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# On the Relationship between Complexity Theory, Professional Learning, and Lesson Study in Intermediate Mathematics Classrooms

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# On the Relationship between Complexity Theory, Professional Learning, and Lesson Study in Intermediate Mathematics Classrooms

by

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## DECLARATION OF ORIGINALITY

I hereby certify that I am the sole author of this dissertation and that no part of this dissertation has been published or submitted for publication.

I certify that, to the best of my knowledge, my dissertation does not infringe upon anyone's copyright nor violate any proprietary rights and that any ideas, techniques, quotations, or any other material from the work of other people included in my thesis, published or otherwise, are fully acknowledged in accordance with the standard referencing practices. Furthermore, to the extent that I have included copyrighted material that surpasses the bounds of fair dealing within the meaning of the Canada Copyright Act, I certify that I have obtained a written permission from the copyright owner(s) to include such material(s) in my dissertation and have included copies of such copyright clearances to my appendix.

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## ABSTRACT

This research adds to the existing knowledge about using the professional learning practice of Lesson Study as a way to build pedagogical knowledge and improve teaching with in-service teachers. It has shown that Lesson Study addresses the key elements of effective professional development as described in the literature and, when viewed through a complexity theory lens, makes use of some of the key characteristics of complex systems.

The research followed a team of math teachers through a modified Lesson Study, where they created a lesson, taught it, observed student learning, and debriefed the experience. The goals of the research were to understand the impact learning about instructional practice had on teachers in the study, to learn which features of the Lesson Study design supported professional learning, and to learn how teachers felt their participation in the Lesson Study impacted their students' learning and achievement.

A Design-Based Research methodology was drawn upon to gather evidence of teacher learning. Through pre-and post-surveys, interviews, observations, and artifacts, evidence was collected to study the impact of Lesson Study on the participants. Results showed teachers improved their understanding and use of strategies to have greater influence on student learning in four dimensions of mathematical reform (i.e., opportunity to learn, student confidence, student-to-student interaction, and teachers' conceptions of mathematics). Teachers in the project reported that lesson planning and the debrief and discussion phase created the strongest opportunities for teacher learning. An efficacy survey showed that teachers improved their confidence in engaging students and improving academic performance. One of the greatest benefits of the Lesson Study, reported by participants, was the opportunity to collaborate and make curriculum connections within and between elementary and secondary school settings. Teachers also reported adopting the Lesson Study process for future professional learning time.

Three recommendations that come from the research of this thesis are offered: establish a clear learning goal for teachers involved in Lesson Study based on a student need, use student data to measure success, and pay attention to the characteristics of complex systems and the elements of effective professional learning to create effective conditions for teacher learning.

## DEDICATION

To my mom, for her fighting spirit. You have been an inspiration and a role model my whole life. Thank you for your undying faith in me and for always making sure I felt supported and loved.

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# CHAPTER 1

## Introduction

How do practicing mathematics teachers learn about new theories of teaching and learning, experiment with them, and integrate them into their practice? This research examined a school board project that adapted the professional learning practice of Lesson Study to see how mathematics teachers put theory into practice. This research sought to understand how to create the necessary conditions, for practicing mathematics teachers, to increase their knowledge and skills and challenge their attitudes and beliefs about teaching mathematics. During the Lesson Study process, teachers reflected on how their participation in professional learning impacted their students' learning and achievement. The goal of the study was to determine what characteristics of the Lesson Study process helped learning emerge for both teachers and students.

### Lesson Study

Lesson Study is a model for professional development that originated in Japan. In Japan, groups of teachers from the same grade and subject, but from different classrooms, come together to discuss issues from their teaching and curriculum, develop research questions to investigate, and set long-term goals for student learning. Together, they create a lesson to respond to specific research questions, anticipate student thinking to address long-term goals, and model a learning trajectory (Lewis, Perry, & Murata, 2006). The process of Lesson Study as described by Murata (2011) continues with one member of the group teaching the lesson to a class while the others observe and collect evidence of student learning. As a group, they reflect together, discussing their observations and data, including student responses. From the feedback, they re-write or modify the lesson to meet student needs. Another member of the group teaches the modified lesson to a different class and the process repeats until everyone in the group is satisfied that the student learning goals have been achieved. The group records its reflections on their learning throughout the entire process to draw out implications for future instruction. In Japan, as part of the Lesson Study process, the lesson, student work, and the reflections on the learning of the group are shared with other teacher groups. Open houses at the end

of the year occur for groups of teachers from all over Japan to share the results of their Lesson Study. In countries around the world, different school districts and researchers have adapted and used the Lesson Study process to address the professional needs of their teachers as learners.

**Rationale for Lesson Study**

Lesson Study is professional development grounded in classroom practice where teachers can affirm or learn a new practice by watching and experimenting with the practice: "Lesson study work…seems to provide a comfortable forum for teachers to tackle challenging ideas about their practice" (Fernandez, Cannon, & Chokshi, 2003). Through Lesson Study, teachers can explore new ministry, school board, or school initiatives or examine new research findings for adaptation in the classroom.

In 2004, the Ontario Ministry of Education established an expert panel, comprised of education and community leaders from across the province, to report on instructional and assessment strategies that could help all students, especially struggling students, develop the mathematical skills and understandings needed for the 21st century. The report called on educators to "adopt the best mathematics instructional and assessment strategies for all students" (Ontario Ministry of Education and Training, 2004, p. 12). Before teachers adopt these strategies, they first need to know what the strategies are, how they work, and what makes them the best strategies for student learning. Teacher professional development programs, by and large, seek to do this by increasing teachers' professional knowledge, improving classroom practices, and ultimately fostering student learning and achievement gains (Fishman, Marx, Best, & Tal, 2003; Loucks-Horsley, Love, Stiles, Mundry, & Hewson, 2003).

Unfortunately, not all professional development leads to improved classroom instruction. Professional learning that is focused on teaching, assessment, and observation of student work is what makes the difference between enhancing teachers' competence and simply providing a forum for teachers to talk (Darling-Hammond & Richardson, 2009). The change professional development promises occurs when teachers learn to describe, discuss, and adjust their practices according to a collectively held standard of teaching quality (Little, 2003). The goal is to create professional development experiences that set conditions for this type of change to occur.

Watanabe (2002) found that "lesson study is a shared professional culture not just a professional development activity" (p. 36). It is not a professional model that tells teachers what to do, how to think, or how to act. It does not advocate for a best strategy, but, rather, is built on teacher curiosities about learning and focuses on helping teachers explore, develop, and practice a variety of strategies in their classrooms to reach each of their students in different ways and improve student understanding.

In Japan, the Lesson Study process works well because Japanese teachers feel a collective responsibility to improve teaching and to see their work in Lesson Study as research on teaching where their classrooms are laboratories for experiment (Fernandez, 2002). In Canada, the act of observing other teachers, giving feedback on teaching, and advancing knowledge on teaching is not a common practice. Teaching is a very private act and teachers do not feel responsible for other teachers' practice (Avalos, 2011). This difference in culture leads to a different implementation or focus for Lesson Study in Canada and a different impact of the Lesson Study process. The goal in North America seems to be more about impacting an individual teacher's practice rather than teaching practice in general. Because the culture of learning is different, many challenges occur with implementing a Japanese process like Lesson Study. One such challenge is "for teachers to move beyond simply looking at their teaching to actually seeing what is of value in this teaching to them as learners" (Fernandez, 2002, p. 400). For some teachers, these are new ideas: seeing themselves as learners, the possibility of their students as teachers, and professional development as an opportunity for challenging their beliefs about teaching and learning. However, research on how to implement Lesson Study in Canada and the effect it can have on Canadian teachers has begun. Zhou and Xu (2014) have looked at how lesson study can help Canadian pre-service teachers learn how to teach and have shown how using the process provides opportunity for practice and collaborative and instant reflection. Work by Bruce, Ross, Flynn, and McPherson (2009) has looked at the effects of Lesson Study and demonstration classrooms on teachers' professional development. Tepylo and Moss (2009) examined the important features of Lesson Study in a Canadian context. Sibbald (2009) looked at the relationship between Lesson Study and teacher self-efficacy.

Research in North America suggests that versions of the Lesson Study process have the potential to create the conditions for teachers to examine the way they learn and think about teaching. Researchers have also expressed concern that educational research, in particularly in mathematics education, has played a limited role in supporting improvement in classroom practice (Stylianides & Stylianides, 2013). During Lesson Study, teachers have the opportunity to examine their preconceptions about teaching and learning, build on previous knowledge, and look to new ideas and ways of teaching to engage their learners and build a deeper understanding of mathematics. In this dissertation, I will examine how the Lesson Study process is being adapted and implemented in one North American context and examine in what ways the design is having an impact on teacher practice.

**Research Questions**

The research questions were designed to understand the impact of a Lesson Study process on teacher learning. Measuring participants' knowledge, skills, attitudes, and beliefs about teaching mathematics before participating in the Lesson Study and after completing the process showed whether the participants had changed because of the process. Because the purpose of the research was to better understand how to modify, implement, and use Lesson Study as a process for professional learning, examining each of the features gave insight about how they supported the conditions for teacher learning. Most teacher professional development is designed to assist teachers to address a student learning need or lack of achievement in a particular area. Because Lesson Study generally begins with teachers identifying a student learning need (Murata, 2011), asking teachers how they felt they addressed this need led to a better understanding of the effect of Lesson Study on both student and teacher learning. Thus, the following research questions were addressed through the research:

1. What impact does professional learning about instructional practice through a Lesson Study design have on the teachers in this study? (e.g., knowledge, skills, attitudes, beliefs, etc.)
2. Which features of the Lesson Study design support professional learning? In what ways?

3. What impact do teachers feel their participation in the Lesson Study has on their students' learning and achievement?

**Local Context**

The teachers involved in this project had never experienced Lesson Study prior to this study. Although the school board experimented with a modified version of Lesson Study, with teachers in the primary (Grades 1–3) and junior (Grades 4–6) divisions, it had not introduced this form of professional learning to the intermediate teachers (Grades 7–10). As a result, students and teachers in the intermediate division were not accustomed to having observers in the classroom. Because Grades 7–8 teachers were in the elementary school and Grades 9–10 teachers were in the secondary school, most of the teachers in the project were working closely and co-teaching with teachers from another school for the first time. Developing this cross panel working relationship was a challenge.

Administrators at the elementary and secondary schools were also invited to participate on the teacher teams to develop and teach lessons. Having administrators participate in professional learning alongside their teachers was also a new practice for most of the administrators and teachers in the project. As a secondary principal in the school board, I was a participant with my school in the project in addition to being the researcher. To minimize my influence, a teacher team from a different school, where I was not a participant, was selected for this study.

# CHAPTER 2

## Literature Review

> To bring theory and practice together takes an act of will, a source of energy, a shift of attention, a reconciling force. (Mason, 1990, p. 185)

Educational researchers have identified teacher learning to be one of the keys to improving the quality of education (Desimone, 2009). In fact, as part of a larger strategy for educational reform, the province of Ontario has addressed the issue of teacher learning through a number of targeted provisions that focus on extensive professional development for educators, to name but one approach, as a way of improving student success (Levin, 2007). This, of course, requires tax dollars for teacher professional development activities at the provincial, school board, and school levels. That said, during declining enrolment and times of financial stress, such as in a recession, taxpayers and governments want measures in place to ensure the most effective professional development is employed. Moreover, despite the importance of professional development, research on professional development suggests that professional learning activities for teachers often are described as ineffective (Hanushek, 2005). This problem reflects an ineffective view of learning, that is, how teachers learn from professional development (Borko, 2004), and the necessary conditions that support and promote teacher growth (Clarke & Hollingsworth, 2002).

Learning is a complex phenomenon; thus, complexity theory can act as a guide to better understand, support and promote teacher learning. First, however, to understand what a complex phenomenon is and why complexity theory would serve us well in our thinking about learning, I turn to an early contributor to what is currently known as complexity theory, Warren Weaver (1948), who played an important role by first defining what complex phenomena are. He explained how problems were either simple, involving few variables and predictable outcomes, or complicated (which he called problems of disorganized complexity), involving many variables that, only after a long period of time and usually only by using statistical methods, could be determine with confidence. Weaver went on to describe a third type of problem that he claimed many scientists at the time avoided—problems of organized complexity or problems having

many variables with rarely predictable outcomes. He observed that when an outcome did emerge for these complex phenomena it was not random but displayed a pattern.

In light of Weaver's early work on complexity, much of the literature on professional development could be described as disorganized complexity where the goal is to find what kinds of intervention could bring order to the system or to find the one instructional strategy that would lead all students to learning. This way of thinking might suggest that we all learn the same way; however, there are many variables that impact teacher and student learning, such as a teacher or student's previous experiences, school culture, an openness to change, and teacher and student efficacy, to name a few. Learning is different for each teacher, meaning what works (i.e., results in a change in practice) with one teacher may not necessarily have the same result for another teacher. As teachers move through their careers, they grow and change and their learning needs along the way change, too. This ever-changing nature of learning, constantly influenced and altered by different experiences, is what makes it a complex system. "A complex system is not just a form with more parts, but one that transforms itself as it experiences its world. Complex systems adapt and learn" (Davis & Sumara, 2005, p. 312).

There are many different definitions of a complex system. Generally speaking, however, a complex system consists of many interconnected parts that exhibit properties that emerge in unpredictable ways from the parts and their interaction with one another. The result is something greater than the sum of its parts or, put differently, something that cannot be found in any one part alone. Complex systems scholars have identified several key properties or characteristics of complex systems and use these characteristics to try to envision emergent phenomena. By looking at these patterns or characteristics in problems of organized complexity or complex systems, insight can be gained in how to better plan professional learning experiences for teachers so learning emerges.

This literature review begins with an exploration of complexity theory as a framework for teacher learning. Drawing upon complexity theory facilitates a shift of thinking from professional development, as something done to teachers, to professional learning, as something that occurs with teachers. The next part of the literature review includes a review of the current literature on professional development, revealing four key elements that are present when effective professional learning occurs. In addition to

these four key elements, the professional development literature also shows the importance of developing collaborative teams for teacher learning and the need to focus on teacher efficacy. Exploring the literature on professional learning for mathematics teaching helps to understand what reform teaching in a mathematics classroom might look like. Figure 1 shows how this chapter is organized.

One of the intents of this literature review is to show how the structure of Lesson Study reflects the elements of effective professional learning, paying attention to certain key characteristics of complex systems. The literature review will outline why Lesson Study has the potential to create the conditions for teacher learning to emerge. A quick review of some of the results, from research in North America on Lesson Study, will highlight how Lesson Study is adapted in North America and why more work needs to be done.

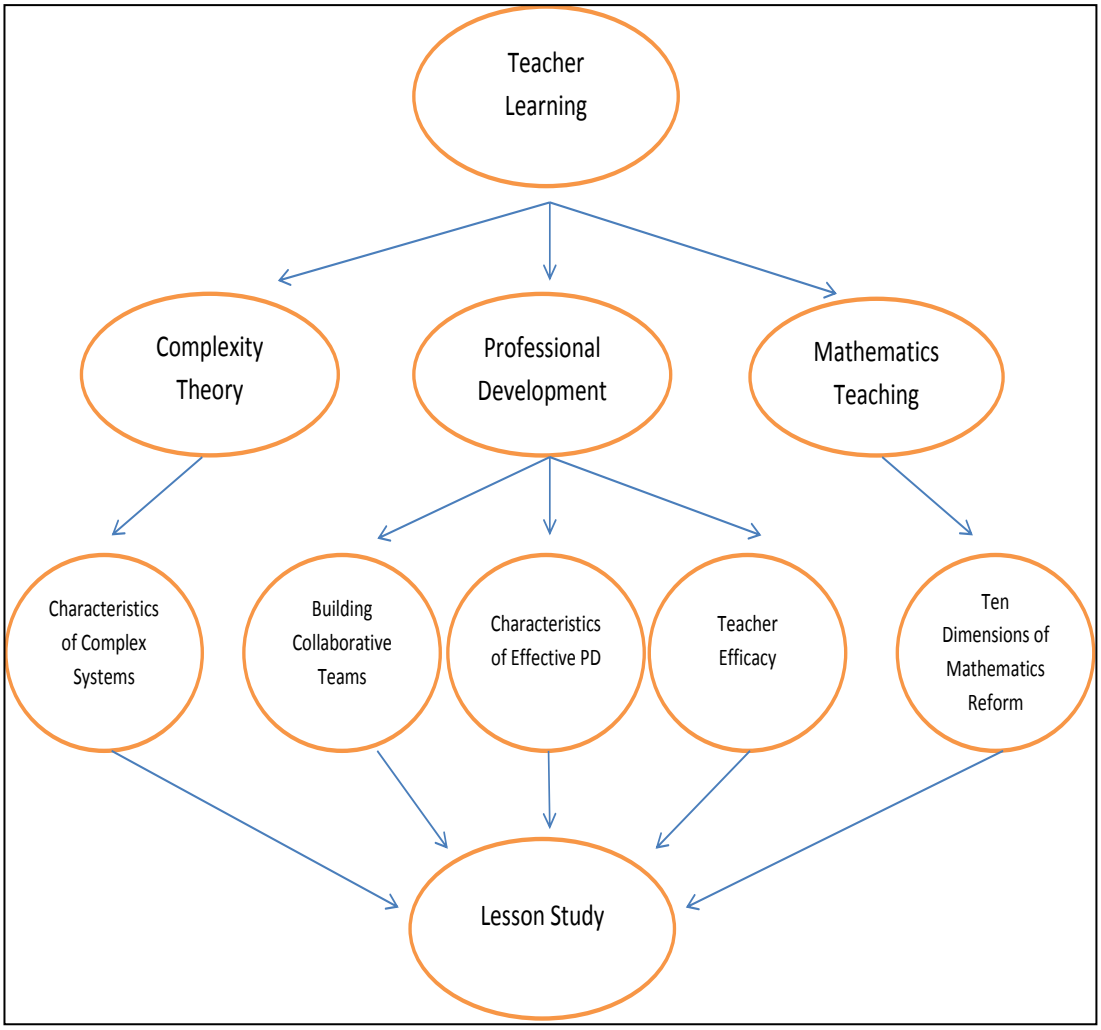


*Figure* 1. Organizer for the Literature Review.

## Complexity Theory as a Framework for Teacher Learning

> Such questions are the topics of complex systems, an interdisciplinary field of research that seeks to explain how large numbers of relativity simple entities organize themselves, without benefit of any central controller, into a collective whole that creates patterns, uses information and in some cases, evolves and learns. (Mitchell, 2009, p. 4)

What is "learning?" There are many different views or theories about learning. Early theories of learning, for example, have framed learning in terms of behaviourism. The behavioural models are primarily based on Skinner's objectivist theory of learning as conditioning (Skinner, 1968). As such, learning is seen as something that happens to you, requiring a great deal of reinforcement or repetition (conditioning). In terms of teaching, then, the model of teaching generally used reflects a transmission model where the teacher imparts knowledge and students practice, usually through drill, to master the material. Social learning theory expanded on behaviourist thinking by considering that learning takes place in a social context and can occur through observation of behaviour (Bandura, 1977b). In the 1990s, the rise of constructivism represented a shift in thinking about learning to reflect more social, conversational, and constructive aspects than in previous transmissive models (Jonassen & Land, 2012). A constructivist view sees learning as the interaction of experience and ideas. In this way of thinking, students learn to make meaning through doing. In this model, the teacher builds on students' previous knowledge by creating individual experiences to construct knowledge (King, 1993).

