes this sentiment "that's the force of the PLC, they learn from each other better than any other way. I mean all the research shows that" (Dolores, Interview, April 27, 2015).

The participants all described how impactful the support and leadership of the Principal has been on their engagement with professional development at Fields High School. “It was our Principal recognizing the power of lesson study and having the 4SI. I mean a lot of 4SI groups haven’t gone that way...with lesson study, and that’s important in this building, that’s how WE change” (Wayne, Interview, April 22, 2015). Knowing that they are supported has freed the teachers to take risks involved in shifting their practice. Dolores sees this as ironic; she explains why she supports the teachers like she does:

It takes a lot of courage to change your practice, you’ve got 30 kids in front of you and you are hoping they will stay with you and not, because if you think you are controlling students you are out of your mind, right, they could pitch you out the window...so it takes courage to suddenly throw out the old and start in with something new but I truly applaud their ability to do that but it’s a lot easier when you are doing it all together and when I’m at the table they go well what happens if this doesn’t work? And I say well we all learn, what’s to lose? Are you kidding yourself into thinking that every lesson you ever taught was a success? That every kid was listening? Can you tell me, look me in the eye that every kid in your class is really on task...and being there with them is huge, I mean the irony is that I’ve never had a teacher come to me and ask permission not to get better (Dolores, Interview, April 27, 2015).

Implications for designers of professional development. Several implications from this study emerged for designers of professional development. These include the importance of designing a prominent role for the Principal, creating opportunities for teachers to meet regularly and for long periods of time, and connections with researchers at higher educational institutions.

I have discussed the impact that Dolores has had on teacher practice at Fields High School; this impact extends into the implications for professional development. When designing professional development for high school mathematics teachers it is crucial to have the support, leadership and presence of the Principal. As Wayne explained, knowing

that you have the support of the Principal and that you are not going to get ‘burned’ encourages teachers to fully commit to a professional development initiative. In addition to the presence of the Principal the OAME project expected school teams to meet for full days, once a month. This regular, extended time period for meetings ensured that teachers would have the necessary time to meet and discuss during the school day, as opposed to on teachers’ own time.

Teachers having access to research, research tools and the assistance of a RA had a positive impact on the PLC. A RA documented the activities of the meetings and offered assistance support to the PLC. This support appears to contribute to the effectiveness of the PLC. The teachers informed me that they don’t have time to compile tools such as the student survey and they have expressed their appreciation for the time to analyze the results that were compiled from the survey. This support enhanced the time the teachers were provided to meet.

Implications for researchers. The main implication that emerged from this study for researchers relates to the amount of time necessary to study PLCs. In order to offer a description of a PLC a researcher may be able to describe a PLC at any moment in time. In order to gain insight into how a PLC is formed, how it is sustained, and how it evolves a researcher would need to spend an extended period of time with a PLC and with individual members of the PLC. It is evident that while PLCs can share similar traits they are each unique. Research can only describe a PLC at a particular moment in time, they are constantly changing based on the individuals that encompass the PLC.

Limitations of this Study

This study focuses on a group of experienced, confident teachers with strong opinions on best practices for mathematics teachers. These teachers are encouraged and supported by the greater mathematics community as well as by their Principal. Less experienced or less confident teachers might find the methods these teachers use intimidating and may not have the support network that the teachers at Fields High School do. The findings in this study might not offer a picture of what professional development might look like in other high schools in other school boards.

This one-year study was only a snapshot of the evolution of this PLC. Revisiting the school beyond this year may present a much different story. The members of the PLC are always changing, teachers may leave the school, individuals may choose not to participate in following years as did the original English teachers chosen to participate in the 4SI project. As well, the access to funding may decrease which would result in less time for teachers to meet and collaborate together. Different administrators may replace Dolores and their agenda and support of the initiative may vary greatly from the current support system in place for the PLC. Many factors contributed to creating the PLC as I observed it. Due to the nature of schools and the unpredictability of these factors it is impossible to suggest that this PLC will continue on the same path that I was exposed to during Year 1 of the OAME project. I discuss some of these changing factors in the following section.

Moving Forward

Through support from the Ministry of Education and the OAME this collaborative inquiry project was approved for a second year. I continued my role as an RA at Fields

High School during the 2015/2016 school year. When meetings commenced I observed that the PLC had once again evolved. The 4SI and the OAME initiatives are no longer merged, they currently are operating as two separate projects. My role is with the OAME project and I therefore only attend meetings dedicated to Grade 9 Applied Mathematics. Through discussions that I was not present for, the decision was made to dedicate all 4SI meetings to Grade 10 Applied courses and dedicate the OAME meetings to the intended target course of Grade 9 Applied Mathematics. The OAME PLC now consists of Wayne, Tasha, Rachel and a new team member Lisa.

Lisa is an experienced mathematics teacher. She has been teaching for over 15 years. She was hired to share the headship of the mathematics department with Wayne. This is her first year at Fields High School but because of her involvement with the mathematics community at the district level she is a familiar face to the rest of the PLC. As any new member would, Lisa's presence has changed the dynamics of the PLC. Lisa has extensive experience working at the board level and she often is interested in discussing issues related to assessment. One thing that stands out to me is that Lisa is committed to adopting the methods the PLC has put into place and is committed to the direction they are taking. It appears to me that Dolores, perhaps in consultation with other members of the PLC, has once again carefully considered and selected a new PLC member that will challenge the PLC and help it evolve. The opportunity to extend this study into the second year presents an opportunity to discuss further the two research questions that guided this study. With the introduction of Lisa and the decision, during the summer between Year 1 and Year 2, to split the group into two smaller PLCs the findings of the study from Year 2 could vary greatly from the results of Year 1.

In addition to the changes at Fields High School I was assigned as a RA to a second school site, Parks High School. Parks High School is a fairly new school in a large suburban center and they have been involved with the OAME project since it began. The teachers involved in this project are younger and newer to the teaching profession. The addition of this second site offers me the opportunity to compare and contrast the way that these two sites examine their practice and to present a multiple case study, possibly guided by the same research questions as this one.

Customarily the different schools participating in the OAME project do not meet, outside of our project wide meetings. This has not been the case with Parks and Fields High School. Parks High School was interested to learn more about Fields High School approach to rearranging the curriculum and they inquired about the possibility of visiting Fields High School. The schools did in fact meet for a day. This adds a new perspective to the idea of PLCs that I find interesting. The shared goals of the OAME project are reaching beyond the boundaries of individual schools and creating new opportunities for collaboration.