It is probably John Dewey's ideas that have been most influential in understanding what learning is. In Dewey's well-known terms: "It is that reconstruction or reorganization of experience which adds to the meaning of experience, and which increases the ability to direct the course of subsequent experience" (Dewey, 2004, p.74). Dewey describes the process of learning as being able to do something and thus defines learning as using an experience to demonstrate, accomplish, or create something. Davis and Sumara (2006) claim learning "is a matter of transformations in the learner that are simultaneously physical and behavioural-which is to say, in biological terms, structural"

(p. 13). Davis and Sumara are describing learning as something more than just an ability to do something but as a physically changed state. As such, the student is a different person after the learning. Not only can they behave differently, such as being able to demonstrate, accomplish, or create something, but their physical biology, the essence of who they are, is different. In other words, once you have learned something and know you have learned it, you can't go back to the way you were before (Maturana & Varela, 1987). This idea that you can't remember how you thought before, or how to think or act in any way but the new way, is the structural change that indicates real learning has happened.

Many things influence a teacher's learning. Biology, previous experience, current living environment, the teacher's beliefs about teaching and learning, the teacher's pedagogical and content knowledge, classroom environment, school and community culture, the teacher's learning community, the school board, and government initiatives are all possible influences, all interconnected in complex ways to form a system of learning. Webster's Dictionary defines a system as "a group of parts combined to form a whole that works or moves as a unit." Although all these pieces are independent, each can influence the other and the interaction together influences the teacher as she engages in a learning experience. Gribbin (2004) describes a complex system as a system that is made up of several simpler components interacting with one another in such a way as to produce something greater than the sum of the parts. These pieces, people, situations, or ideas that form the learning system are not fixed but are constantly changing, making learning a dynamic complex system. Teacher learning can happen in many different ways and might occur as a result of preconditions, some catalyst, the process in which learning was delivered, or some combination of people, events, and ideas (Opfer & Pedder, 2011). In theory, if teacher learning did happen, then the teacher would be transformed, forever changed and unable to return. Different combinations, circumstances, and sequences that may produce teacher learning in one individual may also lead to intellectual stagnation and inertia (i.e., no learning) in another teacher (Opfer & Pedder, 2011). The factors that influence learning for one person can have a completely different effect for another. A complex system of learning is a complex system because of the highly connected ways in which the diverse parts are connected where each part is shaped by and shapes the other

parts. As such, the way learning occurs for one person is not necessarily the same for the next person and this is why learning outcomes are not predictable. Hmelo-Silver and Azevedo (2006) claim, "In complex systems, the aggregate nature of the system is not predictable from isolated components but occurs through the interaction of multiple components" (p. 53). This means interactions rarely reflect a single event but rather how many variables might impact an event and how each event may impact neighbouring variables. To study teacher learning means to examine the connections between influences and to look for conditions in the environment that help learning to emerge.

Although many different frameworks have been used to examine learning, I have chosen complexity theory specifically because of the complex nature of learning. Complexity theory is a conceptual framework used for the purpose of analysing the behaviour of systems that consist of a large number of interacting components (Semetsky, 2008). It is hard to study the components or influences on learning because everything is intertwined in a complex system. By using complexity theory as a framework, we can examine how the pieces of the system are connected and how they impact each other and together influence the result, which is, hopefully, learning. Looking for, or paying attention to, the presence or absence of the certain characteristics of the complex system, such as self-organization, nested structures, or interacting agents, gives insight into the conditions that might help foster or hinder learning(Davis & Sumara, 2006). By making small adjustments to the different components of the system, we can see how these influence the emergence of learning.

**Moving from Professional Development to Professional Learning**

The goal of most professional development is to take a promising educational idea, hopefully based on theory, and incorporate it into practice. The purpose is to have teachers understand and adopt the new theory and apply it in their everyday experiences with students in the hopes that this new practice will improve student achievement (Kelleher, 2003; Loucks-Horsley et al., 2003). The belief is that new learning improves quality teaching and leads to greater student learning or understanding. Fenstermacher and Richardson (2005) describe quality teaching as follows:

> Quality teaching, we argue here, consists of both good and successful teaching. By good teaching we mean that the content taught accords with disciplinary

> standards of adequacy and completeness, and that the methods employed are age appropriate, morally defensible, and undertaken with the intention of enhancing the learner's competence with respect to the content studied…. By successful teaching we mean that the learner actually acquires, to some reasonable and acceptable level of proficiency, what the teacher is engaged in teaching. (p. 191)

Unfortunately, not all professional development improves teaching quality (Kent, 2004; Opfer & Pedder, 2011). Even though a new theory being shared, for example, is sound and appropriate, teachers may fail to learn or adopt the new theory. There are many reasons why this might happen. Teachers may fail to engage in the professional development (Ferguson, 2006). They may not see the value of the educational theory being delivered through the professional development (Foster, 2014). They may question how the new educational theories were arrived at and whether they were tested on real students or, at least, students similar to the ones they interact with (Bissonnette & Caprino, 2015; Kent, 2004). Teachers sometimes fail to see the connection between the theory and the classroom or feel they have already seen that theory under a different name and believe it doesn't work and treat it as a passing fad (Foster, 2014). Teachers may feel the theory is not useful because they cannot see how it is related to their problems of practice (Loucks-Horsley et al., 2003; Wei, Darling-Hammond, Andree, Richardson, & Orphanos, 2009). Teachers sometimes also feel that their experience in the classroom is undervalued because the theory given to teachers is someone else's idea and did not come from the teacher's practice (Lieberman, 2000). Teachers who are not given the opportunity to help guide the agenda for their learning can fail to engage in the learning prescribed for them. Teachers feel motivated to learn when three needs are met: agency or self-determination (able to set goals for and direct their own learning), competence (developing skills they find valuable and applicable to their classroom), and human connection (belonging in mutually valuable relationships) (Lewis, Perry, Friedkin, & Roth, 2012).

Much of the literature on professional development is also focused on developing teachers through the delivery of programs rather than on how to support professional learning (Webster-Wright, 2009). The focus is on what to learn and not on how teachers learn. In reviewing teacher learning opportunities, Gravani (2007) says that "emphasis

should be placed on the processes by which they [teachers] grow professionally, as well as, the conditions that support and promote that growth" (p. 689). Professional learning is more about life-long learning. Kwakman (2003) describes professional learning as "strongly connected to professional goals which demand teachers to strive for continuous improvement of their teaching practices" (p. 152). Bransford, Brown, and Cocking (2000), editors of the National Research Council's report on how people learn, found "much of what constitutes the typical approach to formal teacher professional development is antithetical to what promotes teacher learning" (p. 267). Their report identified three key findings about how people learn that are related to preconceptions, framework, and reflection. Paraphrased and put into the context of teacher learning, they are as follows:

1. Teachers hold preconceptions about teaching and learning. If these initial understandings are not engaged, teachers may fail to grasp or make connections to the new concepts and information to which they are exposed, or they may learn them solely for the purposes of an external mandate and then revert to their preconceptions once it is removed.
2. Teachers need a foundation of declarative and procedural knowledge about their subject content and teaching pedagogy. They can better understand these ideas with the context of a conceptual framework, a cognitive map, or a schema that organizes the fundamental ideas or concepts into categories of information and recognizes relationships among concepts for teaching that facilitates application.
3. Metacognitive, or reflective, opportunities can help teachers take control of their own learning by defining goals and monitoring the progress toward their achievement.

In Daniel Pink's book *Drive* (2009), the subject matter in the book looks at learning in a similar but slightly different way where he found that people stay motivated to learn and produce quality work if three things are present: autonomy, mastery, and purpose. Teachers, like any other workers, have the desire to direct their own life, learn and create new things, and improve life for themselves and others. Teachers want to have control over what they learn, how they will learn it, and when they will learn. Teachers

focus on what works in their classroom for their teaching subject and strive to make a difference in the lives of their students. Professional development models that use these principles of how teachers learn and structure learning to create a sense of autonomy, mastery, and purpose have a greater chance of engaging teachers in learning (Webster-Wright, 2009) and ultimately improving the quality of teaching. For a summary of these ideas see Figure 2.

Teachers, like students, have certain capabilities, previous knowledge, and experiences that shape their understanding of teaching and the role they play in learning. For teacher learning or professional growth to occur, change must occur in multiple areas of influence (Clarke & Hollingsworth, 2002). Professional learning experiences must pay attention to, and attempt to impact, a variety of these influences to create opportunities for teachers to add to their understanding of teaching and assist them in learning about new practices.

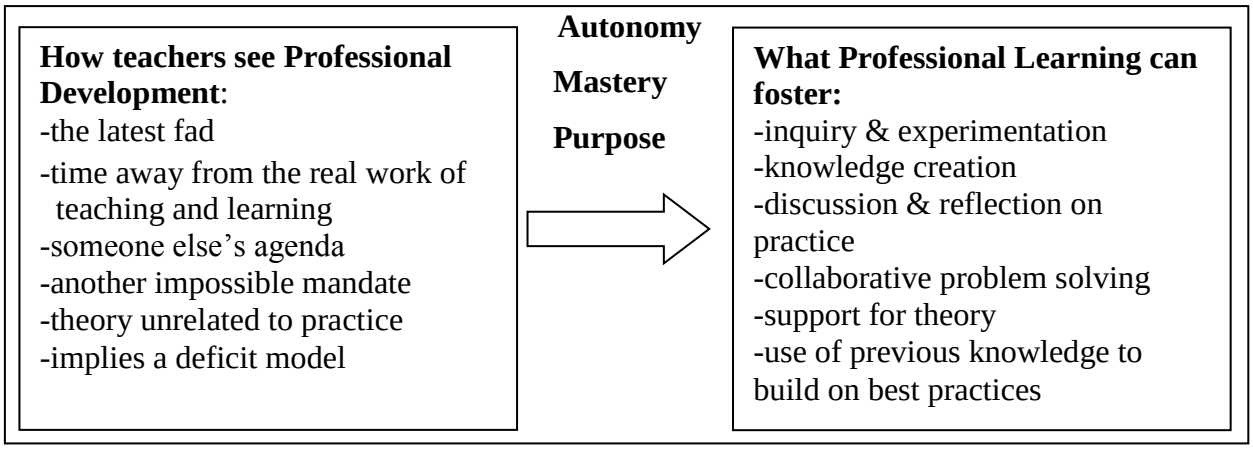


*Figure* 2. Professional Development vs. Professional Learning.

Determining the characteristics of effective professional learning requires collecting evidence to identify the professional development practices that are successful. Evidence of teacher learning could include enhanced subject knowledge, better understanding of student thinking, development of new skills or teaching strategies, changes in attitudes towards teaching and learning, or the adoption of new beliefs about education (Borko, 2004). Looking at the characteristics of professional development where teachers reported self-learning will help build an understanding of the conditions necessary for teacher learning to emerge.

**Characteristics of Effective Professional Development/Learning**

In the first United States large-scale empirical comparison of effects of different characteristics of professional development on mathematics and science teachers' learning, Garet, Porter, Desimone, Birman, and Yoon (2001) identified several key characteristics teachers reported that had increased their knowledge and skills and changed their classroom practice. The key characteristics identified were: (a) a focus on content knowledge, (b) opportunities for active learning, and (c) coherence with other learning activities (connected to their other professional development experiences, aligned with standards and assessment, and foster professional communication). They also found that, primarily through these core characteristics, the following structural features significantly affected teacher learning: (a) the form of the activity (e.g., workshop vs. study group), (b) collective participation of teachers from the same school, grade, or subject, and (c) the duration of the activity (sustained intensive professional development was more likely to have an impact). The study, conducted over 3 years with a sample of 1,027 teachers, showed content focus and coherence as having substantial positive associations with enhanced knowledge and skills. Unfortunately, this study had no measure to verify whether changes in instructional practice took place or led to improved student achievement.

A study by Fishman, Marx, Best, and Tal (2003), claimed teachers' knowledge, beliefs, and attitudes were the aspects of teacher cognition affected by participation in professional development. In their model of teacher learning, they suggested teachers' knowledge, beliefs, and attitudes were not only formed by curriculum, professional development design elements, and the professional development activities, but that they are also formed interactively with classroom enactment (teachers putting the new learning into practice). Student performance was described as also influencing teachers' knowledge, beliefs and attitudes, mediated through the classroom experiences. In their study of over 40 teachers, they measured both teacher and student learning. Surveys were given to teachers to rate their learning and classroom observations of teachers' practice were done by the researchers. Student data were collected from a pre- and post-test on the curriculum teachers were learning. The data presented showed a significant increase in

student achievement in the second year of professional development. This study highlighted the need for sustained teacher learning over time.

Akiba and LeTendre (2009) looked at best practices for improving teacher quality in the United States, Japan, and Australia. Their review of relevant research revealed that effective professional development is: (a) sustained and continuous, (b) coherent with teachers' learning goals, as well as, school missions and reform goals, (c) focused on teaching practices and student learning in the context of actual classrooms, and (d) provides for teacher collaboration. For professional development focused on teaching practices and student learning in the context of actual classrooms, research revealed fewer than 25% of teachers in the United States participate in activities where they review student work or score assessments, develop and practice using student materials, or conduct a demonstration of a lesson, unit, or skill (Birman et al., 2007).

Borko (2004) identified the key elements of a professional development system as (a) the professional development program, (b) the teachers who are the learners in the system, (c) the facilitators who guide the teachers, and (d) the context in which the professional development occurs. She argued that what matters, or what makes the professional development effective, is the quality of the program and facilitators and the teacher characteristics and knowledge. She claimed that the key elements of effective professional development were a focus on subject matter and how students learn that subject matter, engaging teachers as learners and as members of strong professional learning communities. In a 2-year long project from 2004 to 2005, Borko and a team of researchers implemented a professional development model with a summer workshop for teachers to discuss content knowledge and new pedagogical strategies (Borko, Jacobs, Eiteljorg, & Pittman, 2008). During the school year, teachers videotaped themselves applying their new ideas and skills in their classroom. The following summer, teachers debriefed the video evidence and student work from the class. Results showed improved teacher knowledge and skills.

According to Doppelt, Schunn, Silk, Mehalik, Reynolds, and Ward (2009), research showed a consensus on the characteristics of effective professional development to be engaging teachers in an active learning process situated in the curriculum and facilitating a collaborative community of teacher professionals who share student

materials and classroom practice over a series of sessions. Combining this research with the other studies on how people learn leads me to the following key characteristics of effective professional development:

1. build on teachers previous knowledge and address their beliefs and attitudes about education
2. engage teachers in an active learning process situated in the curriculum ( i.e., learning driven responsive teaching)
3. use metacognition and reflection to help teachers set goals and monitor their progress
4. facilitate a collaborative community of teacher professionals for support and sharing of resources

These characteristics pertain to the teacher and to some of the factors that influence teacher learning, such as previous experience, classroom environment, the teacher's pedagogical and content knowledge, the teacher's beliefs about teaching and learning, and the teacher's learning community. When these characteristics are present, sustained over time, and the school and community culture are taken into account, the conditions for teacher learning exist and can lead to improved student achievement (Opfer & Pedder, 2011).

**Building Collaborative Learning Teams**

Effective professional learning places teachers in collaborative learning communities. Learning communities are based on two assumptions. First, professional knowledge is situated in the daily experiences of teaching and is best understood through critical reflection with those who share the same experience (Buysse, Sparkman, & Wesley, 2003). Second, when teachers actively participate in a learning community they increase their professional knowledge and improve students' learning (Vescio, Ross, & Adams, 2008). A strength of learning communities is they acknowledge that learning is social and that teachers learn from and with one another through observation and dialogue. In learning communities, teachers can examine their practice and tackle common problems in teaching and learning. Cochran-Smith and Lytle (1999) suggest that teachers in learning communities:

> pose problems, identify discrepancies between theories and practices, challenge common routines, draw on the work of others for generative frameworks, and attempt to make visible much of that which is taken for granted about teaching and learning. From an inquiry stance, teachers search for significant questions as much as they engage in problem solving. (p. 293)

Working collaboratively in a learning community, participants have the opportunity to challenge their beliefs and attitudes about teaching and learning. As Wenger (1998) puts it, "such participation shapes not only what we do, but also who we are and how we interpret what we do (p. 4)."

Through a *Professional Leaning Inquiry Cycle*, Timperley, Wilson, Barrar, and Fung (2008) described how teachers can use the interactions with groups of teachers, focused collaboration, to move forward in their understanding of teaching and learning. In the first step, teachers ask questions about why students struggle, what knowledge and skills students are missing, and how to help students use what they know to learn what they don't know. After determining a student need, teachers determine what knowledge and skills they need to answer their questions about student learning. As teachers move through the cycle, they deepen their professional knowledge and skills by engaging in professional learning. They use their new understandings to engage their students in new learning experiences. After assessing the impact of the experience on students, teachers reflect on the evidence of the students' and teachers' learning and raise new questions to begin the cycle again. This practice of inquiry where there is a question, new learning, action, and reflection is the practice that most teachers ask or wish for their students. What better way to teach students the practice of inquiry than to model it through teacher practice and learning? This is what teachers engaged in Lesson Study are doing. By participating in a learning community, a network of teachers involved in inquiry (such as a Lesson Study process), the "multilayered self-similar, recursive, and negotiatory natures of teaching and learning" are revealed (Davis, 1996, p. 118).

**Teacher Efficacy**

Many studies have shown that teacher collaboration (such as the work in learning teams) can increase teacher efficacy (Bruce, Esmonde, Ross, Dookie, & Beatty, 2010; Lakshmanan, Heath, Perlmutter, & Elder, 2011; Puchner & Taylor, 2006). Teacher

efficacy can be defined as a teacher's self-assessment of her ability to successfully perform specific teaching and learning tasks within the context of the classroom that support students learning (Bruce et al., 2010; Dellinger, Bobbett, Olivier, & Ellett, 2008). The four main sources of positive teacher efficacy information for teachers, originating from the work on Bandura (1977a), include mastery experiences (e.g., when teachers master a challenging teaching strategy or skill and experience success), vicarious experiences (e.g., observing peers who are seen as similar in skill teaching something challenging and having success), social and verbal persuasion (e.g., receiving positive reinforcement and encouragement from students, peers, and administration), and, lastly, physical and emotional states at the time of a task (e.g., feelings of excitement, success, and confidence).