Of the 10 schools originally selected to participate in the OAME project 9 schools are still involved. Access to the data from all 9 school sites, as well as interacting with the participants at project wide meetings, has allowed me to observe some of the ways that the different school teams work. Several different areas of focus for future research have presented themselves through these observations and interactions. The area that most interests me is the role the Principal plays in the formation and sustainability of the PLC. Through my exposure to two sites, and access to the data from the others, it becomes clear that Principals assume different roles at different schools. While Dolores attended

most meetings during Year 1 of the project she has mainly been absent from the OAME meetings during Year 2. She is still very much involved with the 4SI project and attends the majority of those meetings when her schedule allows it. Many of the school sites have different levels of involvement from the school Principal or the administrator that has signed on to participate in that role for the project.

Other areas of future research could focus on the types of work the teachers engage in and the models of professional development the school teams use. The lesson study model at Fields High School proved successful for them during Year 1 but has not been used so far during Year 2 of the project. Wayne explained to me that both he and William will take part in the 4SI project this term as they are both teaching Grade 10 Applied Mathematics and therefore will have the opportunity to participate in the lesson study process. I have asked on two separate occasions if the OAME project will engage in a lesson study this year. Each time the teachers express a keen interest to do so but the multiple other commitments seem to be getting in the way of the teachers finding time to do this.

The issues around assessment present another possible area of future research. Both Fields and Parks High Schools have spent a great deal of their time discussing the challenges of assessing activity-based learning. Fields High School's primary focus during Year 2 has been on developing common assessments for all students in a Grade 9 mathematics course at their school. They hope to compare how the students in the split Grade 9 mathematics courses are fairing compared to the students in the academic mathematics classes. The members of the PLC have created a common framework of activity-based lessons that spiral through the curriculum and all teachers of Grade 9

mathematics at the school are following this framework. Several other school sites have also mentioned that they are struggling with assessing the students in Grade 9 Applied Mathematics and spend a significant amount of time discussing this issue during their meetings. A study that looked at different ways high school teachers discuss and approach assessment of students in Grade 9 mathematics would be another avenue for future research.

Concluding Thoughts

As I conclude this study I look forward to continuing my work with the OAME collaborative inquiry project. This study presented one instance of many professional collaborative communities across Ontario. Through the study of many of these PLCs we can contribute to the body of knowledge that is being built specifically around the teaching and learning of Grade 9 Applied Mathematics in Ontario.

I was exceptionally fortunate to have been granted access to the PLC at Fields High School. Through my experience with the OAME project and through my previous work in schools with the Galileo Educational Network I realize that this PLC is a rare and unique case. The PLC at Fields High School offers an example of what is possible for a school to achieve when the right elements, structural conditions, and human/social resources are in place. When participants exhibit high levels of engagement and willingness to collaborate to examine and enhance their practice schools can create effective professional learning communities.

References

- Ancess, J. (2000). The reciprocal influence of teacher learning, teacher practice, school restructuring, and student learning outcomes. *Teachers College Record* 102(3): 560-619.
- Askew, M., Brown, M., Rhodes, V., Johnson, D. and Wiliam, D. (1997). *Effective teachers of numeracy, final report*. London: King's College, University of London.
- Attard, K. (2012). Public reflection within learning communities: An incessant type of professional development. *European Journal of Teacher Education*, 35(2), 199-211.
- Ball, D. L. (1996). Teacher learning and the mathematics reforms: What we think we know and what we need to learn. *Hi Delta Kappan*, 77(7), 500-508.
- Ball, D. L., Hill, H. C, & Bass, H. (2005). Knowing mathematics for teaching: Who knows mathematics well enough to teach third grade, and how can we decide? *American Educator*, 29, 14-22.
- Ball, D. L. (1988). "Unlearning to teach mathematics." *For the Learning of Mathematics*, 8(1), 40-48.
- Ball, D., Thames, M., & Phelps, G. (2008). Content knowledge for teaching: What makes it special? *Journal of Teacher Education*, 59, 389-407.
- Barth, R. S. (2006). Improving relationships within the schoolhouse. *Educational Leadership*, 63(6), 8-13.
- Boaler, J. (1998). Open and closed mathematics: Student experiences and understandings. *Journal for Research in Mathematics Education*, 29(1), 41-62.

- Boaler, J. (2013). Ability and Mathematics: The mindset revolution that is reshaping education. *Forum*, 55(1), 143-152.
- Boaler, J., Wiliam, D., & Brown, M. (2000). Students' experiences of ability grouping – disaffection, polarization and the construction of failure. *British Educational Research Journal*, 26(5), 631-648.
- Borko, H. (2004). Professional Development and Teacher Learning: Mapping the Terrain. *Educational Researcher*, 33(8), 3-15.
- Britton, E., Paine, L., Pimm, D. and Raizen, S. (2003). *Comprehensive teacher induction: Systems for early career learning*. Dordrecht, The Netherlands: Kluwer Academic Publishers.
- Buffman, A., Mattos, M., Weber, C. (2009). *Pyramid response to intervention: RTI, professional learning communities, and how to respond when kids don't learn*. Bloomington, IN: Solution Tree.
- Clarke, M., D. (1997). The Changing role of the mathematics Teacher. *Journal for Research in Mathematics Education*, 28(3), 278-308.
- Cochran-Smith, M., & Lytle, S. L. (2009). *Inquiry as stance: Practitioner research for the next generation. practitioners inquiry*. New York: Teachers College Press.
- Cogshall, J. G., Rasmussen, C., Colton, A., Milton, J., & Jacques, C. (2012). *Generating teacher effectiveness: The role of job-embedded professional learning in teacher evaluation*. Washington, DC: National Comprehensive Center for Teacher Quality.
- Cooney, T. J. (2001). Considering the paradoxes, perils, and purposes of conceptualizing teacher development. In F. Lin & T. J. Cooney (Eds.), *Making sense of*

- mathematics teacher education* (pp. 9–32). Dordrecht, The Netherlands: Kluwer Academic Publishers.
- Copland, M.A. (2003). Leadership of inquiry: Building and sustaining capacity for school improvement. *Educational Evaluation and Policy Analysis*, 25(4), 375-395.
- Cormier, R. & Olivier, D.F. (2009). *Professional learning communities: Characteristics, principals, and teachers*. Paper presented at the Louisiana Education Research Association, Lafayette, LA.
- Creswell, J. W. (2013). *Qualitative inquiry and research design: Choosing among five approaches*. Thousand Oaks, CA: Sage.
- Crespo, S. (2006). Elementary teacher talk in mathematics study groups. *Educational Studies in Mathematics*, 63, 29-56.
- Darling-Hammond, L., & Ball, D.L. (1998). *Teaching for high standards: What policymakers need to know and be able to do* (CPRE Joint Report Series, JRE-04). Philadelphia: Consortium for Policy Research in Education and the National Commission on Teaching & America's Future.
- Darling-Hammond, L., & McLaughlin, M. W. (1995). Policies that support professional development in an era of reform. *Phi Delta Kappan*, 76(8).
- Denzin, N. K. & Lincoln, Y. S. (2011). Introduction: The discipline and practice of qualitative research. *The Sage handbook of qualitative research* (4th ed., pp. 1-19). Thousand Oaks, CA: Sage.
- DuFour, R.P. (1999). Help wanted: Principal who can lead professional learning communities. *National Association of Secondary School Principals*, 83(604), 12-17.