In the context of professional learning, teacher efficacy could play a major role in teacher willingness to participate and openness to learning. Teacher efficacy affects teachers' attitudes toward education and their instructional practices (Tschannen-Moran & Barr, 2004). Teachers with a high sense of efficacy display enthusiasm for teaching and are more likely to be open to testing new instructional ideas to meet the learning needs of their students (Bruce & Flynn, 2013). Teacher efficacy as a single factor would not guarantee student success, but a focus on teacher efficacy could help put teachers in the right frame of mind for learning. Could the reverse be true? Could professional learning improve teacher efficacy? There have been few studies that investigate the effects of professional development on teacher efficacy (Bruce & Flynn, 2013; Lakshmanan et al., 2011; Ross & Bruce, 2007). Professional learning that takes into account Bandura's four determinates of self-efficacy, such as planning mastery experiences (like standards-based teaching) with vicarious experiences (like observation of teaching from "likeable" peers in classrooms) with social and verbal persuasion (like coaching and team work) and include planning for physical and emotional states (like release time during the school day for professional learning), should have a positive impact on teacher efficacy. Measuring teacher efficacy before and after professional learning could show whether a learning experience had any impact on teachers' attitudes about teaching and their beliefs in their ability to create conditions for student learning.

Dellinger et al. (2008) call for the measurement of teachers' self-efficacy beliefs to be related to specific important tasks in the context of teachers' classrooms.

**Mathematics Teaching and Professional Learning**

In mathematics, teachers need specific pedagogical content knowledge. Ball, Lubienski, and Mewborn (2001) described pedagogical knowledge as being "about representations of particular topics and how students tend to interpret and use them, for example, or ideas or procedures with which students often have difficulty" (p. 448). Teachers construct knowledge about teaching by watching, doing, and discussing. Stigler and Hiebert (1999) described teaching as a cultural activity, meaning each culture has different beliefs about how students learn and about the role teachers should play in the learning process. Much of what teachers know about teaching has been learned in their experience as students in elementary school through to university. Speaking specifically about mathematics teaching, Suurtamm and Roulet (2007) found that "since teachers often teach in ways they were taught, they need to personally develop an understanding of new mathematical concepts through the process of investigation and modeling for it to have meaning for them" (p. 495). Because most people repeat what they have experienced, teaching strategies have not changed significantly over the years. Stigler and Hiebert claimed teaching practice has remained stagnant and resistant to change because there has been little or no opportunity for teachers to learn how to improve their teaching skills.

The focus is not on looking for what professional development to give to teachers but on looking for what professional learning experiences will bring teachers together and what structures need to be in place to build a community so teachers are guided to act in meaningful ways that inform their practice. Suurtamm and Graves (2007) found that mathematics teachers in Ontario want professional development that teaches them about problem solving, helps them to understand how students learn mathematics, and focuses on new effective teaching strategies.

Schoenfeld (1992), writing on mathematics instruction, claimed that "instruction should be aimed at conceptual understanding rather than at mere mechanical skills, and at developing in students the ability to apply the subject matter they have studied with flexibility and resourcefulness" (p. 32). Mathematics lessons need to create spaces for

learning to emerge and for students to demonstrate their understanding and to make their thinking visible. Mathematics lessons that are centered on teachers telling students how to solve problems are promoted less than lessons centered on students inquiring how to solve problems where they are experimenting with different problem solving strategies. Suurtamm and Graves (2007), talking about changing mathematics teaching, claim that the kinds of changes teachers are being asked to undertake in Ontario "are not simple and require a substantive re-orientation of their basic beliefs about the world in general, and mathematics education in particular" (p. 156).

This kind of mathematics teaching being espoused is what is referred to in the literature as "reform mathematics." Ross, Hogaboam-Gray, McDougall and Bruce (2002) claim, "in traditional mathematics there is a generic script that guides each day's lesson through a manageable body of content. In reform mathematics the day is governed by unpredictable student responses to real life problems" (p. 88). How to measure a teacher's implementation of reform mathematics has been a focus for John Ross and his associates. Based on a review of the key National Council of Teachers of Mathematics (NCTM) documents and 154 empirical studies, Ross, McDougall, and Hogaboam-Gray (2002) developed a list of nine dimensions of standards-based mathematics teaching and a survey for teachers to help self-assess their implementation of the dimensions (Ross, McDougall, Hogaboam-Gray, & LeSage, 2003). The research revealed evidence of the reliability and validity of the self-reported survey to measure elementary teacher commitment to standards-based mathematics teaching. When Ross and McDougall (2003) later did work with secondary teachers, the original 9 dimensions were expanded and reorganized into 10 dimensions (see Appendix A) as:

- Program Scope
- Opportunity to Learn
- Students' Confidence
- Students' Tasks (solution strategies and multiple representations)
- Construction of Knowledge
- Teacher Role
- Mathematical Tools (manipulative use, technology use, and purpose of manipulatives and technology use)

- Student-Student Interaction (explicit instruction, task, and communication)
- Student Assessment (purpose, transparency, and variety)
- Teacher's conception of mathematics as a discipline (dynamic nature and connections)

One question still being explored is whether use of the survey heightens teacher understanding of the dimensions of standards-based teaching? Ross et al. (2002) claim the next step is to test the validity of the survey to track changes in teacher practice in the evaluation of large-scale mathematics teaching improvement projects. Darling-Hammond and McLaughlin (1995) claim that "systems of self or peer reflection, examining the effectiveness of teaching and student learning, enable teachers to change their view of effective models of practice, creating a process of transformational learning for teachers" (p. 3). This type of reflection is a characteristic of effective professional development.

By using the Ontario Ministry's tools or resources for mathematics teachers, such as the three-part mathematics lessons in the Targeted Implementation and Planning Supports (TIPS) documents, the mathematical process expectations (i.e., reasoning and proving, reflecting, selecting tools and computational strategies, connecting, representing, and communicating) outlined in the Ministry documents, the Ministry's Differentiated Instruction Teaching Learning eXamples (i.e., TLX–lesson planning template), software tools (e.g., smart notebook to make interactive lesson on the smart board), and manipulatives (e.g., blocks, tiles, etc., to address kinesthetic learners and allow students to explore and participate in meaning-making), professional learning can be designed and delivered through the Lesson Study model to help teachers reflect on their practice (Lewis et al., 2012) and approach building their students mathematical understanding from an inquiry stance.

If professional knowing is embodied, contextual, and embedded in practice and learning is a change that occurs through experience and reflective action, then professional learning should reflect this understanding and acknowledge the difficulties and limitations in researching such an experience (Webster-Wright, 2009).

**Effective Professional Learning, Lesson Study, and Complexity Thinking**

Takahashi and Yoshida (2004) claim that:

> Lesson Study provides the context for teachers to focus their discussion on planning, implementation, observation, and reflection on classroom practice. By looking at the actual classroom practice, teachers are able to develop a common understanding or image of what good teaching practice entails, which in turn helps students understand what they are learning. (p. 438)

Takahashi and Yoshida's description is the kind of professional learning experience that has the potential to impact teachers and focus their thinking on practice that leads to improved student learning. Lewis, Perry, and Murata (2006) found that Lesson Study strengthened three pathways to instructional improvement: teachers' knowledge, teachers' commitment and community, and learning resources. They found teachers increased their knowledge in subject matter, instruction, observation capacity, and connecting daily practice with long-term goals. In terms of commitment and community, they saw an increase in teacher motivation to improve practice and a greater connection to develop with colleagues who could provide help and a sense of accountability. New and innovative learning resources were created through lesson plans that revealed and promoted student thinking and tools were developed that supported collegial learning during Lesson Study (e.g., observation checklists).

Lesson Study is a framework that supports effective professional learning. Using complexity thinking can increase the potential of Lesson Study to effect change in teachers' instructional practice by creating conditions for learning to emerge. According to Davis and Sumara (2006), several qualities must be present for a phenomenon, such as learning, to be classed "complex." These qualities are not limited to, but include, self-organization, bottom–up emergent properties, interacting agents, nested structures, ambiguously bounded, organizationally closed, structure-determined, and far-from-equilibrium. Through examining each of these qualities or characteristics of complex systems, ideas on how to influence learning will emerge.

Table 1 is meant to be an organizer that highlights the components of the Lesson Study process that connect to each of the elements of effective professional development and with suggestions of which characteristics of complex systems could increase the likelihood of success. For each element, the connection to the Lesson Study process will

be explained as well as various ideas on how to maximise on the characteristics of complex systems.

Table 1. *Effective Professional Development, Lesson Study, and Complexity Thinking*

| **Elements of Effective Professional Learning** | **Lesson Study Process** | **Characteristics of Complex Systems** |
|---|---|---|
| **Element 1**<br>• build on teachers previous knowledge and address their beliefs and attitudes about education | **Teaching and Learning Focus**<br>• creating and observing a subject specific lesson<br>• discussion about practice<br>• focus on responsive teaching | **Structure Determined**<br>• clear boundaries but outcomes not predictable<br>**Far From Equilibrium**<br>• embracing change, look for new and creative solutions |
| **Element 2**<br>• engage teachers in an active learning process situated in the curriculum | **Co-Constructed Knowledge (Collaborative Inquiry)**<br>• teachers work together similar to how students work together : inquiry based<br>• observation of lesson in the classroom (focused on student reactions)<br>• lesson modified through observation and discussion | **Nested Structures**<br>• scale free network ( i.e., any part resembles the whole)<br>**Ambiguously Bounded**<br>• components distinguishable but intertwined<br>• system influences itself and learns from itself |
| **Element 3**<br>• use metacognition and reflection to help teachers set goals and monitor their progress | **Teacher Observation & Reflection**<br>• use of student data to set direction<br>• observation of students work drives lesson development<br>• iterative process (learning | **Bottom Up**<br>• grassroots movements<br>• “seed model” start small and grow<br>**Organizationally Closed**<br>• certain constraints and boundaries have to be in place for the system to |

| | | |
|---|---|---|
| | cycle: plan, teach, observe, reflect)<br>• team sets the focus<br>• students response informs the teacher learning | survive<br>• many possibilities exist within the boundary |
| **Element 4**<br>• facilitate a collaborative community of teacher professionals for support and sharing of resources | **Community of Learners**<br>• team approach<br>• includes outside facilitator as co-learner<br>• discussion about practice<br>• all teams share learning to reach their final product | **Self-Organization**<br>• collective coming together, without outside direction for a shared purpose<br>**Interacting agents**<br>• learning through neighbour interactions<br>• small changes can lead to large effects |

**Element 1: Build on teachers' previous knowledge and address their beliefs and attitudes about education.**

Lesson Study can create the conditions for teachers to examine the way they learn and think about teaching. During Lesson Study, teachers have the opportunity to examine their preconceptions about teaching and learning, build on previous knowledge, and look to new ideas and ways of teaching to engage their learners and build deeper understanding (Lewis, Friedkin, Baker, & Perry, 2011).

Looking for the relationship between Lesson Study and self-efficacy, Sibbald (2009) followed a team of three intermediate teachers through the Lesson Study process. His results highlighted the importance of each teacher's previous ideas of mathematics teaching and the importance of pedagogical or content knowledge that each could share. It was through the sharing of ideas from each teacher's previous knowledge of mathematics teaching that the teachers in the group learned new methods. As the teachers recognized their different approaches, they became open to new ideas and embraced other sources for information on teaching, which Sibbald referred to as their community of practice. This helped the teachers to learn new strategies and expand their repertoire, which increased their self-efficacy. Sibbald's results suggest that Lesson Study can help

teachers to improve their practice, but participants must be able to share, explain, and resolve issues pertaining to details of pedagogical content knowledge and associated content pedagogy. This also suggests that teachers weak in content knowledge may struggle in Lesson Study and would require a strong community of practice to assist with knowledge creation.

Because education is a complex system, educators should always expect surprises no matter how well they plan. How many times has a teacher said, "the lesson did not go as I expected?" Teaching and learning is not about something a teacher says or does that results in students performing the desired outcome, but, rather, teaching and learning are connected and student and teacher move in unison back and forth to trigger learning. Learning is not an event, but is a gradual change in the learner's ever-evolving structure (Davis & Sumara, 2007). In discussing teacher planning, Davis and Simmt (2003) said, "pragmatically speaking, decisions around planning are more about setting boundaries and conditions for activity than about predetermining outcomes and means proscription rather than prescription" (p. 147). Proscription is telling students what they can't do (e.g., you can't leave the room as you investigate or you can't use a calculator for this activity) and prescription is telling students what they have to do (e.g., you must follow the same steps on the board to solve the problem). Making clear the non-negotiables is important when dealing with young people, but allowing learning to unfold rather than to plan it all out creates the space for the emergence of new ideas and connections. In Lesson Study, teachers have an opportunity to plan a lesson, think about how students will respond, and then test their assumptions. Rarely do teachers, in North America, have this opportunity to watch what happens and test their preconceived ideas (Lewis et al., 2012). Sometimes colleagues and even members of society espouse that educational outcomes are pre-determined by social economic factors. This would imply that only certain students have the ability to learn and that only certain conditions, such as affluent schools, can produce learners. If teachers recognize that the structure of the education system is determined, but that the outcome for students can be different, depending on the teaching strategy used, then they are more likely to take time to explore and find these strategies. If Lesson Study is to achieve its potential, then teachers need to be afforded this time (Cajkler, Wood, Norton, Pedder, & Xu, 2015). When teachers are encouraged to work together and

given time to experiment, inquire about and interact with a concept, draw on their previous experiences, see a purpose for learning, and create their own meanings rather than be told what to think, then the necessary conditions for learning are present (Cajkler et al., 2015; Lewis et al., 2012).

Many policy makers believe education is about continuous improvement. Goldstein (1994) states, "at equilibrium a system seeks to stay the same, continuing its habitual patterns and in a sense constantly repeating the past" (p. 14). Thus, for real sustainable change to happen, a far-from-equilibrium state has to be in place, a state where conditions "facilitate an organization or work group in coming up with creative, new solutions to the challenges it faces" (Goldstein, 1994 , p. 15). Following a district for four years through widespread implementation of Lesson Study, Perry and Lewis (2009) found schools were able to use Lesson Study on a school-wide basis to address high priority district initiatives. Perry and Lewis reported that views of Lesson Study shifted over the study period, moving from "emphasis on the lesson as an instructional product, to a view of lesson study as a process for instructional improvement" (p. 8). Lesson Study created the space for continuous improvement.

Complexity theory helps us see that learning is not something that can be predicted and predetermined, but, rather, the teacher's role can be to create the conditions for learning to happen. Stanley (2009) uses complexity science to suggest:

> that teachers can be less prescriptive; rather than thinking of learning as linear and sequential, teachers could be encouraged to imagine it as a web of playful possibility, where their role is to outline the "playing area," allowing for connections and insights to arise through shared class activities. When the classroom is thought about and organized in this way, it is the interactions among students and ideas that propels learning forward. (p. 2)

It may be new and challenging for teachers to give up control and to let student interactions dictate direction. In reality, this is what frequently happens even when teachers try to plan and rehearse every moment. Participation in Lesson Study is an exercise in accepting unpredictability in the classroom. Teacher-observers, in the process, watch the lesson unfold and try not to interact with students, but instead notice how students respond. By observing students and how they respond to the lesson, teachers see

new possibilities and are able to explore different solutions to their problems of practice (Lewis et al., 2012).

**Element 2: Engage teachers in an active learning process situated in the curriculum.**

Lesson Study brings teachers of the same subject together and focuses on the specific pedagogy of that subject. Together, through the Lesson Study process, teachers are co-constructing knowledge about the best ways to teach their subject (Lewis et al., 2012). The topic of the lesson is chosen by the participating teachers to gather information on a problem of practice. The lesson becomes a collaborative inquiry about finding the most effective teaching strategies. In the Lesson Study, teachers are looking at what students are doing during the teaching of the lesson and using evidence of how students are making sense of the teacher's instruction to inform their teaching practice. As Wang-Iverson (2002) explains, "the real *lesson* of lesson study is not product, but process. It compels teachers to examine their own practice in depth, connects them with their students and their professional community, and inspires them to teach better every day" (p. 2, *emphasis* in original).

Puchner and Taylor (2006) followed two different Lesson Study teams of elementary mathematics teachers from different school districts. They documented each team of four teachers as they went through each stage of Lesson Study (i.e., planning, teaching, observing, and debriefing). The stories showed some of the ways participating teachers experienced Lesson Study and, through the process, created a climate of collaboration and inquiry among themselves. Puchner and Taylor claimed their results showed the impact of Lesson Study included not only teacher recognition of the benefits of collaboration, but a renewed understanding for teachers that they could, through their instruction, significantly impact their students' learning. Teachers in their study developed "a belief that there may be changes in the way that mathematics is taught that could impact student learning" (p. 931). Seeing the impact they had on student learning changed their beliefs about what was an effective mathematics instructional strategy.

Tepylo and Moss (2011) followed one Lesson Study group of four elementary mathematics teachers and found similar results to Puchnea and Taylor's study. As the teachers in their study discovered a range of student strategies for solving fraction

problems, “their conceptions of effective teaching also seemed to expand. This suggests possible changes in beliefs” (p. 75). Teachers in both studies were able to change their thinking about teaching and learning mathematics. Student responses influenced teacher beliefs and new teacher beliefs influenced the classroom dynamic. There was learning at the teacher, classroom, and student level, leading to the idea of nested structures. This study also exemplified how the system influenced itself. Intentional instructional moves led to changes in student understanding that influenced teacher thinking and led to further changes in classroom practice.

The idea of a nested structure or scale free network is that any part resembles the whole (Davis & Sumara, 2006). Enlarging any one piece generates an image that closely matches the original. Whenever we are looking at learning we can look at the individual level or the collective level or we can look at the student level or the teacher level. Active learning at the teacher level is similar to the active learning at the student level especially when we are looking at inquiry. Scale free means things don’t get simpler as you zoom in or out. Complex systems are studied at the level of their emergence and learning can emerge at every level with interaction across levels. Teachers, through their participation in the Lesson Study, are in classes actively modeling for students the inquiry process and observing students as they interact. It is through this observation that teachers are discovering and noticing the conditions present as student learning emerges (Cajkler et al., 2015). In the debrief sessions, teachers are interacting with one another, reflecting on students’ work and observation notes. It is through this debrief that teacher learning is emerging as the collective modifies and adjusts its understanding of teaching and learning (Dudley, 2013). No matter what scale we are looking at, the processes in play are self-similar and hence form a nested structure. Davis and Sumara (2006) suggest that the items in the nested structure “operate and unfold in similar ways” (p. 92). At each level (whether individual or collective, student or teacher), the learning is interconnected and occurring at all levels in a similar way. Teachers coming into Lesson Study with an open learning stance, willing to have their thinking challenged and to do the necessary work, similar to what they ask of their students, are more likely to be successful in their goals for professional learning.

In complex systems, it is difficult to distinguish between boundaries, levels, or influences (Morrison, 2008). For example, are children influenced more by their biological makeup or by the environment in which they grow up? It is the nature versus nurture argument. Many studies have been conducted to determine whether nature or nurture has the greater influence, but no exact amount has been calculated in favour of either. The boundary of where one takes on a greater influence over the other is not consistent in every situation (Pinkner, 2004). In education, the question can be asked, "Who has more influence over a student's learning, the teacher or the student's peers?" My answer is: it depends on the context and the student.