- DuFour, R. P. (2001). In the right context. *Journal of Staff Development*, 22(1), 14-17.
- DuFour, R. P. (2004). *Schools as learning communities*. *Educational Leadership*, 61,(8), 6-11. Retrieved December 15, 2015 from <http://www.allthingsplc.info/files/uploads/DuFourWhatIsAProfessionalLearningCommunity.pdf>.
- DuFour, R. & Eaker, R. (1998). Professional learning communities at work: Best practices for enhancing student achievement. Bloomington, IN: Solution Tree.
- DuFour, R., Eaker, R., & DuFour, R. (2005). Recurring themes of professional learning communities and the assumptions they challenge. In R. DuFour, R. Eaker, and R. DuFour (Eds.), *On common ground: The power of professional learning communities* (pp. 7-27). Bloomington, IN: Solution Tree.
- Eaker, R., DuFour, R., & DuFour, R. (2002). Getting started: Reculturing schools to become professional learning communities. Bloomington, IN: National Educational Service.
- Eaker, R. & Keating, J. (2008). A shift in school culture. *Journal of Staff Development*, 29(3), 14-17.
- Educational Quality and Accountability Office (EQAO). (n.d.). *EQAO*. Retrieved From <http://www.eqao.com/en>
- Educational Quality and Accountability Office (EQAO). *Summary of results and strategies for teachers, 2013-2014: Grade 9 assessment of mathematics*.

Retrieved from <http://www.eqao.com/en/assessments/grade-9-math/assessment-docs/summary-results-strategies-for-teachers-grade9-2014.pdf>

- Eisenhardt, K. M. (1989). Building theories from case study research. *Academy of Management Review*, 14, 532-550.
- Ernest, P. (1989). The impact of beliefs on the teaching of mathematics. In P. Ernest (Ed.), *Mathematics teaching: The state of the art* (pp. 249-254). New York: Falmer Press.
- Ernest, P. (1991). *The philosophy of mathematics*. New York: Routledge Falmer Press.
- Ernest, P. (2000). Why teach mathematics? In S. Bramall and J. White, eds, *Why learn maths?* London: Institute of Education, 1–14.
- Ernest, P. (2014). What is mathematics, and why learn it? In P. Andrews and T. Rowlands eds, *Masterclass in mathematics education: International Perspectives on Teaching and Learning* (pp. 3-14). London: Bloomsbury.
- Even, R. (1990). Subject matter knowledge for teaching and the case of functions. *Educational Studies in Mathematics*, 21, 521–544.
- Even, R. (1993). Subject-matter knowledge and pedagogical content knowledge: Prospective secondary teachers and the function concept. *Journal for Research in Mathematics Education*, 24(2), 94–116.
- Even, R., & Ball, D. L. (2009). Setting the stage for the ICMI study on the professional education and development of teachers of mathematics. In R. Even & D. L. Ball (Eds.), *The professional education and development of teachers of mathematics: The 15th ICMI study* (pp. 1–9). New York: Springer.

- Fullan, M. (2007). *The new meaning of educational change (4th Ed)*. New York: Teachers College Press.
- Fullan, M., & Hargreaves, A. (1996). *What's worth fighting for in your school?* New York: Teachers College Press.
- Goddard, R. D., Hoy, W. K., and Hoy, A. W. (2000). Collective teacher efficacy: Its meaning, measure, and impact on student achievement. *American Educational Research Journal*, 37(2), 479-507.
- Grossman, P., Wineburg, S., & Woolworth, S. (2001). Toward a theory of teacher community. *Teachers College Record*, 103, 942–1012.
- Guskey, T. R. (1999). Apply time with wisdom. *Journal of Staff Development*, 20(2), 10-15.
- Hargreaves, A. (1994). *Changing teachers, changing times: Teacher's work and culture in the postmodern age*. New York, NY: Teachers College Press.
- Hattie, J. (2012). *Visible learning for teachers*. New York: Routledge.
- Hill, H. C, Ball, D. L., & Schilling, S. G. (2008). Unpacking pedagogical content knowledge: Conceptualizing and measuring teachers' topic-specific knowledge of students. *Journal for Research in Mathematics Education*, 39(4), 372-400.
- Hord, S. M. (1997). *Professional learning communities: Communities of continuous inquiry and improvement*. Austin, TX: Southwest Educational Development Lab.
- Hord, S. M. (Ed.). (2004). *Learning together, leading together: Changing schools through professional learning communities*. New York: Teachers College Press.
- Hord, S.M. & Sommers, W.A. (2008). *Leading professional learning communities: Voices from research and practice*. Thousands Oaks, CA: Corwin Press.

- Huffman, J. (2003). The role of shared values and visions in creating professional learning communities. *National Association of Secondary School Principals*, 87(637), 21-34.
- InPraxis Group Inc. (2006). *Professional learning communities: An exploration*. Online Submission. Alberta Education. Retrieved December 15, 2015 from https://education.alberta.ca/media/6412493/professional_learning_communities_literature_review_2006.pdf.
- Kersting, N. B., Stigler, J. W., Givvin, K. B., & Sotelo, F. L. (2010). Teachers' analyses of classroom video predict student learning of mathematics: Further Explorations of a novel measure of teacher knowledge. *Journal of Teacher Education*, 61(1-2) 172–181.
- Killion, J. (1998). Scaling the elusive summit. *Journal of Staff Development*, 79(4), 12-16.
- Kruse, S., Louis, K. S., & Bryk, A. S. (1994). *Building professional community in schools*. Madison, WI: Center on Organization and Restructuring of Schools.
- Kruse, S. D., Louis, K. S., & Bryk, A. (1995). An emerging framework for analyzing school-based professional community. In K. S. Louis & S. D. Kruse (Eds.), *Professionalism and Community: Perspectives on Reforming Urban Schools* (p. 23–42). Thousand Oaks, CA: Corwin Press.
- Lachance, A., & Confrey, J. (2003). Interconnecting content and community: A qualitative study of secondary teachers. *Journal of Mathematics Teacher Education*, 6(2), 107-137.

- Lambert, L. (2003). *Leadership capacity for lasting school improvement*. Alexandria, VA: Association for Supervision and Curriculum Development.
- Leithwood, K., Louis, K. S., Anderson, S., & Wahlstrom, K. (2004). *How leadership influences student learning: Review of research*. Minneapolis: University of Minnesota, Center for Applied Research and Educational Improvement.
- Lieberman, A. (1998). *Building a professional culture in schools*. New York: Teachers College Press.
- Liljedahl, P. (in press). Building thinking classrooms: Conditions for problem solving. In P. Felmer, J. Kilpatrick, & E. Pekhonen (eds.) *Posing and Solving Mathematical Problems: Advances and New Perspectives*. New York, NY: Springer.
- Liljedahl, P. (2014). The affordances of using visually random groups in a mathematics classroom. In Y. Li, E. Silver, & S. Li (eds.) *Transforming Mathematics Instruction: Multiple approaches and practices*. New York, NY: Springer.
- Loucks-Horsley, S., & Matsumoto, C. (1999). Research on professional development for teachers of mathematics and science: The state of the scene. *School Science and Mathematics*, 99(5), 258-271.
- Loucks-Horsley, S., Stiles, K. E., Mundry, S., Love, N., & Hewson, P. W. (2010). *Designing professional development for teachers of science and mathematics*. (3rd ed.). Thousand Oaks, CA: Corwin Press.
- Louis, K. S., Dretzke, B., & Wahlstrom, K. (2010). How does leadership affect student achievement? Results from a national survey. *School effectiveness and school improvement*, 21(3), 315–336.

- Louis, K. S., & Marks, H. (1998). Does professional community affect the classroom? Teachers' work and student experiences in restructuring schools. *American Journal of Education*, 106, 532–575.
- Manitoba Education. (2013). *Kindergarten to grade 8 mathematics: Manitoba curriculum framework of outcomes 2013*. Retrieved from http://www.edu.gov.mb.ca/k12/cur/math/framework_k-8/index.html
- McLaughlin, M.W. (1993). What matters most in teachers' workplace context? In J.W. Little & M.W. McLaughlin (Eds.), *Teachers' work: Individuals, colleagues, and contexts* (pp. 79-103). New York: Teachers College Press.
- McLaughlin, M. & Talbert, J. (2001). *Professional communities and the work of high school teaching*. Chicago: The University of Chicago Press.
- Miles, M. B. & Huberman, A. M. (1994). *Qualitative data analysis (2nd edition)*. Thousand Oaks, CA: Sage Publications.
- Miller, R. J., Goddard, Y. L., Goddard, R., Larsen, R., & Jacob, R. (2010, November 17–20). *Shared instructional leadership: A pathway to teacher collaboration and student achievement*. A paper presented at the University Council for Educational Administration Convention (UCEA), Pittsburgh, PA.
- Moller, G. (2003). Case study # 4: The role of principal commitment in creating learning communities. In J.B. Huffman & K.K. Hipp (Eds.). *Reculturing schools as professional learning communities* (pp. 121-128). Lanham, MD: Scarecrow Education.
- Morrissey, M. (2000). *Professional learning communities: An ongoing exploration*. Austin, TX: Southwest Educational Development Laboratory. Retrieved on

- December 12, 2015 from <http://www.willettsurvey.org/TMSTN/PLCs/plc-ongoing.pdf>.
- National Research Council. (1999). *How people learn: Brain, mind, experience, and school*. J. Bransford, Brown, A., & Cocking R. (Eds.). Washington, DC: National Academy Press.
- National Council of Teachers of Mathematics (NCTM). (2000). *Principles and standards for school mathematics*. Reston, VA: NCTM.
- National Council of Teachers of Mathematics (NCTM). (2014). *Principles to actions*. Reston, VA: NCTM.
- Ontario Ministry of Education. (2005). *The Ontario curriculum Grades 1-8 mathematics revised*. Toronto: Queen's Printer for Ontario.
- Oakes, J. (1990). *Multiplying inequalities: The effects of race, social class, and tracing on opportunities to learn mathematics and science*. Santa Monica, CA: RAND
- Oakes, J. (2005). *Keeping track: How schools structure inequality* (2nd ed.). New Haven, CT: Yale University Press.
- O'Shea, T. (2003). The Canadian mathematics curriculum from the new math to the NCTM Standards. In G. M. A. Stanic & J. Kilpatrick (Eds.), *A History of school mathematics* (pp. 843-896). Reston, VA: NCTM.
- Pyc, M. A., & Rawson, K. A. (2009). Testing the retrieval effort hypothesis: Does greater difficulty correctly recalling information lead to higher levels of memory? *Journal of Memory and Language*, 60 437-447.

- Roberts, S. M., Pruitt, E. Z. (2009). *Schools as professional learning communities: Collaborative activities and strategies for professional development*. Thousand Oaks, CA: Corwin Press.
- Rohrer, D., Dedrick, R. F., & Burgess, K. (2014). The benefit of interleaved mathematics practice is not limited to superficially similar kinds of problems. *Psychonomic Bulletin & Review*, 1-8.
- Rosenholtz, S. J. (1991). *Teachers' workplace: The social organization of schools*. New York: Teachers College Press.
- Sackney, L., & Mitchell, C. (2001). Building capacity for a learning community. *Canadian Journal of Educational Administration and Policy*, 19.
- Saunders, W. M., Goldenberg, C. N., & Gallimore, R. (2009). Increasing achievement by focusing grade level teams on improving classroom learning: A prospective, quasi-experimental study of title I schools. *American Educational Research Journal*, 46(4), 1006–1033.
- Schifter, D., & Fosnot, C. T. (1993). *Reconstructing mathematics education: Stories of teachers meeting the challenges of reform*. New York: Teachers College Press.
- Schmoker, M. (1999). *Results: The key to continuous improvement*. Alexandria, AV: Association of Supervision and Curriculum Development.
- Schmoker, M. (2004). Learning communities at the crossroads: Toward the best schools we've ever had. *Phi Delta Kappan*, 86(1), 84-88.
- Schoenfeld, A. (2004) The math wars. *Educational Policy* 18(1), 253-286.
- Schram, T. H. (2006). *Conceptualizing and proposing qualitative research*. Columbus: OH: Merrill, Prentice Hill.