Where do we focus first? Which level should get the most attention? In a complex system, the components in the nested structure are distinguishable but intertwined and can exist in the same space (Davis & Sumara, 2006). This means the answer to the question of where to focus is not clear because all the areas influence each other. Focusing on teacher learning, for example, impacts teacher practice that can then impact classroom expectations and student learning (Kent, 2004). As students' learning occurs, student responses can impact teacher action just as it did in Puchner and Taylor's (2006) study described above. The system influences itself and learns from itself. In Lesson Study, teachers can use observed student action and learning to influence the lesson and to help teachers learn more about effective practices. The iterative process of plan, teach, observe, modify, re-teach, observe, and, so on, in Lesson Study means the learning at each level is influencing the whole system. Where the system begins and ends is unclear. This iterative process is the key to both Lesson Study and teacher learning (Lewis et al., 2006).

### Element 3: Use metacognition and reflection to help teachers set goals and monitor their progress.

Observation and feedback promote dialogue and reflective thought (Darling-Hammond & Richardson, 2009). The iterative process of Lesson Study helps teachers to create communities of learners that can collaboratively inquire about effective practice, test theories, and reflect on progress. For example, in a study conducted by Podhorsky and Fisher (2007), participants named reflection as the most significant influence of Lesson Study. Reflection occurred during the group planning sessions and observational

debriefing sessions. Teachers in the study reported increased levels of reflection on teaching practices.

Participants in the Podhorsky and Fisher (2007) study also identified the structure of Lesson Study as a model for teacher-led professional development. The focus on a lesson allowed teachers to work with curriculum and "formulate more effective short and long-term goals and plans for their student and themselves" (Podhorsky & Fisher, 2007, p. 453). The process gave teachers the opportunity to strengthen their content and pedagogical knowledge and monitor their progress on both. Teachers felt that they were directing their own learning or that their learning was bottom-up emergent.

The idea of bottom-up emergence in education has been seen in the notion of "grass-roots initiatives" (Davis & Sumara, 2006). Typically, initiatives have come from the top down. New mandates have been proclaimed by governments, passed down through school boards, schools, teachers, and then implemented with students. In contrast, the structure of Lesson Study allows teachers to reflect on their own students' success, pose questions about their own students' struggles, and set the direction of their own learning that can impact their practice. Teachers need to collaboratively decide the agenda; choosing the focus of learning and the direction the teacher learning takes should be based on student work in a Lesson Study. Teachers are making changes to their practice in real time, in response to how students are making sense of the learning (Lewis et al., 2012). Capra (2002) describes how introducing change in the workplace often meets resistance so the goal is to make the change process meaningful, elicit participation, and create an environment where creativity can flourish. In Lesson Study, teacher learning should not be about top-down mandates or about control but cooperation and partnership between teachers, teachers and students, and amongst students (Lewis et al., 2011). Describing the potential of such networks, Davis and Sumara (2007) note, "the resulting higher-order unities have capacities that can vastly surpass the potentials of their participants" (p. 58). Using the concept of emergence, new ideas, not thought of before, are possible. Teams of teachers in a Lesson Study could find new ways to connect with students that trigger learning. Telling teachers to improve their practice and mandating in-services has not produced increased student achievement. Creating time for teachers to

participate in a professional learning cycle during their working day such as in Lesson Study could trigger the conditions for emergence that could impact student learning.

Bruce, Ross, Flynn, and McPherson (2009) compared the use of the professional development practices of Lesson Study and Demonstration classes on improving teacher knowledge and skills. In the Lesson Study, teachers set their own learning goals that focused on facilitating effective student communication in mathematics with the use of tools and technology, including manipulatives, as well as, the interactive whiteboard (IWB). Teacher learning was identified by their understanding of the purpose and value of mathematics communication and the consolidation section in the three-part lesson; teaching from an inquiry stance using problem solving and exploration; and the management of materials, strategic grouping, and scaffolding to enable student communication. Findings from the research from Bruce and her colleagues showed that teachers were successful because students were "observed using the communication stems with increasing comfort over the course of the year, and with teacher scaffolding, were able to agree and disagree with reasons in whole group and smaller group settings. Across the cases, the interactive whiteboard emerged as a powerful facilitator of student mathematics communication" (p. 46). Content-specific improvements were found in student performance when the tests used were directly focused on the content areas that teachers had targeted for improvement. Teachers had achieved their own learning goal and this resulted in improved student learning. This was important because the reason for providing time for professional learning for teachers is to impact student learning and achievement. Student achievement is a necessary condition or constraint of the education system.

For a system to survive, certain constraints or boundaries have to be in place. For example, for the human body to exist, it needs to eat and sleep. If the constraints are not upheld, the system becomes extinct. Schools have certain constraints that permit a wide variety of students to go through them but still allow schools to continue to be there afterwards. After many years of existence, schools still exist with the same essential goal to educate students even though schools today may seem very different from those schools 10, 20, or 50 years ago. The goal to graduate students has not changed, but the means of achieving the goal has been allowed to change. Some of basic structures are still

in place, like attending daily classes and passing subjects, but when and how long classes happen and how student success is measured has changed. Goldstein (1994) suggests, "the boundary must be firm and nonpermeable enough to keep the system intact as a unique system" (p. 49). Without some basic constraints or boundaries, schools would not have continued to survive. Then, how much constraint does a system have to have? If we want emergence to happen, for new learning to take place, then we need to create conditions that make it safe to explore. Boundaries help to create an identity and a feeling of security. Lesson Study is a process where teachers work with peers in the same subject area. There is a sense of security when you are in your program area with the people you see every day. What a team focuses on in their study is dependent upon what they want to learn about or what questions they want to answer. Learning is allowed to emerge as teachers interact with each other, their students, and their thoughts and ideas about teaching and learning. The team has the potential to learn and create something bigger than themselves. Davis and Sumara (2006) said, "knowledge production might be described as an ever-expanding space of possibility that is opened and enlarged simply by exploring the space of what currently is possible" (p. 134). It is my conjecture that operating in the boundaries or structure of the Lesson Study, the team can still learn something they did not image before that will improve the quality of their practice.

**Element 4: Facilitate a collaborative community of teacher professionals for support and sharing of resources.**

Rarely do teachers get an organized opportunity to work and plan together. While Lesson Study brings together a team of teachers that create, reflect, and learn together, it also includes a consultant or facilitator who leads the group through the process and provides support for learning with resources and educational theory.

Rock and Wilson (2005) followed six intermediate teachers through a Lesson Study process and found that teachers were able to engage in the inquiry process of Lesson Study and successfully make changes in their practice to address the individual learning needs of their students. The following observations emerged from their research: all the participants found the focused and sustained work to stimulate their growth as teachers; they experienced an increase in their professional confidence; they stressed that the peer collaboration was valuable to their professional development; they found the

reading and sharing of professional literature and the consultations with experts that directly related to the problem of study were very beneficial to the process; they expressed their belief that peer coaching and mediation training would improve their abilities to engage in Lesson Study more effectively. As a result of their findings, Rock and Wilson called for more investigation on the role each part of the Lesson Study process plays in teacher learning. They also called for student data to measure the impact of teacher involvement in Lesson Study on their students learning.

Rock and Wilson (2005) point out that Lesson Study assumes teachers can develop valid questions about their practice, design lessons to address their questions, collect meaningful data from student observation, and analyze them to give insight into teaching. This process is not always easy or intuitive. Teachers are already teaching the best lesson they know; so, to do better, they need to learn something new and be willing to experiment with new strategies. Teachers, like students, need guidance and feedback on their learning, which is the role the facilitator plays in Lesson Study. The facilitator keeps the conversation going and, without trying to control the outcome, motivates the teachers to think deeply and to look for patterns in their learning.

Schools and classrooms are complex systems, and communication in a culture of support is the only way to keep a complex system thriving (Collay, Dunlap, Enloe, & Gagnon, 1998). When groups of teachers in Lesson Study document and revisit reflections, whether written or in conversation, they can see patterns emerge and become aware of the complex systems of teaching and learning. As individuals reflect on their learning and make meaning for themselves, their sharing in the group improves both the individual and collective thinking (Dudley, 2013). These reflections become guides for teachers outside the Lesson Study group to understand the process the lesson went through and the responses students gave along the way. What is captured is a product (lesson and reflections) that is informed from multiple sources, such as different teachers creating it, different classes experiencing it, and different students interacting with it. Typically in Lesson Study, the product created becomes a resource or starting point, for all teachers in that subject area (Lewis et al., 2012). What is important is not the actual lesson but the findings from teaching it. Catherine Lewis (2000) said, “The research lesson is not a finished product that is expected to be used *in toto* elsewhere, but an

example of a goal or vision of education in action" (p. 5, *emphasis* in original). Lessons might be developed to encourage more student dialogue in class or to develop student problem solvers. The goal of the Lesson Study is to produce a new result from teaching for its participants by testing and sometimes changing their beliefs and values around teaching and learning (Cajkler et al., 2015). Teachers in Lesson Study choose their goal and then work at modifying their lesson to reach the goal.

Self-organization is the idea of a collective coming together, without outside direction, for a shared purpose. Goldstein (1994) defines self-organization as "a process of transformation whereby the inner potentials for change that are locked up in the organization are unleashed and actualized by the right kind of challenge" (p. 3). Self-organization is about creating the conditions so the agents (such as students, teachers or principals) who are involved work within the boundaries to transform (or to learn). A key characteristic is that the transformation is not hierarchically driven but is self-generating. Goldstein claims self-organization happens "when a work group or an organization is facing a challenge and is allowed to respond to that challenge in a spontaneous, unshackled manner" (p. 9).

In Lesson Study, self-organization is utilized when teachers are given time to work together to ask research questions about their own problems of practice and find solutions to improve student learning in their subject areas. Self-organization is in play when teachers give students time to work together in groups to investigate open-ended problems and to pose possible solutions. In Lesson Study, it is the observation of students' work and reactions to the lesson that drive teacher learning with adjustments to the lesson and the teaching. To take advantage of the self-organization characteristic, teachers and students should be allowed to reflect and interpret the results of their work rather than accept a predetermined result. When there are random departures from the status quo, they should be noticed, encouraged, amplified, and even incorporated into the way the group operates (Goldstein, 1994). Teachers will need to be willing to share their understandings and misunderstandings and to truly listen to their peers if self-organization is utilized. Being open to not knowing and able to admit to not having a new idea for teaching a concept could be difficult. Many teachers will know the mathematics

but struggle with how to teach it so all students may learn it. Self-organization is about discovering the answers together though experimentation, including failure.

Much of education today is about large-scale school reform (Peurach & Glazer, 2012), but complexity theory shows us that small changes can lead to large effects. Similar to the idea of a multiplier effect, where taking advantage of a small genetic difference can lead to increase capacity in an area, small changes in educational structure can lead to big results in student learning. Gladwell (2002) suggests, "that in order to create one contagious movement, you often have to create small movements first" (p. 192). The idea of dividing a school board or school into small groups of teachers connected by facilitators (as in Lesson Study) shows how small groups can be used to move an idea forward by facilitators who affect the members of the group. Facilitators do not need to be formal leaders or to lead the group formally, but they can connect the group to other groups through other facilitators in the other group. This allows learning to move between groups.

Information in a complex system is passed on, through its local connections. Centralized control or top-down administration should not be the driving force for new ideas but relationships among people and teams should be nurtured so ideas can emerge through interactions. Lewin (1999), using complexity theory to give advice to businesses, said, "create the conditions for constructive emergence rather than trying to plan a strategic goal in detail. Evolve solutions, don't design them" (p. 203). Based on Lewis's theory, a school board wouldn't benefit from using Lesson Study to mandate a specific strategy or use of a new tool, but it could use Lesson Study as a way to have a team of teachers explore a new idea and work together to test and adapt it into their practice.

In schools and classrooms, it is not just working in groups that is important but "the neighbors that must interact with one another are ideas, hunches, queries, and other manners of representation" (Davis & Sumara, 2006, p. 142). Complexity theory tells us, it is through inquiry, experimentation, discussion, and sharing that teachers and students learn. Bumping into each other's ideas and hunches leads to more ideas and eventually to solutions to problems (Davis & Sumara, 2006). Through the planning, observing, debriefing, and final sharing, the Lesson Study process creates an environment where expressing ideas and hunches are encouraged and regularly shared (Lewis et al., 2011).

In summary, through the Lesson Study process, teachers can examine a new theory, a new instructional strategy, a lesson design model, the use of a new technology, etc. Whatever new learning wished for teachers to experiment with can be shared in a Lesson Study. What makes Lesson Study different from other professional development practices is that, by design, it gives teachers control and responsibility for their own learning and, when carefully implemented, it can bring in many factors that impact teacher learning.

# CHAPTER 3

## Research Design/Methodology

> The strengths of design studies lie in testing theories in the crucible of practice; in working collegially with practitioners, co-constructing knowledge; in confronting everyday classroom, school, and community problems that influence teaching and learning and adapting instruction to these conditions; in recognizing the limits of theory; and in capturing the specific of practice and the potential advantages from iteratively adapting and sharpening theory in its context. (Shavelson, Phillips, Towne, & Feuer, 2003, p. 25)

Lesson Study is an established practice for building pedagogical knowledge and improving teaching (Cerbin & Koop, 2006). To see, hear, and understand how participation in a Lesson Study achieves this goal requires a combination of qualitative and quantitative data to be collected by observing and listening to teachers and students in a Lesson Study. This research study concerned one school board's Lesson Study design and followed its teachers through a modified Lesson Study. This chapter outlines how both qualitative and quantitative data were collected through surveys, interviews, and observations to help answer the research questions about which features of Lesson Study design supported professional learning and how the Lesson Study design impacted teacher learning and teacher beliefs about students' learning.

Design-Based Research was the methodology used. Design-Based Research looks at the impact a design or intervention has on learning (Anderson & Shattuck, 2012). How Lesson Study lent itself to this methodology will be explained. Figure 3 outlines how the chapter unfolds.

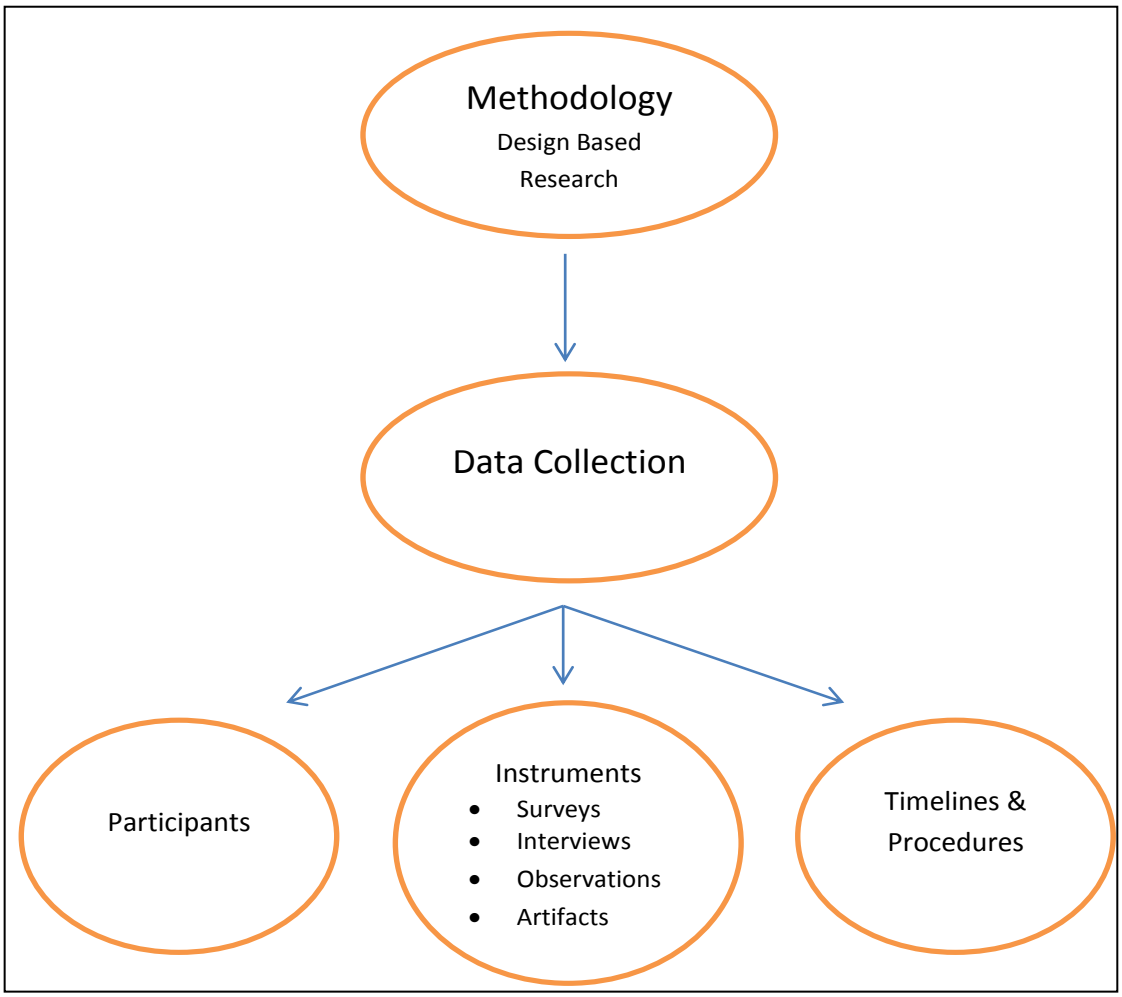


*Figure* 3. Organizer for the Methods Chapter.

**Design-Based Research**

Design-Based Research involves a partnership between researcher and practitioner. In some ways, Design-Based Research is similar to action research as both involve identifying a problem of practice, developing plans to solve the problem, and then following through with implementation (MacDonald, 2008). They differ in the way the problem is identified and the goal of the research. In action research, it is the teacher who discovers the problem and the researcher who comes in to help with the process (Wang & Hannafin, 2005). In Designed-Based Research, it is the researcher who comes to the location with a theory and a research design and invites the teachers to participate. Design-Based Research is built on and conducted to further an educational theory (Wang & Hannafin, 2005), where action research is conducted to build the participant knowledge to be applied immediately.

Design-Based Research is concerned with "using design in the service of developing broad models of how humans think, know, act and learn; that is, a critical component of Design-Based research is that the design is conceived not just to meet local needs, but to advance a theoretical agenda, to uncover, explore, and confirm theoretical relationships" (Barab & Squire, 2004, p. 5). The study is about more than just showing how a design, such as Lesson Study, works, but is also about generating evidence of how learning is happening and furthering knowledge of how learning can be enhanced by the different characteristics of a Lesson Study. One of the strengths of this methodology is that it embraces the complexity of education and the setting in which learning occurs, whether for students or teachers (Cobb, Zhao, & Dean, 2009). Theory on learning is developed in the context in which it is used. Ford and Forman (2006) claim that "the aim of educational research is to improve instruction and learning; conversations about methodology need to address the relationship between research and practice" (p. 140). Education is a discipline driven by practical means and research should inform practice. The intention of Design-Based Research in education is to inquire more broadly into the nature of learning in a complex system and to refine generative or predictive theories of learning (Design-Based Research Collective, 2003). Using the literature on how people learn, Design-Based Research tests an idea of how learning emerges and the specific means that might be used to support and organize the learning.

The research-based instructional strategies that are currently being advocated for in mathematics instruction emphasize using cognitively challenging tasks and maintaining a certain level of challenge as tasks are enacted in the classroom while ensuring opportunity for students to communicate mathematically and make their thinking visible (Cobb et al., 2009). Ford and Forman (2006), in discussing this type of instruction or reform education in mathematics, state that "reform would require a change in focus from memorization and practice of routine algorithms to an emphasis on inquiry processes and communication" (p. 139). This type of instruction is complex, demanding, uncertain, and not reproducible as a predictable routine. Stylianides and Stylianides (2013) claim that educational research that has the potential to improve mathematics classroom practice must be (a) conducted in classrooms, (b) directly address problems of students learning and how this learning can be supported by teaching and (c) test theories of learning and how and why they work. Design-Based Research can draw researchers and teachers together to form a community of learners that work together to apply a theory of learning and adopt challenging instructional practices by exploring their use in classrooms.

Lesson Study lends itself well to the Design-Based Research methodology because it is built on an iterative process and focuses on the conditions necessary for learning to emerge. Design-Based Research encourages teachers to respond to what is happening in the classroom and to make adjustments to the lesson design as needed rather than following a treatment protocol. Lewis et al. (2006), referencing Lesson Study, call for "cycles of Design-Based research that test key design features and create actionable artifacts to leverage learning at new sites" (p. 10). The lessons teachers create through the Lesson Study process are in response to the needs of learners. Teachers are learning "what works" in classrooms and, through this iterative process, are discovering the conditions necessary for student learning. The belief is that Lesson Study, through the "local proof route," can provide a professional knowledge base for teaching.

Typically in Designed-Based Research, several iterative cycles of an intervention would occur. This research reports on the first year or first cycle of a school board's use of Lesson Study with intermediate and senior teachers. The goal for the project was to observe the impact Lesson Study had on teaching practice in a school board while

advancing theory about teacher learning that could be of use to others. The teachers in the project were looking at their classroom and how their lesson design impacted how their students learned mathematics. The students were learning mathematics and the teachers were learning through the Lesson Study process how best to create the conditions for student learning and what instructional practices were most effective. Michelsen (2010) claims that "design research is directed at understanding learning and teaching processes by active innovation and interaction in classrooms" (p. 153). Teachers can gain knowledge about mathematics teaching in partnership with their colleagues, using, sharing, and developing this knowledge in the design project. Teacher participation in a Lesson Study can result in professional learning that enlarges their pedagogical content knowledge and expands their ability for action in their classrooms. Examining which features of the Lesson Study design have impact on teacher learning determines how a Lesson Study design supports teacher and student learning.

"DBR is a methodology designed by and for educators that seeks to increase the impact, transfer, and translation of education research into improved practice" (Anderson & Shattuck, 2012, p. 3). Educational researchers who use a DBR methodology want to learn more about learning.

**Data Collection**

Several methods of data collection can provide information about a design for teacher learning. Surveys can help the researcher learn about teachers involved in the research and identify important attitudes and beliefs those teachers have about teaching (Creswell, 2008). Completing surveys or open-ended questionnaires before and after participating in a Lesson Study can provide insight in to how the professional learning impacted the teachers. Qualitative data are typically collected from interviews, observations, reflections, and artifacts/documents (Creswell, 2008). During the Lesson Study process, these rich data sources show and help the researcher to understand how teachers are making sense of the professional learning.

For this study, a pre-survey provided background information on the participants in the project, such as biographical information and previous experiences with professional learning. These quantitative data helped to understand who was participating

in the project and establish whether Lesson Study was a new process of professional learning for participants.

In this study, pre- and post-survey data were designed to capture trends in overall teacher adoption of reform mathematics (the pedagogical knowledge) and teacher efficacy (improving teaching) as a result of the Lesson Study project. Using a Likert scale to rate individual responses to the same questions helped pre- and post-surveys show overall trends or changes in the participants' general knowledge, skills, attitudes, and beliefs about teaching mathematics.

In the post-survey, written questions gave individual teachers opportunity to describe their learning during each aspect of the Lesson Study process. These qualitative data captured teacher's opinions about the Lesson Study process and its impact on their learning.

By closely following one selected team through the Lesson Study process and collecting more qualitative data through interviews, observations, reflections, and artifacts from the lessons, the team's previous and new knowledge, skills, attitudes, and beliefs about teaching mathematics were recorded as well as the their interactions during the Lesson Study process. Together with the survey results, these data were used to answer the research questions on page 4.

**Participants**

In 2012, the Student Success Branch of the Ontario Ministry of Education provided funding to selected school boards to build capacity for effective instruction through a project called Building Innovative Practices (BIP). The school board studied in this research received BIP funding and chose to focus on the instructional strategies of Teaching Through Problem Solving (TTPS) and three-part lesson structure with Grade 7 to 10 mathematics teachers. All school boards in the BIP project were encouraged by the Ministry to use a collaborative inquiry approach where teachers would follow a cycle of learning to address a problem of practice. Because of previous experience with a modified Lesson Study approach, the school board in this study designed its collaborative inquiry for the BIP project to have cross panel of (elementary and secondary) mathematics teachers co-plan and co-teach three-part TTPS lessons. The funding allowed for all participating mathematics teachers from 4 secondary schools and all Grade 7 and 8

teachers, from the feeder schools for each of the secondary school, to each receive 4 days of release time to participate. This project presented me, the researcher, with an opportunity to observe and collect data on the effect of teacher participation in a modified Lesson Study on teacher and student learning.

The school board determined which schools would participate in their project. They suggested that results on EQAO and willingness to participate were determining factors in their selection. Secondary schools (Grade 9-12) were selected first partly because the funding came from the Ministry's Student Success Branch that funds Grade 7–12 initiatives and partly because the project coordinator for the school board was a secondary curriculum leader. Four secondary schools and their mathematics teachers were chosen for the project. The school board also decided to include 4 additional secondary mathematics teachers, from 4 non-participating secondary schools, in an attempt to widen the impact of the project on the system. Once the secondary schools were selected, each of the elementary feeder schools, which feed into the high schools, was asked to participate. A secondary school and its elementary feeder schools is called a "hub." Thus, this project had 4 hubs. At the time, it is important to note that there was education labour unrest in Ontario, with a significant amount of dispute in the elementary panel in the school board participating in the study. As a result, many of the elementary feeder schools chose not to participate. This left the number of participants (see Table 2) in the school board project at 60 with 23 elementary and 37 secondary teachers participating.

Table 2. *Number of Teachers Participating in School Board Project by Hub and Level*

| | Hub (secondary school with feeder schools) | | | | |
|---|---|---|---|---|---|
| | #1 [a] | #2 | #3 | #4 | Total |
| Elementary teachers | 7 | 4 | 4 | 8 | 23 |
| Secondary teachers | 13 | 6 | 8 | 6 | 33 |
| Secondary teacher from a non-participating school | 1 | 1 | 1 | 1 | 4 |
| Total teachers in each hub | 21 | 11 | 13 | 15 | 60 |
| Administrators | 2E, 1S [b] | 1E | 2E, 1S | 2E, 1S | |

[a] The team followed through the research project came from hub 1.

[b] E = elementary, S = secondary

All 60 teachers were invited to participate in the research. Twenty-eight of the 60 teachers (see Table 3) chose to complete the pre-survey and 14 of those participating in the study completed the post-survey. Pre- and post-survey results did not include responses from the team chosen to be closely followed through for the project.
Pre-survey data revealed that 22 participants were full contract teachers, 2 were partial contract teachers, and 4 were long-term occasional teachers (e.g., filling in for leave such as a maternity leave). Survey participants represented a wide range of teaching experience from new to close to retirement (see Table 4).

Table 3. *Number of Teachers Participating in the Research Pre- and Post-Survey*

| | Elementary | Secondary | Total | Percent |
|---|---|---|---|---|
| Teachers in the School Board Project | 23 | 37 | 60 | |
| Teachers who completed **pre-survey** | 8 | 20 | 28 | 47% of teachers from project participated |
| Teachers who completed **post-survey**[a] | 2 | 12 | 14 | 50% of teachers who completed a pre-survey participated |

[a] Post-survey only offered to teachers who completed a pre-survey

Table 4. *Number of Years Participants have Taught*

| 1-5 years | 6-10 years | 11-15 years | 16-20 years | 21-25 years | 26-30 years |
|---|---|---|---|---|---|
| 8 | 5 | 7 | 4 | 2 | 2 |
| 29% | 18% | 25% | 14% | 7% | 7% |

The selected team came from hub 1. The 21 teachers in hub 1 formed 3 separate Lesson Study groups. Each group had a combination of elementary and secondary teachers.
The selected Team included:

- 2 elementary teachers from the same elementary school responsible for teaching intermediate mathematics
- 6 secondary mathematics teachers (5 from the secondary school the elementary school fed into and one from a different secondary school)
- 1 secondary administrator responsible for mathematics at the main secondary school

- 3 school board curriculum leaders all with mathematics responsibility (2 elementary and 1 secondary)

### Instruments

All teachers involved in the school board's Lesson Study project were invited to participate in the research project. I explained the purpose of the research, my role as the researcher (in addition to my role as a team member in my own school), and the data collection methods to all participants at an initial school board in-service, in February 2013. The in-service was run by the school board to introduce the Lesson Study project to the schools. It was made clear to teachers at the in-service that participation in the research was optional and not required for participation in the school board's project.

#### *Pre- and Post-Surveys*

The pre-survey was handed out to all teachers, at the initial in-service, in a sealed envelope that contained a return envelope addressed to the researcher. The envelope also contained consent forms for participants to sign. Some participants completed and returned the pre-survey and consent form at the initial in-service. Other participants returned the pre-survey and consent form through school board courier. A post-survey was sent through the school board courier to participants who completed a pre-survey and consent form. The post-survey was sealed in an envelope and contained a return envelope addressed to the researcher. Participants were also notified by email that a post-survey would arrive in the school board courier. Post-surveys were returned to the researcher through the school board courier. Teachers were asked to create a unique identifier to label their pre- and post-survey so pre- and post-surveys could be matched up in the researcher's database (without names) to measure growth.

The pre-survey questions were divided into three parts and can be found in Appendix B. The first part was a teacher questionnaire, with some questions adapted from the Organisation for Economic Cooperation and Development (OECD) Teaching and Learning International Survey (TALIS), including questions on: (a) teacher experience and qualifications, (b) professional development/learning, and (c) feedback on practice. The second part was an Ontario-developed survey measuring an elementary teachers' commitment to standards-based mathematics teaching (Ross et al., 2003). The

last part was a teacher self-efficacy beliefs survey (Dellinger et al., 2008), modified for this study.

The post-survey included both the self-efficacy beliefs survey and the standards-based mathematics teacher survey from the pre-survey and a new set of descriptive questions that reflected the Lesson Study process (see Appendix C). The surveys gathered data on participants' impressions of their knowledge/skills and attitudes/beliefs about mathematics education and their own learning. They were analyzed to see whether changes occurred in participant thinking as a result of the professional learning. The first part of the pre-survey was summarized to describe the general background of the participants. The second and third part of the pre-survey on commitment to standards-based mathematics and teacher self-efficacy was analyzed by comparing responses to the same sections on the post-survey to determine how the Lesson Study affected the teachers' knowledge/skills and attitudes/beliefs about teaching mathematics. The rubric for standards-based mathematics was used to help gauge where teachers were in their understanding of reform mathematics and the skills the school board hoped to address through the Lesson Study project. The first part of the post-survey, describing how the parts of the Lesson Study impacted the teacher's practice, was used to confirm interview and observation data. In this part of the survey, teachers commented on their personal learning in each step in the Lesson Study process, giving details of how their ideas of teaching and learning were challenged. In each question, about a different part of the process, all the replies were examined to look for common responses. Creswell (2008) describes this process as open coding, where the researcher forms initial categories for the information by segmenting the information. Data for each question was grouped by similar responses so common themes could emerge about what teachers saw as impacting their practice. Data was then gathered on the number of teachers responding under each theme.

### *Pre- and Post-Interviews*

Interviews were conducted by the researcher with: school board curriculum leaders, responsible for designing the professional learning; one selected team of teachers from the project that agreed to be followed closely through the process; and an administrator from the secondary school of the teacher team being studied. The pre- and

post-questions are in Appendix D and E and answers were recorded by taking written notes.

The pre-project interviews were created by the researcher to gather information on the design for the learning, the goals of the professional development, and how success would be determined or measured by the school board and the participants. The post-project interviews were created by the researcher to gather evidence on the success or failure of the intervention to address the purpose of the learning and meet the desired results for everyone involved. The interviews were also used with the observations and survey to develop themes in the findings.

*Curriculum Leader Interview.* A pre-interview was conducted with one curriculum leader at the beginning of the research project and a pre-interview was conducted with a second curriculum leader (because more than one consultant was working with the selected team) the day of the first team meeting prior to the team's arrival. The purpose of the pre-project interview with the curriculum leaders was to understand the unique design features of the school board's intervention, why they chose a modified Lesson Study design, and how they would measure success of their intervention. The risk associated with the interview was minimal since the curriculum leader was only outlining the school board's own design for the project.

The post-interview with curriculum leaders was conducted at the final team meeting, held at the secondary school, after the team had left. The purpose of the post-project interview was to gauge the success of the intervention from the school board's point of view. Risk was minimal because the curriculum leader was only being asked to be reflective.

*Team Interview.* The pre-project interview with the whole team together took place at the selected team's first meeting before they began the project. The questions were asked to the whole group and responses were recorded in writing. Team members were told they would not be identified by name in the results. The purpose of the pre-project interview was to understand the selected team's expectations for their learning. There was minimal risk to team participants in the pre-project interview because the teachers had not begun the project and were only being asked about why they chose to participate in the school board project and what they hoped to learn.

The post-project interview took place at the end of the last meeting of the selected team. Again, the questions were asked to the whole group and responses were record in writing. The purpose of the post-project interview was to capture the teachers' reflections on the intervention. There was medium risk to participants in the post-project interview because the teachers shared their thoughts openly on how successful they thought the project was, what they learned, and how they felt about the Lesson Study process in front of each other and the curriculum leaders. Through the intervention, the selected team became comfortable with each other and built a strong rapport. Sharing constructive criticism with each other, as part of the Lesson Study process, helped to increase trust and minimize risk.

*Administrator Interview.* The pre-project interview with the school administrator occurred at the secondary school on a day convenient for the school administrator prior to the start of the project. As part of the design, each of the four secondary schools had all the teachers in their mathematics department participate in the project, which resulted in several Lessons Study teams at each school. The secondary administrators were responsible for organizing the teachers into teams at each school and contributing to what the focus for the lessons would be. The purpose of the pre-project interview was to understand the administrators' role in the project, their goals for the project, and how they would measure success. The risk was minimal because they were sharing their own intentions.

The post-project interview with the administrator occurred over the phone after the project was completed. The purpose of the post-project interview was to capture the administrators' impression of the intervention and its success in meeting the administrators' goals. The risk was medium because the administrator was commenting on the implementation of the school board's design and his teachers' participation.

### *Observations*

The school board called its modified version of Lesson Study a "CLiC" (collaborative learning in classrooms). The school board's CLiC process was designed to happen in one day. In Japanese Lesson Study, the process is usually much longer and happens over several days. Prior to the project, school board curriculum leaders would arrive at a school to work with a group of either primary (Grade 1–3) or junior (Grade 4–

6) teachers. The team would choose a lesson focus and together develop the first two parts of a three-part lesson, the minds-on and the action. They would then go into a pre-chosen classroom and a pair of teachers from the team would teach the lesson while the others in the team would observe. After the action was completed, student work was collected and the team would leave to analyse the responses. Together the team would develop, based on the student work, the consolidation part of the three-part lesson and return to the class to teach the consolidation. The day would end by reflecting on the whole process.

I observed the selected team during each of two full CLiC days, one in the elementary school and one in the secondary school as well as on a third day, which they used for discussion and reflection. During these observations, I was not a participant in the conversation, but was listening and taking notes. I observed the selected team as they planned the lesson, in the classroom when they taught it, and during the reflection time. I captured the events as they unfolded, making written notes of comments from each team member during planning, discussions, reflections, and actions in the classroom. The focus was to capture participant comments about their own learning, their students' learning, and the modified Lesson Study process. My notes were typed and compared with survey and interview data to find overall themes in the data. The lesson observation notes were also analyzed using a modified rubric that reflected the 10 dimensions of standards-based mathematics teaching as identified by Ross and McDougall (2003) (Appendix A). The observation notes were also analysed with the elements of effective professional learning to ensure the necessary conditions for learning were present. The focus was on the teacher learning and documenting how their practice might be changing through the Lesson Study experience.

### *Artifacts*

To understand the Lesson Study process and its impact at each step on teacher learning, several artifacts (which are created as part of the Lesson Study process) were collected and examined. All the artifacts used in the results came from following the selected team and were collected during their CLiCs. The artifacts helped to support the findings from the survey and interviews and to judge the impact of the modified Lesson Study on the research participants. The artifacts collected included:

- Lesson observation notes from observers (taken on a form the school board created)
- Photographs and copies of lessons at each stage
- Teacher goal/reflection form from the second CLiC (school board form)
- Photographs of student work samples completed by participants both during the lesson, and in exit cards at the end of the lesson (from both CLiCs)

In the classroom setting, two teachers in the selected team chose to teach the lesson and the others acted as observers. There were several observers (teachers from the team, curriculum leaders, and supply teachers covering the class) as part of the Lesson Study process. Each observer was asked to capture what students were saying and doing during each part of the lesson on an observer form the school board provided (see Appendix F).

As an observer in the planning, teaching, and debriefing meetings, I was able to see the lesson as it developed and changed in the planning room, watch teachers make observation notes as the lesson was delivered in the classroom, and photograph samples of student work teachers collected for the debriefing sessions. These observations and artifacts supported the conversations captured in the CLiC observation notes.

At the second CLiC, the curriculum leaders reviewed the goals of the school board project and asked participants to fill out a goal and reflection form. This form was part of the school board's data collection to measure success of its project. This form asked participants to set a learning goal for the day and then to reflect on whether they met their goal at the end of the day. Two members of the selected team elected to fill out this form and share it with me.

In the Lesson Study process, the teacher must assess what students are learning. One purpose of Lesson Study is to create lessons that increase students learning. Teachers measure the success of their own learning and the success of their lesson based on what students are learning. The selected team collected student work from the lessons to measure its success and to inform changes needed to the lesson/instruction. I was able to take photograph copies (to include in my dissertation) of the students' work samples on

which the team based their discussion on. These work samples supported the conversation captured in the CLiC observation notes.

### Timeline and Procedures

The school board's Lesson Study project took place in semester two of the 2012–2013 school year (see Table 5). It was originally scheduled to begin in October of the 2012–13 school year, but, due to labour unrest in the province, was delayed until the second half of the year. The project began with the introductory meeting to introduce TTPS and the three-part lesson structure to the teams of teachers participating. Pre-surveys were handed out to all participants in the school board's project at this meeting. Also, at this meeting, teams chose initial dates for their future meetings.

The selected team chose their first CLiC to be at the elementary school. The pre-project interview with the selected team was conducted with all 8 teacher members participating.