- Senge, P. (1990). *The fifth discipline: The art & practice of the learning organization*. New York: Doubleday.
- Senge, P., Cambron-McCabe, N., Lucas, T., Smith, B., Dutton, J., & Kleiner, A. (2000). *Schools that learn*. New York: Doubleday.
- Shulman, L.S. (1986). Those who understand: Knowledge growth in teaching. *Educational Researcher*, 75(2), 4-14.
- Shulman, L.S. (1987). Knowledge and teaching: Foundations of the new reform. *Harvard educational review*, 57(1), 1-23.
- Speck, M. (1999). *The principalship: Building a learning community*. Upper Saddle River, NJ: Prentice Hall.
- Stake, R. E. (2005). Qualitative case studies. In N. K. Denzin & Y. S. Lincoln (Eds.), *The SAGE handbook of qualitative research* (pp. 443-466). Thousand Oaks, CA: Sage.
- Stigler, J., & Hiebert, J. (1997). Understanding and improving classroom mathematics, instruction: An overview of the TIMSS video study. *Phi Delta Kappan*, September 12-21.
- Stoll, L., Bolam, R., McMahon, A., Wallace, M., & Thomas, S. (2006). Professional Learning communities: A review of the literature. *Journal of Educational Change*, 7(4), 221-258.
- Suurtamm, C. (2013). Mathematics teacher education. In L. Meyer (Ed.) *Oxford bibliographies of education*. Oxford University Press.
- Swann, J and Pratt, J (eds) (2004) *Educational research in practice: Making sense of methodology*, London: Continuum.

- Timperly, H. & Robinson, V. (2000). Workload and the professional culture of teachers. *Educational Management & Administration*, 28(1), 47-62.
- Vesio, V., Ross, D., & Adams, A. (2008) Review of research on the impact of professional learning communities on teaching practice and student learning. *Teaching and Teacher Education*, 24, p. 80-91.
- Wilson, S. M., & Berne, J. (1999). Teacher learning and the acquisition of professional knowledge: an examination on contemporary professional development. In A. Iran-Nedjad & P. D. Pearson (Eds.), *Review of Research in Education* (Vol. 24, pp. 173-209). Washington, DC: AERA.
- Wiley, S. (2001). Contextual effects of student achievement: School leadership and professional community. *Journal of Educational Change* 2(1), 1–33.
- Westheimer, J. (1998). *Among school teachers: Community, autonomy, and ideology in teachers' work*. New York: Teachers College.
- Westheimer, J. (1999). Communities and consequences: An inquiry into the ideology and practice in teachers' professional work. *Educational Administration Quarterly*, 35(10) p.71-105.
- Westheimer, J. (2008). Learning among colleagues: Teacher community and the shared enterprise of education. In M. Cochran-Smith, S. Feiman-Nemser, D. J. McIntyre, & K. E. Demers (Eds.), *Handbook of research on teacher education: Enduring questions in changing contexts*, 3rd edition (pp. 732 755). New York: Routledge.
- Wright, P. (2012). The math wars: Tensions in the development of school mathematics Curricula. *For the Learning of Mathematics*, 32(2), 7013.
- Yin, R. K. (2003). *Case study research: design and methods*. Thousand Oaks, CA: Sage.

Appendix A: Shulman's Necessary Knowledge for Teaching (1987)

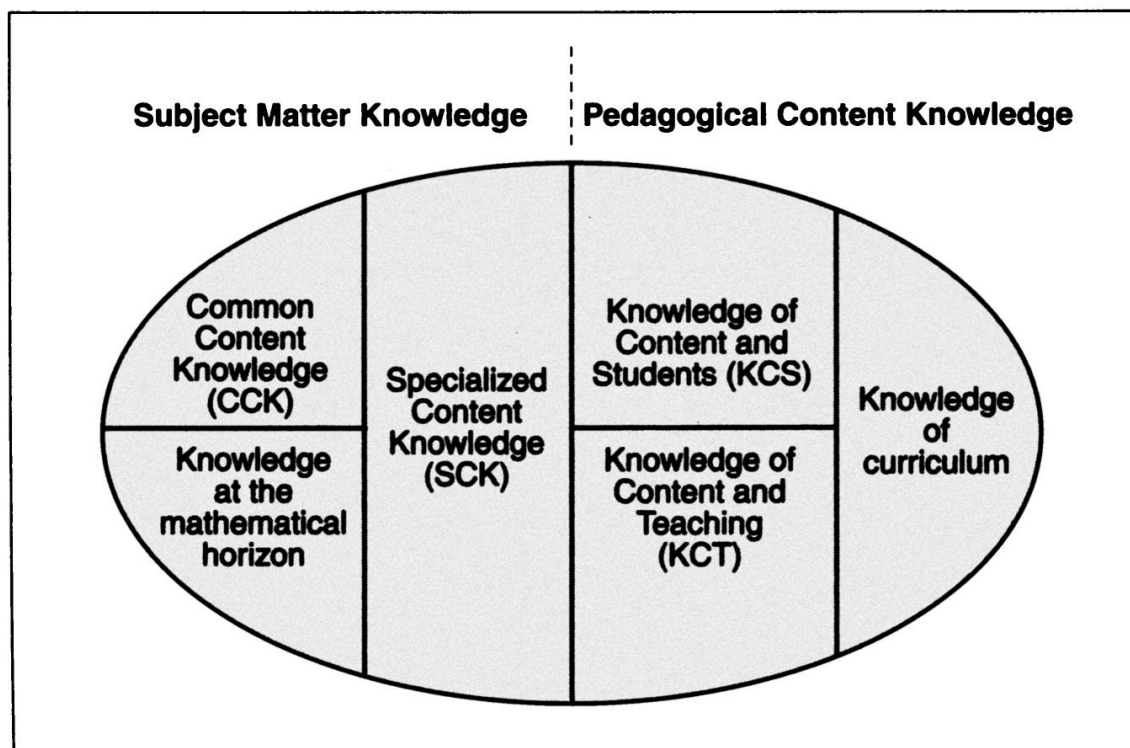
Categories of the Knowledge Base

If teacher knowledge were to be organized into a handbook, an encyclopedia, or some other format for arraying knowledge, what would the category headings look like? At minimum, they would include:

- ✓ Content Knowledge;
- ✓ General pedagogical knowledge, with special reference to those broad principles and strategies of classroom management and organization that appear to transcend subject matter;
- ✓ Curriculum knowledge, with particular grasp of the materials and programs that serve as “tools of the trade” for teachers;
- ✓ Pedagogical content knowledge, that special amalgam of content and pedagogy that is uniquely the province of teachers, their own special form of professional understanding
- ✓ Knowledge of learners and their characteristics;
- ✓ Knowledge of educational contexts, ranging from the workings of the groups or classroom, the governance and financing of school districts, to the character of communities and culture;
- ✓ Knowledge of educational ends, purposes, and values, and their philosophical and historical grounds.

(Shulman, 1987, p. 8)

Appendix B: What Teachers Need to Know to Teach Math



Reprinted from: Hill, H. C, Ball, D. L., & Schilling, S. G. (2008). Unpacking Pedagogical Content Knowledge: Conceptualizing and Measuring Teachers' Topic-Specific Knowledge of Students. *Journal for Research in Mathematics Education*, 39(4), 372-400.

Appendix C: Interview Protocol - Focus Group

Sample interview questions for focus group interview at monthly meetings

Please note that the questions may vary as issues and ideas emerge and as the project evolves. Also, once a rapport is established, very little prompting should be required.

First meeting:

Gathering information about participants

1. As we go around the table please state your name and your role with respect to this school team (principal, teacher, etc.)
2. What were your reasons for volunteering to be part of this team?

Discussion of their focus

3. What are some ways you have helped to support students in Grade 9 Applied?
4. What areas do you feel you want to work on through this project?
5. How do you see yourselves working on these areas?
6. What are ways that you see the research team supporting your work?

Subsequent meetings:

1. How have things been going with respect areas you have been working on?
2. Last time you mentioned that you were going to try XXXXX, how did that play out? How did students (or staff) respond?
3. What issues have arisen since the last time we met?
4. What new ideas have emerged?
5. Where do you feel you are taking this next?

Appendix D: Interview Protocol - Principal Interview

PLC – Collaborative Inquiry

Research Questions:

1. How is a PLC formed and sustained, and how does it evolve throughout the process of examining practice?
2. What happens when a professional community of learners comes together to discuss, dissect and reflect on their own practice with the intention of broadening their understanding of teaching mathematics?

Interview Questions:

1. Can you tell me about the history of this PLC?
2. How would you define your role within the PLC?
3. What do you think has been the biggest challenge in establishing the PLC at your school?
4. What would you describe as the greatest success of the PLC so far?
5. How has the PLC evolved over time, if at all?
6. What are some of the important things that have happened in the PLC that have influenced how you think or teach?

Appendix E: Interview Protocol - Teacher Interview

PLC – Collaborative Inquiry

Research Questions:

1. How is a PLC formed and sustained, and how does it evolve throughout the process of examining practice?
3. What happens when a professional community of learners comes together to discuss, dissect and reflect on their own practice with the intention of broadening their understanding of teaching mathematics?

Interview Questions:

1. Tell me about your math teaching experience.
2. Have you always taught math the same way?
3. How did you come to be part of the PLC here at this school?
4. What do you think has been the biggest challenge in establishing the PLC at your school?
5. What would you describe as the greatest success of the PLC so far?
6. How has the PLC evolved over time, if at all?
7. What are some of the important things that have happened in the PLC that have influenced how you think or teach?

Appendix F: Wayne - Lesson Plan

Developing awareness of influences in cooperative problem solving

Process Expectation

Reflecting: Demonstrate reflecting on and monitoring thinking to help clarify understanding as when completing an investigation or solving a problem

Materials:

1. Video: *When not knowing Math can cost you \$15,000 - Who Wants to Be a Millionaire?* reference link <https://www.youtube.com/watch?v=BbX44YSsQ2I>
2. Response Sheet for each student
3. Signs A, B, C, D - one for each corner
4. Reflection Sheet for each student

Lesson Outline:

Students, sitting individually, facing the front are given a very brief time to answer the following question on paper; Which of these square numbers also happens to be the sum of two smaller square numbers? A: 16 B: 25 C: 36 D: 49

Response 1: Once they have handed in their response, they are handed a sheet to record their answers, their reasons, and their confidence level, from the initial paper.

Students are told that at any point in the activity they can change their answer choice.

Response 2: Without speaking, students are instructed indicate their choice (A,B,C,D) by moving to the corresponding corner of the room. They are then asked to return to their desks to record their choice.

Response 3: Students are instructed to move to the corner of their choice to discuss quietly why they choose that particular answer. They are then asked to return to their desks to record their choice.

Response 4: Students are instructed to move to the corner of their choice to come up the main reason that they feel their answer is correct. The teacher asks each group to voice their reason. They are then asked to return to their desks to record their choice.

Response 5: Students are asked to watch the video quietly (up to the point where the studio audience votes 1:21). They are then asked to record their choice.

Response 6: Students are asked to watch the video quietly (to the point where the AOL network votes 1:33). They are then asked to record their choice.

The last minute of the video is shown to reveal the final answer.

Students are asked to write a reflection on the activity using the questions on the reflection sheet as a guideline.

Response Sheet

Name _____

Which of these square numbers also happens to be the sum of two smaller square numbers?

A: 16

B: 25

C: 36

D: 49

#	Choice	Reason for choice	Confidence
1			0 ----- 100%
2			0 ----- 100%
3			0 ----- 100%
4			0 ----- 100%
5			0 ----- 100%
6			0 ----- 100%

Reflecting

Name _____

Describe how you felt when the final answer was revealed in the video.

Describe when you felt the most confident in your choice.

Describe the strongest influence to change or not to change your choice.

What else could have helped you with your choice?

What did you learn about the way you make choices?

Appendix G: William - Lesson Plan

Protocol

1. Prompt of a scenario
2. notice and wonder
3. Targeted class question
4. Students develop individual plan and begin to implement
5. Group Students either on similar or different approaches
6. Whole class share
7. Connect different approaches based on class discussion

T Shirts

Day 1 (two days before observed lesson) Monday April 20

Pile of unfolded t-shirts on my desk in room 205

As students walk in hand them a notice and wonder sheet.

Consolidate notice and wonder.

How many t shirts?

How long to fold? As an individual? As a class?

What area could we cover with all those t-shirts?

What is the volume of all those t-shirts?

How long would it take to wash those t-shirts? And fold? And put away?

.....

Focus on "How many T-shirts are in that pile?"

Guess too low-guess too high- best guess

Individual time-Come up with a strategy to figure out how many t-shirts are in the pile?

What information might you need to execute your strategy?

Visible Random Groups (3) – Decide on a strategy and write down your thinking and execution of the strategy on VNPS

-What information might your group need to execute your strategy?