Table 5. *Project Meeting Dates for the Selected Team*

| Date | Meeting | Location |
|---|---|---|
| February 26, 2013 | Introduction to project | Arena |
| March 27, 2013 | Pre-project Interview<br>CLiC 1 | Elementary School |
| April 29, 2013 | CLiC 2 | Secondary School |
| May 17, 2013 | CLiC 3 ( debrief meeting)<br>Post-project Interview | Secondary School |

During the first CLiC, the selected team was observed for a full day at the elementary school during planning, teaching, and reflecting. All teachers and both elementary curriculum leaders were present all day. The administrator was not present this day and the secondary curriculum leader was present for a half day.

In between the CLiC days, teachers were encouraged to practice using the three-part lesson structure and to create contextual problems on their own. The selected team, in particular, practised creating these types of problems, creating time in their daily lessons for students to explore a variety of strategies as well as time for students to struggle with these problems.

During the second CLiC, the selected team was observed for a full day at the secondary school during planning, teaching, and reflecting. Seven of the teachers (both

elementary and 5 secondary from the same school) and 1 elementary curriculum leader were present all day. The administrator was present for part of the day.

All teams in the school board's project were to complete at least one CLiC in the elementary school and one CLiC in the secondary school. Teams were given a choice between the elementary and secondary school for the last funded day. Most teams in the project selected to return to the secondary school. Some teams did a CLiC in a senior class, and some tried repeating the lesson in a similar class (i.e., two sections of Grade 10 mathematics) in one day, modifying the lesson in-between the classes. Each team was allowed to adjust the design to meet their learning needs.

During the third CLiC, the selected team was observed for a full day during reflection and planning for next steps. Six of the eight teachers (both elementary, 3 secondary from the same school, and 1 secondary from other school) and all 3 curriculum leaders were present all day. The administrator was not present. All 6 teachers from the selected team participated in the post-interview (2 secondary teachers from the main school were absent on the last meeting, 1 for the whole day and 1 for half a day). The administrator and two curriculum leaders participated in an individual pre- and post-interview. One secondary teacher (from the other secondary school in the selected team) completed the pre-survey, but no other members of the selected team participated in the pre- or post-surveys. All teams completed their project, using their four funded days for each teacher, by the end of the school year.

# CHAPTER 4

## Results

> Instructional improvement that benefits all students often rests on observation about such things as how various students respond to elements of a curriculum, or, which students need reinforcement in particular skills-evidence available only through up-close attention to classrooms and students.(McLaughlin & Talbert, 2006, p. 4)

### Introduction

The results are reported through responses to each of the three research questions. Pre- and post-survey data, interview notes, and observation data all helped to show the impact Lesson Study had on the participants' knowledge, skills, attitudes, and beliefs as asked in Question 1. The Standards-based Mathematics Rubric (Appendix A) helped to organize these results based on the key dimensions targeted by the school board's project targeted. Participant descriptions of learning during each part of the Lesson Study process in the post-survey along with observation data helped to answer Question 2. Each part of the Lesson Study process discussed in Question 2 highlighted the key elements of effective professional learning. Self-efficacy survey data, observations, and samples of student work all contributed in creating a response to Question 3. Figure 4 outlines the three sections in the chapter, one for each research question, and the subsections under each question.

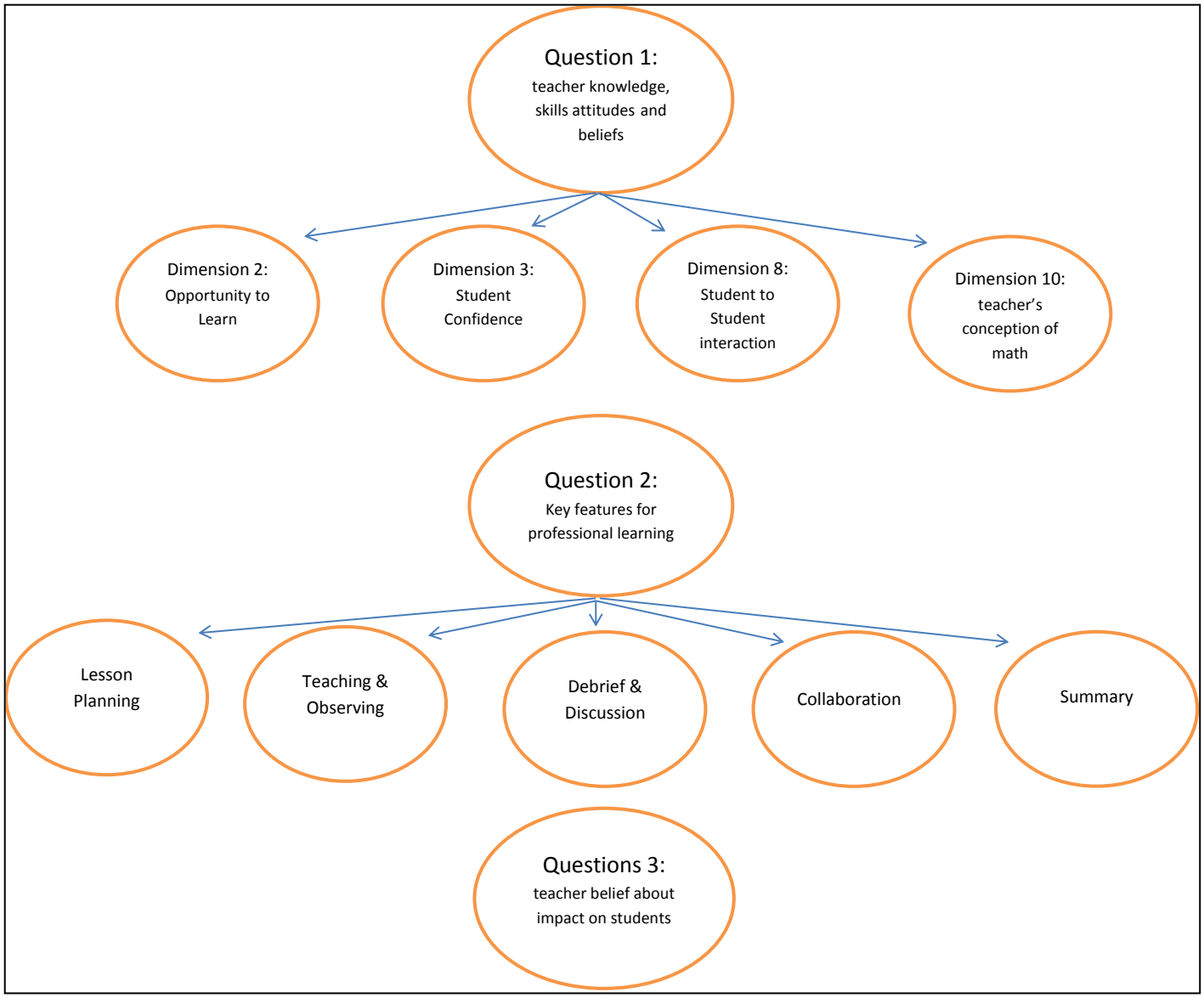


*Figure* 4. Organizer for the Results.

**Question 1**

*What impact does professional learning about instructional practice through a Lesson Study design have on the teachers in this study? (e.g., knowledge, skills, attitudes, beliefs, etc.)*

From interviews with the curriculum leaders, the main goal of the school board's Lesson Study project was to have teachers learn about, experiment with, and adopt a "Teaching Through Problem Solving" (TTPS) approach. The Ontario Ministry of Education (Ontario Ministry of Education and Training, 2006) defines TTPS as "using problems as the medium for teaching mathematical content. They present engaging problems to students as a way of motivating students to investigate mathematical concepts and to develop and apply their own understanding of those concepts" (p. 7). The TTPS approach is about moving away from the traditional "watch me" method of teaching towards a method in which students are actively involved and challenged and in which they use representations (concrete and graphic models, pictures, or diagrams) to gain a deeper understanding of mathematics. The school board project was also focused on continuing to promote the "Three-Part Lesson" structure (minds-on, action, and consolidation) with all its mathematics teachers. Teachers in the project were asked to create three-part lessons that used a TTPS approach.

The process of working with colleagues to create a lesson together, followed by teaching and observing the lesson and then reflecting on the teaching, was a new professional learning process for most teachers in the project. The pre-project survey revealed that participants spent the least amount of professional learning time team teaching with a colleague in the classroom, followed by observing other teachers teach and providing feedback, followed by engaging in collaborative inquiry with other teachers as seen in the Table 6. Most teachers did spend professional learning time in conversations about learning development of specific students on a regular basis as seen in Table 6.

The school board's modified version of Lesson Study was given the name CLiC (Collaborative Learning in Classrooms) by the school board. This name reflected the school board's previous participation in the CIL-M (Collaborative Inquiry Learning in Mathematics) project with the Ontario Ministry of Education. The curriculum leaders

stated in the pre-interview that they had adapted the CIL-M process to better fit the needs of their teachers.

Table 6. *Teacher Questionnaire: Pre-Survey Results for Time Engaged in Professional Activity*

| Rank (highest to lowest) | Type of Activity | mean | median | mode | number of participants who said they never engage in this activity | Percentage of survey participants who never engage in activity |
|---|---|---|---|---|---|---|
| | | (1 never, 2 yearly, 3 few times a year, 4 monthly, 5 weekly) | | | | |
| 1 | Have conversations about learning development of specific students | 4.28 | 4 | 5 | 3 people left this question blank | |
| 2 | Examine data on student achievement | 3.18 | 4 | 4 | 1 | 4% |
| 3 | Use student work to guide meeting with colleagues | 3.17 | 3 | 3 | 2 | 7% |
| 4 | Follow a professional learning cycle (plan, act, observe, reflect) with colleagues | 2.89 | 3 | 4 | 4 | 14% |
| 5 | Engage in collaborative inquiry with other teachers | 2.75 | 2.5 | 2 | 3 | 11% |
| 6 | Observe other teachers teaching and provide feedback | 1.75 | 2 | 1 | 13 | 47% |
| 7 | Team teach with colleagues in the same classroom | 1.5 | 1 | 1 | 19 | 68% |

Having had success with their CLiC process in the primary division (Grade 1–3) and junior division (Grade 4–6), the school board was now looking to apply the CLiC process with intermediate division (Grade 7–10) teachers. It is important to note that Grade 7 and 8 teachers work in the elementary schools and Grade 9 and 10 teachers work in the secondary schools. The school board's CLiC process had yet to be used in secondary schools. The curriculum leaders, who participated in this research, were

hoping to learn how to best adapt the CLiC process for use at the secondary school level. Curriculum leaders also identified in the pre-interview their hope that the intermediate teachers (especially those in secondary schools) would adopt a version of the CLiC process as their way of working together in their professional learning communities (PLCs).

Looking at the pre- and post-survey responses on the mathematics teaching survey revealed evidence of the impact the Lesson Study design had on the knowledge, skills, attitudes, and beliefs (on teaching) of the teachers in the study. The mathematics teaching survey, based on 10 dimensions of mathematical reform (see Appendix A), was intended to measure a teacher's commitment to each dimension. Given the school board's goal for teachers to adopt the TTPS approach, the key dimensions involved were dimension 2: Opportunity to Learn, dimension 3: Student Confidence, dimension 8: Student-Student Interaction, and dimension 10: Teachers Conception of Mathematics. These four dimensions together addressed the main tenets of TTPS the school board was trying to implement.

**Dimension 2: Opportunity to Learn.**

Questions 13 and 16 in the pre-survey were identified as aligning well with Dimension 2: Opportunity to Learn. Table 7 shows pre- and post-survey responses from participants in the project.

Table 7. *Mathematics Teacher Survey: Total Likert Responses to Questions 13 & 16*

| Question | | | 1 Strongly disagree | 2 | 3 | 4 | 5 Strongly agree |
|---|---|---|---|---|---|---|---|
| 13 | I model all my mathematics lessons after the three-part lesson (minds-on, action, consolidation). | Pre | 5 | 11 | 4 | 7 | 1 |
| | | Post | 2 | 3 | 5 | 3 | 1 |
| 16 [a] | I like my students to master basic mathematical operations before they tackle complex problems. | Pre | 2 | 6 | 13 | 5 | 2 |
| | | Post | 0 | 3 | 4 | 5 | 2 |

[a] Negative worded question

*note.* N=28 for the pre-survey and N=14 for the post-survey

A three-part lesson structure involves a minds-on activity to activate prior knowledge, an action where students are engaged in inquiry, and finishes with consolidation where students share responses. In the three-part lesson, teachers use student responses to highlight key ideas before assigning independent practice. Teachers moving towards a three-part lesson structure are planning for and using a more student-centred approach in their teaching. This is different from the traditional lesson where the teacher introduces a new concept, models solving problems by providing step-by-step instructions on the chalkboard, and then assigns independent practice. Teachers working on the reform idea of creating opportunity to learn would also focus on giving students a context for a problem to help motivate and encourage exploration. This means starting with a big idea or larger problem and covering basic skills as needed.

Table 8. *Mathematics Teacher Survey: Comparison of Pre- and Post-Survey Results for Questions 13 & 16*

| Question | | Number that strongly agree/ disagree both pre & post | Number and percent that agree more on post | | Number and percent that agree less on post | |
|---|---|---|---|---|---|---|
| 13 | I model all my mathematics lessons after the three-part lesson (minds-on, action, consolidation). | 1 | 7 | 54% | 1 | 8% |
| 16[a] | I like my students to master basic mathematical operations before they tackle complex problems. | 0 | 7 | 50% | 0 | 0% |

[a] Negative worded question, number of participants is 14

Prior to the project, only one participant agreed strongly that they model all their lessons after the three-part lesson. An additional 54% (see Table 8) of the remaining post-survey participants agreed more strongly with the statement (#13) after the project, suggesting that these participants developed a better understanding of, and saw value in, the three-part lesson structure to provide opportunity for students to learn.

Prior to the project, the majority of participants were undecided about whether they felt students should master basic mathematical operations before tackling complex problems. The post-survey results (see Table 8) suggest more participants feel basic skills

must be mastered first. This way of thinking is seen as contrary to TTPS. A look at the conversations in the observed team gives insight to this finding.

During the first CLiC, at the elementary school, when planning the lesson, the secondary teachers expressed concern. They stated that usually students can solve simple equations (after Grade 8) but that little or no evidence usually exists that students use a method to do so. The conversation during the planning stage focused on concepts versus procedural fluency. Secondary teachers expressed worry that if they focused on teaching concepts then students would not learn to follow procedures. One teacher said, "if we focus on the concept they can't follow the procedure." Through all phases of the first CLiC, the secondary teachers continued to be very focused on procedures, form, and presentation, rather than concepts and ideas.

Despite the desire to teach procedural fluency, the selected team followed the TTPS model and gave students a rich question (with context) and directions to explore the problem and record their thinking. After the first teaching, the group gathered to look at student work. They discussed how surprised they were to hear students questioning their reasoning. Teachers heard students ask "what makes sense" and "what's wrong." They remarked how students knew they needed an algebraic expression and one teacher said, "This is good." The group said how truly impressed they were with the student work. Many of the student groups tried to set up equations in their solutions. This created the need for the teacher to introduce the balanced model (their original goal) when they returned for the consolidation. Teachers saw how TTPS created a "need to know" for students and how a big question led to a discussion about procedure.

The second CLiC, at the secondary school, started with one of the secondary teachers sharing a story. Her student had stopped her in the hall very upset and in tears. The teacher had been practicing the TTPS model in her class and the student was very frustrated. He begged the teacher to stop and to go back to telling him all the steps to solve problems. He did not want to discover things, but just wanted to be told exactly what to do. The teacher was shaken by the conversation and asked the group what she should do. She felt, after seeing it work at the elementary school and testing it in her classroom, that the TTPS approach was the correct one to build understanding in her students, but the student's pleading made her second guess the approach. The team all

said they understood and had similar encounters. They, too, were coming to believe that the TTPS approach, in the long run, would be better for students to develop understanding in mathematics. They all agreed they were struggling with many students who had been taught to be passive learners (even by them in the past). This new approach definitely shook their students' confidence and exposed students' misunderstandings. The TTPS approach also left them wondering about what strategies they could try to support the students struggling with the new instructional method.

Beliefs and practice are linked. Research supports the finding that to change teaching practice you need to challenge teacher beliefs (Stipek, Givvin, Salmon, & MacGyvers, 2001). By allowing the teachers to experiment with and practice three-part lessons and TTPS in their classroom, they "bump-up" against their traditional values and thinking about teaching and learning.

**Dimension 3: Student Confidence**

Teachers in a reform setting strive to raise student self-confidence in mathematics rather than impede it (Ross et al., 2003). Question 2 and 7 on the mathematics teaching survey align with this belief of raising student confidence in mathematics. Table 9 shows pre- and post-survey responses from participants in the project.

Table 9. *Mathematics Teacher Survey: Total Likert Responses to Questions 2 & 7*

| Question | | | 1 Strongly disagree | 2 | 3 | 4 | 5 Strongly agree |
|---|---|---|---|---|---|---|---|
| 2 | I regularly have my students work through real-life mathematics problems that are of interest to them | Pre | 1 | 14 | 10 | 3 | 0 |
| | | Post | 0 | 1 | 3 | 6 | 4 |
| 7 | Every child in my room should feel that mathematics is something he/ she can do. | Pre | 0 | 0 | 2 | 4 | 22 |
| | | Post | 0 | 0 | 0 | 3 | 11 |

*note.* N=28 for the pre-survey and N=14 for the post-survey

In the pre-survey, most respondents (79%) agreed strongly that every child in the room should feel that mathematics is something they can do. Perhaps surprisingly, very

few respondents reported regularly having students work through real-life problems that were of interest to students.

Of the 14 people who completed a pre- and post-survey, no participant on the pre-survey strongly agreed with the statement in Question 2: I regularly have my students work through real life mathematics problem that are of interest to them (See Table 10). After the project, 10 of the 14 (71%) survey respondents reported an increase in agreement with the statement. Prior to the project, most participants had a strong belief that students should feel capable in mathematics, but the response to Question 7 could suggest they lacked strategies to help raise confidence.

Table 10. *Mathematics Teacher Survey: Comparison of Pre- and Post-Survey Results for Questions 2 & 7*

| Question | | Number that strongly agree/ disagree both pre& post | Number and percent that agree more on post | | Number and percent that agree less on post | |
|---|---|---|---|---|---|---|
| 2 | I regularly have my students work through real-life mathematics problems that are of interest to them | 0 | 10 | 71% | 1 | 7% |
| 7 | Every child in my room should feel that mathematics is something he/ she can do. | 10 | 2 | 50% | 1 | 25% |

On the post-survey, teachers were asked to describe their learning in each part of the Lesson Study process. Participants commented many times in different parts of the process that letting students struggle with the problem was new learning for them. This further supports the idea that teachers were trying the TTPS approach in the project, but that they found it hard to allow the student struggle to occur. Common sense suggests teachers know that letting students struggle with a question and figuring it out on their own creates more student confidence in their own ability to solve problems than when teachers tell students the answer. The comments on the post-survey support the idea that teachers did not know or access strategies like TTPS before the project.