Sharing of work. Jigsaw-one from each group. Keep it or trade it.

Average all answers.

Reveal.

How long to fold?

Show video of folding. Tell students to go home and practice.

Day 2

Rate day

Individually write down strategy to get their rate of Number of t-shirts folded per second.

Discussion about ways to get their rate. Group discussion and method on white boards.

Strategy decision for class.

Table graph paper. Plot time versus number of shirts folded (0,0) (10 sec, #F), (20 sec, #F), (30 sec, #F), etc.

Slope gives rate.

By end of period.

Day 3

Observation day.

- Provide all observers with:
 - Photocopy of names with pictures
 - Observation sheet
 - Lesson plan
 - Rate sheet for everyone

Timing	Teacher Moves	Observations / Improvements
Before students arrive	• Desks grouped in 3's or 4's • Vertical non permanent surfaces (VNPS) set up by group number, names of students, • Camera to record learning • Graph paper, tape, Graphing Calculator, Graphing Calculator instructions	
As students arrive	• Hand them their data on T-shirt folding	
	• Question "How long will it take the class to fold the 282 t_shirts?" • Individually students write a strategy to figure out how long it will take. (individual) • Random groups of three – group strategy. • On whiteboards write down group strategy with execution. • Group solutions on the whiteboards • VNPS and VRG	
	• Exit Card	

Appendix H: Tasha - Lesson Plan

LESSON STUDY: WOULD YOU RATHER \$20 WORTH OF TIMBITS OR \$20 WORTH OF DONUTS?		
	Teacher Moves	Observations
Phase 0 ~2 min	- Set up <i>Would You Rather</i> presentation. - Separate and place mini-whiteboards and marks on desks. - Students sit randomly at individual desks and wait for instructions.	
Phase 1 ~2 min	- Present <i>Would You Rather...</i> question. - Instruct students to think about their answer by using reasoning and their prior knowledge, experience, judgement, intuition and gut feeling, and write down their thoughts on the whiteboards. - As they are thinking, hand out the Personal Reflection sheets. - Ask them to fill in Part 1 and flip over their sheet once they are have answered.	
Phase 2 ~5 min	- Display the list of student partners. - Instruct the students to take 5 minutes, bring their whiteboards and find a place in the room to share thinking with their partner.	
Phase 3 ~10 min	- After 5 minutes, have them to return to their seat to fill in Part 2 of their Personal Reflection sheet. - Give the students 10 minutes to gather information (use search box on class website) to work out justification for their choice.	
Phase 4 ~10 min	- Group the students in 3 or 4 and have them share their work. - Have them to return to their seat to fill in Part 3 of their Personal Reflection sheet.	
Phase 5 ~25 min	- Survey the students and have group them (max. 4 per group) based on their choice. - Have the groups work out their justification of their selection on the whiteboards.	
Phase 6 ~15 min	- When they have completed Part 4, have them walk around to review other groups' work. - Once done, have them return to their seat to fill in Part 5 of their Personal Reflection sheet.	
Phase 7 ~5 min	Have students fill out the Exit Card	

Personal-Reflection

Name: _____

WOULD YOU RATHER \$20 WORTH OF TIMBITS OR \$20 WORTH OF DONUTS?

Reflection Questions		Commitment Level	
Describe your thinking and give reasons for your choice.		Circle your choice Timbits Donuts	
Part 1	How did the discussion with your partner impact your thinking? Explain.	Mark an X on the line to indicate your commitment to your choice. 0% 100% Committed Committed	
Part 2	How did the discussion with your group impact your thinking? Explain.	Mark an X on the line to indicate your commitment level. 100% Committed Committed To Choosing Timbits To Choosing Donuts	
Part 3	How did examining others groups' work impact your thinking? Explain.	Mark an X to indicate your commitment level 100% Committed Committed To Choosing Timbits To Choosing Donuts	
Part 4			

Exit Card

Name: _____

WOULD YOU RATHER \$20 WORTH OF TIMBITS OR \$20 WORTH OF DONUTS?

1. What do you think the point was to today's activity?

2. How did participating in today's activity make you feel? Explain.

3. Are you happy with how your answer evolved from the beginning to the end? Explain why or why not.

4. Which group's solution do you think was the best? Why?

Exit Card

Name: _____

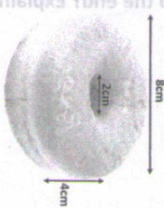
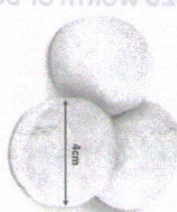
WOULD YOU RATHER \$20 WORTH OF TIMBITS OR \$20 WORTH OF DONUTS?

1. What do you think the point was to today's activity?

2. How did participating in today's activity make you feel? Explain.

3. Are you happy with how your answer evolved from the beginning to the end? Explain why or why not.

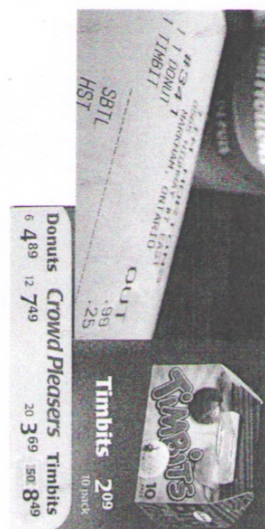
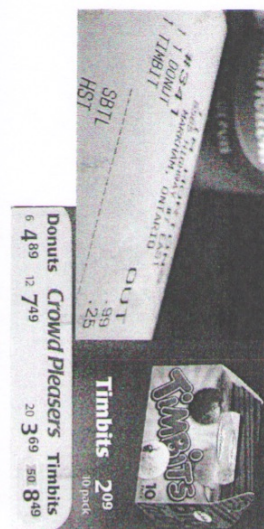
4. Which group's solution do you think was the best? Why.



HONEY DIP 1MBIT									
Serving Size: 14 g Amount Per Serving									
Crackers	Fat	Saturated Fat	Trans Fat	Cholesterol	Sodium	Carbohydrates	Fiber	Sugar	Protein
45	15	0.5g	0g	0mg	20mg	5g	0g	4g	1g
% Daily Value									
Vitamin A	Vitamin C	Calcium	Iron						
9% DV	9% DV	2% DV	10% DV						

Variety: sites.google.com/a/locdb.ca/mathphn/wyr-v
 Costs: sites.google.com/a/locdb.ca/mathphn/wyr-c

Dimensions: sites.google.com/a/locdb.ca/mathphn/wyr-d
 Nutrition: sites.google.com/a/locdb.ca/mathphn/wyr-n



TIMBITS®

- Apple Fritter
- Honey Dip
- Old Fashion Plain

- Old Fashion Glazed
- Chocolate Glazed
- Sour Cream Glazed

- Blueberry
- Strawberry
- Raspberry

- Lemon

DONUTS

- Apple Fritter
- Chocolate Dip
- Honey Dip
- Vanilla Dip
- Maple Dip

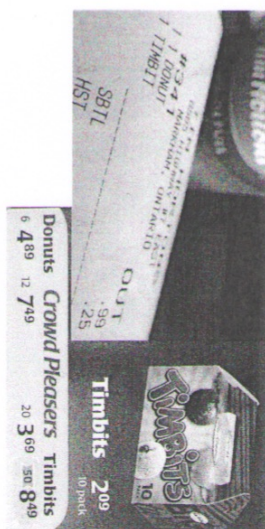
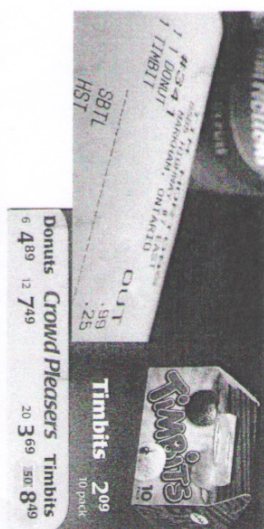
- Chocolate Glazed
- Strawberry
- Old Fashion Plain
- Old Fashion Glazed
- Sour Cream Plain

- Strawberry Vanilla
- Strawberry
- Boston Cream
- Canadian Maple
- Sour Cream Glazed

- Honey Cider
- Blueberry
- And many more

Variety: sites.google.com/a/locdb.ca/mathphn/wyr-v
 Costs: sites.google.com/a/locdb.ca/mathphn/wyr-c

Dimensions: sites.google.com/a/locdb.ca/mathphn/wyr-d
 Nutrition: sites.google.com/a/locdb.ca/mathphn/wyr-n



TIMBITS®

- Apple Fritter
- Honey Dip
- Old Fashion Plain

- Old Fashion Glazed
- Chocolate Glazed
- Sour Cream Glazed

- Blueberry
- Strawberry
- Raspberry

- Lemon

DONUTS

- Apple Fritter
- Chocolate Dip
- Honey Dip
- Vanilla Dip
- Maple Dip

- Chocolate Glazed
- Strawberry
- Old Fashion Plain
- Old Fashion Glazed
- Sour Cream Plain

- Strawberry Vanilla
- Strawberry
- Boston Cream
- Canadian Maple
- Sour Cream Glazed

- Honey Cider
- Blueberry
- And many more

Appendix I: Student Beliefs and Attitudes Survey

First Name *

Last Name *

Teacher *

Gender *

1. What grade is your mathematics course? *

2. What Stream is your mathematics course? *

3. The math that I learn in school is mostly facts and procedures that have to be memorized *

- ☐ Strongly Agree
- ☐ Agree
- ☐ Disagree
- ☐ Strongly Disagree

You can be creative in math class *

- ☐ Strongly Agree
- ☐ Agree
- ☐ Disagree
- ☐ Strongly Disagree

4. In math you can discover things on your own *

- ☐ Strongly Agree
- ☐ Agree
- ☐ Disagree
- ☐ Strongly Disagree

5. Making mistakes in math helps me learn *

- ☐ Strongly Agree
- ☐ Agree
- ☐ Disagree
- ☐ Strongly Disagree

6. It is important to get the right answer in math *

- ☐ Strongly Agree
- ☐ Agree
- ☐ Disagree
- ☐ Strongly Disagree

7. I enjoy working on challenging math problems *

- ☐ Strongly Agree
- ☐ Agree
- ☐ Disagree
- ☐ Strongly Disagree

8. I prefer to work on math problems by myself *

- ☐ Strongly Agree
- ☐ Agree
- ☐ Disagree
- ☐ Strongly Disagree

9. I enjoy group work in math class *

- ☐ Strongly Agree
- ☐ Agree
- ☐ Disagree
- ☐ Strongly Disagree

10. Some people are good at math and some are not *

- ☐ Strongly Agree
- ☐ Agree
- ☐ Disagree
- ☐ Strongly Disagree

11. People can't really change how intelligent they are in math *

- ☐ Strongly Agree
- ☐ Agree
- ☐ Disagree
- ☐ Strongly Disagree

12. All students would be good at math if they worked hard at it *

- ☐ Strongly Agree
- ☐ Agree
- ☐ Disagree
- ☐ Strongly Disagree

13. When I see a math problem, I get nervous *

- ☐ Strongly Agree

- ☐ Agree
- ☐ Disagree
- ☐ Strongly Disagree

14. I like to go to the board or share my answers with peers in math class *

- ☐ Strongly Agree
- ☐ Agree
- ☐ Disagree
- ☐ Strongly Disagree

15. I enjoy hearing the thoughts and ideas of my peers in math class *

- ☐ Strongly Agree
- ☐ Agree
- ☐ Disagree
- ☐ Strongly Disagree

16. I forget how to do problems that I have solved before. *

- ☐ Strongly Agree
- ☐ Agree
- ☐ Disagree
- ☐ Strongly Disagree

17. If I get stuck on a math problem I ask for help *

- ☐ Strongly Agree
- ☐ Agree
- ☐ Disagree
- ☐ Strongly Disagree

18. If I get stuck on a math problem I usually try to figure out a different way that works *

- ☐ Strongly Agree
- ☐ Agree
- ☐ Disagree
- ☐ Strongly Disagree

19. I like math *

- ☐ Strongly Agree
- ☐ Agree
- ☐ Disagree
- ☐ Strongly Disagree

20. Math is one of my favourite subjects *

- ☐ Strongly Agree

- ☐ Agree
- ☐ Disagree
- ☐ Strongly Disagree

21. The math I learn now helps me do work in other subjects *

- ☐ Strongly Agree
- ☐ Agree
- ☐ Disagree
- ☐ Strongly Disagree

22. I need to do well in math to study what I want later *

- ☐ Strongly Agree
- ☐ Agree
- ☐ Disagree
- ☐ Strongly Disagree

23. Doing homework helps me understand math *

- ☐ Strongly Agree
- ☐ Agree
- ☐ Disagree
- ☐ Strongly Disagree

24. I talk about math when I am not at school *

- ☐ Strongly Agree
- ☐ Agree
- ☐ Disagree
- ☐ Strongly Disagree

25. Write 2 words to describe math *