During the observation of the selected team, in the secondary school, teachers commented on how much they wanted to help students when they were observing. They talked about how hard it was to let students struggle. A teacher said, "I wanted to prompt so they would not struggle." The teachers had not mastered the skill of when and how to intervene. The group worried about how to respond to students who had not mastered the content in the lesson. Exit cards revealed that several students were still confused with the lesson concepts at the end of the lesson and would require remedial help in the next class. One teacher said, "how will they do the homework." A discussion occurred about how to group students the next day and re-teach or reinforce the concepts. The elementary teachers shared many strategies that had worked for them but all involved spending more time on the content and with the students. The secondary teachers admitted they typically didn't do much remedial work with students as they felt pressure to cover their curriculum and move on to a new topic each day. One secondary teacher said, "I don't see how we can take them along given the time and content." Although secondary teachers were very receptive to doing the remedial work, they struggled to see how they could make time for this on a regular basis.

Once teachers had a plan to address student misunderstandings (with learning centers the next day), the conversation led to a discussion on student ownership for learning. The secondary teachers were frustrated that many students did not seem to take advantage of supports like extra help, and in their minds, that there was "so much pressure on students to go to university." Teachers felt they were very encouraging and always available for extra help. They were concerned that some students had a poor work ethic and were satisfied with minimal success. Teachers were afraid they were setting students up for failure by **not** discouraging students with poor work habits from pursuing academic courses. They felt strongly that students, placed in the wrong level (academic versus applied), felt like a failure, were frustrated, and didn't know what to do. They were concerned about student confidence. An elementary teachers said, "they saw (as a result of conversations and observations) that secondary teachers were doing all the work in class and students were passive participants." One secondary teacher said, "we are doing it for them—we are pushing them through."

Teachers in the selected team clearly recognized the importance of student confidence for learning. Given their acknowledgement that teaching at the secondary level was mostly teacher directed, it was surprising they did not see the correlation between directed teaching and passive learning. Their comments revealed that using TTPS challenged their students. Although students who may have struggled before still struggled, teachers had a much better sense of who was struggling and what they were struggling with as revealed by exit cards and teacher observations. On exit cards some students didn't use any algebra revealing their struggle to create equations and on observation notes teachers wrote comments like "didn't take the registration fee into account" and "not recognizing (x, y) is (class, cost)." This evidence allowed teachers to plan for remediation. Participation in the project resulted in secondary teachers acquiring new ideas and strategies to help their struggling learners. This result was similar to that reported by Dudley (2013) that observing students in Lesson Study raised teachers awareness of students learning needs and "revealed methods of classroom application they had not previously considered using" (p. 115).

The observations of the selected team and their comments on the post-survey also support the idea that teacher learning in the project resulted in teachers attempting to change their practice by moving away from a traditional form of teacher directed teaching to one focused on student inquiry and discovery.

**Dimension 8: Student-to-Student Interaction**

In the three-part lesson structure, students are actively solving a problem usually in groups or pairs during the action phase and students are sharing, discussing, and analysing their work with other students in the consolidation phase (Ontario Ministry of Education and Training, 2009). With the focus of the school board's project on three-part lesson planning and TTPS, student-to-student interactions were promoted. Questions 3, 6, and 9 on the Mathematics Teaching Survey all address the teachers' beliefs and use of this strategy.

Table 11 shows pre-and post-survey responses from participants on Questions 3, 6, and 9. Seventeen of the 28 teachers (61%) who completed the pre-survey agreed or strongly agreed with the statement: when two students solve the same problem correctly with different strategies they have students share their solutions. Slightly more teachers

(64%) who completed the pre-survey also agreed or strongly agreed with the statement: that students learn mathematics best when they can work together. Almost all teachers (89%) who completed the pre-survey disagreed or strongly disagreed with the statement: that it is not very productive for student to work together during mathematics time. The pre-survey data would suggest that most teachers agree student-to-student interaction is important in learning mathematics.

Table 11. *Mathematics Teacher Survey: Total Likert Responses to Questions 3, 6, & 9*

| Question | | | 1 Strongly disagree | 2 | 3 | 4 | 5 Strongly agree |
|---|---|---|---|---|---|---|---|
| 3 | When two students solve the same mathematics problem correctly using two different strategies I have them share the steps they went through with each other. | Pre | 0 | 4 | 7 | 10 | 7 |
| | | Post | 1 | 1 | 1 | 6 | 5 |
| 6 [a] | It is not very productive for students to work together during mathematics time. | Pre | 20 | 5 | 2 | 1 | 0 |
| | | Post | 10 | 2 | 1 | 1 | 0 |
| 9 | In my classes, students learn mathematics best when they can work together to discover mathematical ideas. | Pre | 1 | 1 | 8 | 15 | 3 |
| | | Post | 0 | 1 | 1 | 8 | 4 |

[a] Negative worded question

*note.* N=28 for the pre-survey and N=14 for the post-survey

For the 14 teachers who completed the post-survey, the data (see Table 12) showed that 7 or 50% of the teachers in this group, who did not strongly agree with the statement in Question 3, agreed more with the statement after using TTPS and 33% of the teachers who did not agree strongly with the statement in Question 9 agreed more with the statement after using TTPS. Teachers are reporting that they are having students share more solutions in class and that students are working in groups more. This suggests that TTPS helped more teachers see the importance of student- to-student interaction in a mathematics class. The negatively worded statement in Question 6 had a high number of teachers who disagreed strongly and after the post-survey none agreed more strongly but three of the five teachers (60%) who did not disagree strongly agreed more with the statement. This means three teachers increased their belief that group work in

mathematics classroom can be productive. When teachers use group work to give over more control of the learning to students there is inevitability more student questions and more evidence of student struggle. Teachers referenced the difficulty they had in letting students struggle many times throughout the data. This difficulty with letting students struggle may explain why many teachers in the survey reported no change in their beliefs around group work.

Table 12. *Mathematics Teacher Survey: Comparison of Pre- and Post-Survey Results for Questions 3, 6 & 9*

| Question | | Number that strongly agree/ disagree both pre& post | Number and percent that agree more on post | | Number and percent that agree less on post | |
|---|---|---|---|---|---|---|
| 3 | When two students solve the same mathematics problem correctly using two different strategies I have them share the steps they went through with each other. | 2 | 5 | 50% | 2 | 20% |
| 6 [a] | It is not very productive for students to work together during mathematics time. | 9 | 3 | 60% | 0 | 0% |
| 9 | In my classes, students learn mathematics best when they can work together to discover mathematical ideas. | 2 | 4 | 33% | 2 | 17% |

[a] Negative worded question.

After the two CLiC days, the selected team used their third day of release for the project to reflect on the whole process, including what had been happening in their classes in between the CLiC days. During their reflection, the elementary teachers expressed their feelings of success with three-part lessons and problem solving. The teachers felt they were more aware of how students were approaching problems. The action part of their lesson in their class was all student-to-student interaction. The teachers were using highlighting in the consolidation phase to understand how groups of students were thinking, using the formulas they were choosing, and having students discuss the approaches they were taking. Through highlighting, the teachers felt they

covered more material. It was during highlighting when they were now doing any direct instruction. One teacher said, "I am using highlighting to show how different groups did it – formulas, communication, and I rank answers by how they went about it so it allows me to cover so much more and it's when direct instruction comes in."

The group talked about previous styles of teaching as being mostly direct instruction, and, as a result, students were expecting the teacher to tell them everything. The student role was to memorize the material and "regurgitate" it on a test. Students were given solved examples to learn from and focused on memorizing procedure, not on understanding concepts. Teachers noted that TTPS required students to take more responsibility for the learning. One teacher in the group, with respect to the purpose of using TTPS, said, "TTPS should be about creating the need to know." In the past, the responsibility for learning was with the teacher and now it was with the student. Furthermore, teachers wanted students to learn the procedure today and do it tomorrow. Now, they wanted students to not just learn the procedure, but to understand it and, in the future, to be able to draw upon it, use it, and communicate how to use it in a meaningful way. The teacher's role now was one of guiding the student along this journey of sense making. The "struggle" was occurring because students didn't know what to do; they hadn't been held responsible before for their own learning, and they didn't know how to learn. The work now was for the teacher to learn new skills to help the students, to motivate them, and, as one teacher in the project put it, to "fight for their learning." The teachers talked about the many supports they put in place, the wikis with all their notes and solved examples, extra help sessions, etc., but, in the end, now realized the students had to do the learning, not teachers doing the telling. The curriculum leaders stressed the need for students to deconstruct the learning goals and adopt them and for teachers to do "think out louds" (teacher models a metacognitive process by describing their thinking when solving a problem) with anchor charts (a visual posted in the classroom that describes procedures, processes, or strategies) on how and what to think about. The focuses needed to shift to students to be reflective of their learning and to think about what they needed to do to be successful. A secondary teacher talked about how she was now doing less work in planning and said, "I was doing more song and dance and creating so many different activities for different learners and now I am getting out of

their way and letting them do more." The teachers talked about needing to create a "culture of learners" where failure was welcomed. Teachers admitted that they struggled with letting kids fail and making mistakes. They acknowledged they were always trying to save their students from failure. The majority of teachers admitted that in the past they always wanted right answers. They saw TTPS as a possible strategy that supported a "culture of learners."

Teachers realized during the reflection that they never helped students to understand the student role in the three-part lesson or TTPS. One teacher said, "maybe we never helped kids to know their role in 3 part TTPS lesson – very different than their role in the past – now they have so much responsibility." Teachers recognized the students' roles as being very different in a TTPS classroom than in the traditional classroom with students now having more responsible for the learning. Teachers agreed that, as a result of the project, they needed to be more explicit with students about the student role in learning. They needed to tell students what learning is and how it happens. They needed to teach students how to work in groups, how to learn from each other, and how to ask questions. One teacher said, "we help kids learn to ask questions and work in groups." As a result of the project, teachers placed more emphasis on student-to-student interaction in their classroom. TTPS had helped them to create a purpose and give space for student-to-student interaction.

**Dimension 10: Teachers' Conception of Mathematics**

Whether teachers see mathematics as a fixed body of knowledge or as a dynamic body of knowledge based on human activity impacts how they teach mathematics.

Questions 15 and 20 in the mathematics survey identified teachers' beliefs about mathematical knowledge. Table 13 shows participants' pre- and post-survey responses. The majority of teachers in the project saw mathematics knowledge as a dynamic body of knowledge before the project. In the pre-survey, 64% of respondents disagreed or strongly disagreed with the statement: A lot of things in mathematics must simply be accepted as true and remembered and 71% of respondents disagreed or strongly disagreed with the statement: You have to study mathematics for a long time before you see how useful it is (see Table 13).

Table 13. *Mathematics Teacher Survey: Total Likert Responses to Questions 15 & 20*

| Question | | | 1 Strongly disagree | 2 | 3 | 4 | 5 Strongly agree |
|---|---|---|---|---|---|---|---|
| 15 [a] | A lot of things in mathematics must simply be accepted as true and remembered. | Pre | 11 | 7 | 8 | 2 | 0 |
| | | Post | 4 | 8 | 2 | 0 | 0 |
| 20 [a] | You have to study mathematics for a long time before you see how useful it is. | Pre | 10 | 10 | 5 | 2 | 1 |
| | | Post | 11 | 3 | 0 | 0 | 0 |

[a] Negatively worded question.
*note.* N=28 for the pre-survey and N=14 for the post-survey

After the project, participants who changed their mind to agree more or less with the statement about things in mathematics being something to simply accept as true and to be remembered was about the same (see Table 14), showing no overall gain for the group in this understanding. However, post-survey responses on the statement about mathematics being something you have to study a long time to see is usefulness, changed with 70% of post-survey respondents who were not already strongly disagreeing with the statement disagreeing more (see Table 14). Participation in the project with learning about TTPS may have helped teachers to see useful applications of mathematics and to change their view of mathematics from a fixed body of knowledge to one that changes and adapts with new experiences.

Table 14. *Mathematics Teacher Survey: Comparison of Pre- and Post-Survey Results for Questions 15 & 20*

| Question | | Number that strongly disagree both pre & post | Number and percent that agree more on post | | Number and percent that agree less on post | |
|---|---|---|---|---|---|---|
| 15[a] | A lot of things in mathematics must simply be accepted as true and remembered. | 2 | 5 | 42% | 4 | 33% |
| 20[a] | You have to study mathematics for a long time before you see how useful it is. | 4 | 1 | 10% | 7 | 70% |

[a] Negatively worded question.

In the final reflection the selected team talked about the skills students needed to have entering high school. Working with fractions and integers were identified as lagging skills. Elementary teachers commented that they also saw more need for teaching algebra in their classes as a result of their time at the high school. The comments that revealed the most about the teacher's belief about mathematics came when the group talked about practicing skills. Their first thought was to give review sheets for specific skills as extra practice to complete at home, but after more discussion they changed their thinking. The group came to the realization that students would improve their skills by using them in an appropriate context. One teacher said, "we need do it (teach skills) in context throughout the year." Teachers said they needed to highlight these "lagging" skills throughout the year in all the problems they presented so students would see their value and importance in context. Although the group still felt strongly about the need for procedural fluency, they felt that the "learning skills" should be the focus. One teacher said, "The TTPS approach requires kids to use the learning skills" and another teacher asked "how to we make students more responsible to show their thinking." The group discussed the importance of students being able to figure out when they did something wrong and how to show new learning. At the end of their discussion, they agreed that the important skills students needed to enter high school were "initiative and self-advocacy."

**Question 2**

*Which features of the Lesson Study design support professional learning? In what ways?*

The Lesson Study design in the school board's project can be divided into three phases: Lesson Planning, Teaching and Observation, and Debrief and Discussion.

**Phase 1: Lesson Planning**

In the post-survey, teachers were asked to describe how each part of the Lesson Study process impacted their practice, i.e., what they learned in each step that affected their ideas about teaching and learning. Three questions in the post-survey focused on the Lesson Planning phase. Table 15 shows different themes found in participants' responses to Questions 1a, 1b, and 1f.

Table 15. *Teacher Questionnaire: Post-Survey Responses in Phase 1, Lesson Planning*

*1a. Choosing a research questions/lesson focus*

| **Response Themes** | **Number of Responses** |
|---|---|
| Linking curriculum to one big idea or learning goal | 7 |
| Developing a question | 3 |
| Value in collaboration | 3 |
| Team size | 1 |

*b. Collectively developing the lesson plan*

| **Response Themes** | **Number of Responses** |
|---|---|
| Learning from each other through collaborating and sharing ideas | 9 |
| Teaching strategies | 3 |
| Lesson structure | 2 |

*f. Collaboratively modifying the lesson*

| **Response Themes** | **Number of Responses** |
|---|---|
| Different ideas for improving lesson | 6 |
| How to focus student work | 6 |
| Letting students struggle | 1 |

In previous years, the school board in-serviced teachers on using Understanding by Design (UbD) and big ideas to develop their courses. In the year prior to this project, the school board placed a heavy focus on developing and using learning goals and success criteria. Responses to Question 1a indicate that teachers were using their previous knowledge about big ideas and learning goals to help set the lesson focus.

Some of the written responses teachers wrote for Question 1a about having to choose a research question/lesson focus were:

- "Helped me to see how you need to continue to concentrate on the big ideas when choosing a lesson focus." (Participant 16)
- "This reminded me of the need to always have a specific learning goal/objective for each lesson linked to the curriculum." (Participant 11)
- "Helped me focus my process to go from the curriculum to the real-life connection." (Participant 10)

In the first observation of the selected team during the planning session, secondary teachers commented on their struggle to see how TTPS fit with UbD, their current model for instructional design. The group questioned the purpose of TTPS and wondered

whether the goal was just to increase student engagement. During this first planning session, the group also struggled with the purpose of minds-on, developing a clear learning goal, and when to introduce the learning goal. The group was very apprehensive and nervous about going into the class with the lesson but also were eager to see whether the TTPS approach and the lesson they created would work, i.e., engage the students in learning.

After the first teaching, the selected team reviewed student work they collected and planned the consolidation part of the lesson. This time, their planning focused on what they understood students to know as a result of their observation and collected students' work. They debated a variety of consolidation strategies and made their strategy choice based on the student work samples.

On the second CLiC day, the selected team was much faster at planning the lesson and the conversation about the minds-on focused on the common errors students make. In developing their lesson, the group debated different teaching strategies and whether to use manipulatives. They continued to struggle with the idea of not giving students a specific procedure and giving students time to think about the problem. They decided on letting students do a *turn and talk* (a strategy where students turn to the person next to them and talk about the questions posed) on what procedure they would use to solve the problem. The turn and talk strategy was first prompted by the Literacy and Numeracy Secretariat (LNS), a department in the Ontario Ministry of Education responsible for student success in Grades K–6, in a monograph from their capacity building series called Communication in the Mathematics Classroom (Literacy and Numeracy Secretariat, 2010). Teachers in the project planned to use the students' responses, from the turn and talk, to develop a procedure checklist during the consolidation.

These data and observations reflect the first element of effective Professional Learning: build on teachers' previous knowledge and address their beliefs and attitudes about education. Teachers in the project clearly used their understanding of UbD and the school board's requirement for learning goals and success criteria as a starting place for discussion. The focus in the planning session was on the teaching and what teachers would say and do when they arrived in the classroom. When teachers returned, after teaching and observing, to prepare the consolidation lesson or to refine the lesson, they

were more focused on responding to students. Their predetermined ideas of how the lesson should go were allowed to change based on students' responses. Teachers were more open to an unpredictable outcome. The teachers adopted a new view, were starting to embrace change, and were willing to look for new and creative solutions. Teachers became more purposeful in their planning for students' responses, i.e., choosing strategies to give students the opportunity to demonstrate the learning goal, as they progressed through the project.

Teachers on the post-survey expressed similar responses to what was observed by the selected team. One comment on Question 1f about modifying the lesson was: "makes us focus on what we want the kids to know and come up with, something that will show us that they get it. It puts the focus on the learning goal." (Participant 26)

**Phase 2: Teaching and Observation**

Teachers reflected on this Phase in four questions on the post-survey. Table 16 and 17 show different themes found in participants responses to Questions 1c, 1d, 1g, and 1 h.

Most respondents answered the questions as if the first teaching and observation (see Table 16) were at the elementary school and the second teaching and observation (see Table 17) were at the secondary school.

Table 16. *Teacher Questionnaire: Post-Survey Responses in Phase 2, First Teaching*

*c. The first teaching*

| **Response Themes** | **Number of Responses** |
|---|---|
| Creating the minds-on ( or hook) | 4 |
| Allowing student to struggle | 4 |
| Ways to engage students | 4 |

*d. The first lesson observation*

| **Response Themes** | **Number of Responses** |
|---|---|
| Lesson structure/timing | 6 |
| Listening for student mathematics talk | 3 |
| Allowing students to struggle | 2 |
| Creating student engagement | 2 |

Most groups broke their elementary lesson into two teachings: one for the minds-on and action and one for the consolidation. In their secondary lesson, most groups taught

once with all three-parts of the lesson, but some groups taught over 2 days with time to reflect before teaching the consolidation part of the lesson. Other secondary groups, however, did teach the same lesson twice in one day and modified the lesson in between the teachings.

Table 17. *Teacher Questionnaire: Post-Survey Responses in Phase 2, Second Teaching*

*g. The second teaching*

| **Response Themes** | **Number of Responses** |
|---|---|
| Lesson structure/timing/impact | 6 |
| How to engage students | 2 |
| Feedback to students on progress | 1 |
| Letting students struggle | 1 |

*h. The second lesson observation*

| **Response Themes** | **Number of Responses** |
|---|---|
| Student involvement in lesson/learning | 4 |
| Letting students struggle | 2 |
| Value in cross panel viewing | 1 |

The responses to the post-survey about the teaching were very focused on the three-part lesson: minds-on, action, and consolidation. Although three-part lessons in mathematics were not a new idea for the teachers, very few of them regularly followed the three-part structure. Teachers seemed to struggle with creating a minds-on problem, to activate prior knowledge. Most teachers reported being good at assigning independent practice, but highlighting and sharing in the consolidation phase was new for most teachers. An action that required students to struggle and explore solving a real-life problem in small groups, the essence of TTPS, was clearly new for all the teachers involved. Teachers were clearly engaged in active learning about the three-part lesson and TTPS. Some of the comments were:

- "Finding the right minds-on is sometimes a challenge (so it will lead directly to the main activity)." (Participant 11)
- "We learned a lot about minds-on. We found that we often made it too long and involved and it was almost an action in itself." (Participant 16)
- "When given the opportunity and students feel that they are part of the learning, they will engage." (Participant 31)

- "Students need to be re-assured that their ideas are on right path before they go on to more practice. I need to plan more consolidation." (Participant 19)
- "Need to give students time to discover, students need an understanding of why they are doing this." (Participant 15)
- "How to guide students to a discovery without doing it for them." (Participant 24)

While observing students, teachers seemed generally surprised with the conversations students were having and the level of knowledge and engagement. Most of the responses about what was observed focused on what students were doing and how students were reacting to the lesson. Some participants' comments were:

- "It was interesting how much kids know without telling them. Kids thought of things in way we would never have guessed." (Participant 25)
- "Students like to share their work, students don't like revising mistakes." (Participant 24)
- "Interesting to see the engagement level achieved by choosing a good problem." (Participant 28)
- "Using something that connects with the kids engages them a lot more." (Participant 29)

For the selected team, the teachers expressed surprise with students' choices during the lesson in each CLiC. During the elementary CLiC, they were surprised that no group chose the t-chart for a strategy in solving the problem. They were surprised to hear students reflect and question their own reasoning. Teachers heard students ask, "what makes sense?" and "what's wrong?" Teachers commented that they were truly impressed with the students' work. In the secondary CLiC, teachers were again surprised that students did not select what teachers thought to be the obvious strategy to solve the minds-on question. They also noted that students really understood the concept of "slope," which was one part of the lesson, but that they did not have a good understanding of what "b," as the y-intercept, was in the algebraic equation for a linear function.

The observation allowed the teachers to really see and hear their students. Reflecting on their learning from what they observed, one of the selected team members

said, “I feel like I learned that it is easy to miss how some “low-key” students DO participate when I am distracted by the rest of the class.”

In the post-interview with one of the curriculum leaders, he stated that the biggest growth for the teachers occurred when they saw how students responded to instruction. He commented on how teachers were surprised by the students’ actions and commented on how the students knew more and could do more than teachers expected.

During the observation, teachers in the selected team struggled to just observe and not to assist students with the problem. Observers were each given an observation form to record what students were saying and doing in each part of the lesson. The instructions were to sit with one group of students and write down what they observed. Although many in the group tried to follow the plan, most could not sit and just watch. They moved around the room observing all the groups. Teachers in the role of observer commented on how difficult it was to watch students struggle with the problem and to make computational errors.

These data and observations reflect the second element of effective Professional Learning: engage teachers in an active learning process situated in the curriculum. Teachers were very engaged in learning the three-part lesson structure and understanding each part. TTPS was a new and challenging concept, but the repeated reference to letting students struggle showed that teachers were attempting to implement TTPS. Teachers were experiencing some of the same struggles their student were. Teachers were also very focused on student reactions to their lessons and how engaged students were in learning. Student responses impacted the plans for consolidation lessons. As a result of student reactions, the selected team commented on the changes they would make to their minds-on when they repeated the lesson.

### Phase 3: Debrief and Discussion

Teachers reflected on the Debrief and Discussion Phase in two questions on the post-survey. Teachers commented that the debrief served two main purposes. First, it allowed time for teachers to reflect on the actual lesson, what worked, and what needed improvement. Second, it allowed teachers time to have a meaningful discussion with their peers about teaching and learning in general. Table 18 shows different themes found in participants’ responses to Questions 1e and 1i.

Some of the responses on their learning were:

- "Great discussion amongst teachers about what we saw and how to improve student learning." (Participant 31)
- "What questions to ask students – how to make consolidation student led not teacher led – which solutions to include ( variety) ( different strategies)." (Participant 15)
- "Assessment of learning works." (Participant 10)
- "The different ways to consolidate/share from experiences of students, show a sequence, find value in many solutions." (Participant 19)

Table 18. *Teacher Questionnaire: Post-survey Responses in Phase 3, Debrief and Discussion*

*e. The debrief discussion after first observation*

| **Response Themes** | **Number of Responses** |
|---|---|
| Having time for reflection to express a variety of ideas | 7 |
| Using and Improving student responses | 6 |

*i. Debrief discussion after the second observation*

| **Response Themes** | **Number of Responses** |
|---|---|
| Identify student learning/understanding | 5 |
| Planning | 2 |

Teachers were reflecting on their new learning about creating and delivering a three-part lesson that focused on TTPS. Having had the opportunity to try the lesson, to observe students' reaction to it, to study student work during it, and to have time to debrief all the parts made teachers very reflective about their practice, in general. The selected team found the debrief and discussion time to be so valuable they used their third release day as a full day debrief and discussion. In the debrief after each CLiC, the selected team looked at independent practice they assigned as an exit question. This student work guided their discussion.

In the secondary CLiC, several students struggled with the exit question, leading teachers to a discussion about how they used groups. The teachers wondered if they had used pairs instead of groups of 3-4 whether more students would have gotten the exit

question. The results of the student work led to a discussion about the next lesson and how the teacher could address struggling students individually or in small groups.

Teachers on the second CLiC day were asked to set a personal learning goal for themselves at the beginning of the day and to reflect on their goal at the end. One secondary and one elementary teacher completed the task. The secondary teacher's goals were to learn how to deliver a three-part lesson and gather ideas for classroom management. He reported learning how he needed to create as much choice as possible in the activity part of the lesson, to scaffold the consolidation, and to ensure that he kept track of time so the majority of class time could be used for consolidation. The elementary teacher's goals were to see how high school classes function and to further develop understanding of consolidation. She reported learning about differentiating "minds-on" to allow for different entry points, learning ways to do more authentic highlighting, such as making anchor charts/bulletin boards of the thinking in regards to the learning goal, and learning different ways of sharing answers rather than just displaying on the board such as stay and stray (a strategy where one group member stays with the group's work and the other group members walk around to observe work from other groups) and guiding questions.

These data and observations suggest that the third component of effective Professional Learning, using metacognition and reflection to help teachers set goals and monitor their own progress, was attempted. Although interview questions, pre-project, showed that some teachers in the selected team entered the project because they were told to, others entered the project with a real goal for learning (to understand how TTPS works, to see what TTPS looks like in a classroom, to make connections with teachers in the other panel, and to see what learning looked like in the other school). This mix of initial goals helped to create some diversity among participants and led to a rich discussion about the role of the teacher in learning. While all the teachers in the project had teaching responsibility for mathematics and shared an interest in each other's students (some of the Grade 9 students were previously taught by the elementary teachers and the Grade 8 students would soon be heading to the secondary school) which helped to create common ground on which to build an initial connection among the members of the team, they still initially saw their roles as teacher differently. The elementary teachers

commented on how they felt secondary teachers were teachers of content and elementary teachers were teachers of the whole child. Some research supports this thinking, finding that lecturing and teacher-centered behaviors, such as the unilateral transmission of knowledge, steadily increases from the elementary grades to the secondary grades, while interaction with students and active modes of learning progressively decreases (Schulte, Slate, & Onwuegbuzie, 2008).

In the final reflection day, the selected team commented that they would never have believed in the value of the three-part lesson and TTPS if they were just told about it. They felt they had to see it in action, try it out to understand it, and build their own reasons for doing it. One teacher said, "we had to jump in and try to build the why" and another teacher said "we came because of the myths – we needed to see it." They needed it to feel like a grassroots initiative. As a result, the group said they were now motivated to make changes to their practice. One teacher said, "we were doing active learning, parallel questioning, critical thinking, etc., and that three-part lesson with TTPS helped to pull it all together." She also commented on how her sequence was different now and said, "I was doing more song and dance and creating so many different activities for different learners and now I am getting out of their way and letting them do more." Teachers saw more possibilities in their teaching practice with their new learning.

**Collaboration**

Evidence of the last component of effective Professional Learning, to facilitate a collaborative community of teacher professionals for support and sharing of resources, came out in many of the questions. Teachers commented many times about the value of collaboration in the project.

In the pre-survey, most respondents felt they had a strong to very strong belief (20 out of 28 or 71%) in their capabilities to work collaboratively with colleagues to develop effective tools for teaching (see Table 19). An equally large percent of respondents (79%) felt they contribute to meaningful dialogue with colleagues about the teaching-learning process.

Table 19. *Self-Efficacy Survey: Total Likert Responses for Questions 14 & 15*

| Question: Right now in my present teaching situation, the strength of my personal beliefs in my capabilities to…. | | | 1 Weak belief | 2 Moderate belief | 3 Strong belief | 4 Very strong belief |
|---|---|---|---|---|---|---|
| 14 | work collaboratively with colleagues to develop effective tools for teaching | Pre | 0 | 8 | 13 | 7 |
| | | Post | 0 | 0 | 7 | 7 |
| 15 | contribute to meaningful dialogue with colleagues about the teaching-learning process based on evidence collected from student work/observation | Pre | 1 | 5 | 16 | 6 |
| | | Post | 0 | 0 | 7 | 7 |

Data from the post-survey indicates teachers in the project, who did not already strongly agree in their capabilities, increased their belief in their capabilities to work collaboratively and contribute in meaningful ways (see Table 20).

Table 20. *Self-Efficacy Survey: Comparison of Pre- and Post-Survey Results for Questions 14 & 15*

| Question: Right now in my present teaching situation, the strength of my personal beliefs in my capabilities to…. | | Number who had very strong belief in capabilities both pre & post | Number and percent that increased belief | | Number and percent that decreased belief | |
|---|---|---|---|---|---|---|
| 14 | work collaboratively with colleagues to develop effective tools for teaching | 3 | 6 | 55% | 1 | 14% |
| 15 | contribute to meaningful dialogue with colleagues about the teaching-learning process based on evidence collected from student work/observation | 3 | 5 | 45% | 2 | 18% |

In the post-survey, teachers were asked whether they would use Lesson Study as a process to engage in collaborative inquiry learning and to give their own reason why. Of the 12 respondents to this question, all responded yes (see Table 21) to using Lesson Study again and the majority (58%) stated having the opportunity to collaborate with colleagues as the reason.

Table 21. *Teacher Questionnaire: Post-Survey Responses on Future Use of Lesson Study*

*3. Would you use Lesson Study as a process to engage in collaborative inquiry learning/ why?*

| **Response** | **Comment themes** | | **Number of Responses** |
|---|---|---|---|
| No answer | Blank | | 2 |
| Yes | Collaborate with colleagues | 7 | 12 |
| | Need a smaller group | 2 | |
| | Involves students | 2 | |
| | Learn lesson structure | 1 | |

Some of the responses from Question 3 in the post-survey that focus on collaboration were:

- "Yes, there is so much to learn and it gives the opportunity for me to bounce ideas off of colleagues." (Participant 26)
- "Yes it promotes professional time for exchange of ideas and problem solving." (Participant 11)
- "Yes. Great to work with teachers in elementary and even secondary colleagues to gain new perspectives. Different ways of teaching, technology, etc. We need to reflect on parts of our lessons, and how to develop or change ways we teach things. It's nice to see the big picture and then work as a team to maximize learning/teaching." (Participant 15)

During the post-interview for the selected team, teachers commented on how comfortable they had become with each other and how they hoped to have more opportunity to work together. They commented on the value of the project, allowing them to share and exchange ideas. One teacher said, "I like bouncing ideas off each other and don't think my lesson would have been the same without the group." Other comments included, "interaction excellent," "nice social support," "liked small group format," "get to pick curriculum brains." Teachers in the group also commented on how much they enjoyed collaborating with curriculum leaders from the school board and the new experience of having someone with pedagogical knowledge support and work with them in the classroom.

**Summary**

In the post-survey, participants were asked which part of the Lesson Study process was most important to their learning and why. Lesson planning was ranked the highest (see Table 22) among the post-survey participants, but the participants discussed impact from all three phases.

Table 22. *Teacher Questionnaire: Post-Survey Responses on Most Important Phase*

*2. Which part of the Lesson Study process was most important to your learning? Why?*

| **Response** | **Comments** | **Number of Responses** | **Percent of Responses** |
|---|---|---|---|
| Lesson Planning | - see other ideas<br>- creating 3 part lesson ( minds-on)<br>- cross panel conversation | 6 | 43% |
| Teaching & Observation | - see how it impact students<br>- see engagement level | 4 | 29% |
| Debrief and Discussion | - discuss common challenges in both panels<br>- share strategies<br>- discuss what to consolidate | 3 | 21% |
| Whole thing | - Working with other teachers | 1 | 7% |

Some of the responses from participants on Question 2 included:

- "The co-planning, it helped me see ideas that other teachers bring to their lessons." (Participant 24)
- "planning; allowed cross panel conversation , curriculum continuum; see how simple minds-on could be; confirmed my current practice was moving in direction of TTPS." (Participant 19)
- "Observation and creation of lessons. Actual action allowed me to see/change/modify my practice and approach to creating lessons. Idle conversations kill progress and are difficult to sift through to find applicable information." (Participant 27)
- "The discussion about common challenges faced in elementary and secondary mathematics teaching. It was great to collaborate and share strategies and

language around mathematics topics. Should allow for consistency and flow between levels in the future if collaboration were to continue." (Participant 20)

The three teachers, in the selected team who completed the post-reflection, all suggested the debrief was the most important part in their learning. Their responses included comments on the constructive debate they had, the sharing of ideas, clarifying misconceptions, and, most importantly, how to improve instruction. One responded, "the debrief was the most important part for me because it helped me understand how the lesson could be changed for the better and how I could change my delivery to try for better results the next time." (Selected team member)

The data show that all three phases of this Lesson Study design—lesson planning, teaching and observation, and debrief and discussion—were necessary for learning. Different teachers found different parts of the design more value to their personal learning, but all parts were necessary to create an overall effective professional learning experience. For the surveyed teachers and the selected team, each reported they would participate again suggesting the experience was effective in creating conditions for teacher learning. Combining responses from surveyed and the selected team, indicates lesson planning, and the debrief and discussion have the greatest impact. Given that creating three-part lessons and TTPS were new concepts for most participants, it is not surprising they found lesson planning to be one of the features that presented the greatest opportunity to gain knowledge. Many teachers in this project commented about not having many prior opportunities to sit and have a conversation about teacher and learning with their colleagues from the other panel or even in their own schools. The debriefing phase set the conditions for their conversations about teaching and learning to happen. These conversations led to the teachers developing a common language around teaching mathematics as describe in the comment above from Participant 20. The debrief also focused on the lessons they had just observed, setting the condition for a conversation based on observing students' learning. It was these conversations that had the most impact on teaching practice.

**Question 3**

*What impact do teachers feel their participation in the Lesson Study has on their students' learning and achievement?*

The school board's project was focused on teacher learning. The underlying belief was that improved teaching practice would lead to improved student learning and achievement. The self-efficacy survey measured teachers' belief in their capabilities to impact student learning. Responses to some of the questions that relate to the goals of the project are in Table 23.

Table 23. *Self-Efficacy Survey: Comparison of Pre- and Post-Survey Results for Various Questions*

| Question: Right now in my present teaching situation, the strength of my personal beliefs in my capabilities to…. | | Number who had very strong belief in capabilities both pre & post | Number and percent that increased belief | | Number and percent that decreased belief | |
|---|---|---|---|---|---|---|
| 1 | plan activities that accommodate the range of individual differences among my students | 2 | 3 | 25% | 1 | 8% |
| 3 | use allocated time for activities that maximize learning | 3 | 3 | 27% | 3 | 27% |
| 4 | maintain high levels of student engagement in learning tasks | 2 | 5 | 42% | 0 | 0% |
| 5 | communicate to students the specific learning outcomes (success criteria) of the lesson | 1 | 5 | 38% | 2 | 15% |
| 6 | communicate to students the purpose and/or importance (goals) of learning tasks | 4 | 3 | 30% | 0 | 0% |
| 8 | provide students with specific feedback about their learning | 1 | 5 | 38% | 3 | 23% |
| 11 | adjust teaching and learning activities as needed | 4 | 4 | 40% | 2 | 20% |
| 12 | motivate students to perform to their fullest potential | 3 | 4 | 36% | 2 | 18% |
| 13 | improve the academic performance of students, including those with learning disabilities | 2 | 5 | 42% | 1 | 8% |

On some questions, teachers already had a strong belief in some of their own capabilities both pre- and post-survey as reported in Table 23. The reported increases or decreases in beliefs in Table 23 are for teachers who did not report a very strong belief both pre- and post-survey for that question. The data suggest that some teachers in the

project changed their belief in their capabilities. For the 14 teachers who submitted a post-survey, all but one teacher reported an increase in belief in their capabilities in at least one question and two teachers reported an increase in belief in their capabilities in as many as eight questions. The greatest reported increase was in Question 4 on engaging students and in Question 13 on improving academic performance.

In post interviews, with the selected team, teachers reported an increase in student engagement. This was a result they were impressed with. In the administrator post interview, the vice-principal, when asked about changes he saw in teacher and students learning, reported that some teachers commented that their participation in the project "helped them to think differently and reflect on their practice in the classroom."

In both CLiC days, teachers were able to engage all the students in the three-part TTPS lessons they created. The first day, in the elementary class, the action problem required students to choose the best hall for a teacher's upcoming wedding given she had a fixed amount she could spend. Each hall had a different fixed rental cost for the hall and a different cost per person attending. Recognizing they could use linear equations to solve problems was the learning goal. Every student group was able to engage in, and find a solution to, the problem with some using algebra. Some student solutions are shown below, in Figure 5.

Teachers were very pleased with the engagement and the different approaches students took in solving the problem as seen in the results Question 4 in Table 23 about being able to maintain high level of engagement. In consolidation, students were asked to list what was the same and what was different in the different group solutions presented. Teachers chose to have each group present their solution to the class so they could all receive feedback from their peers and the teachers. This helps to explain the increase in Question 8 in Table 23 about providing feedback about learning.

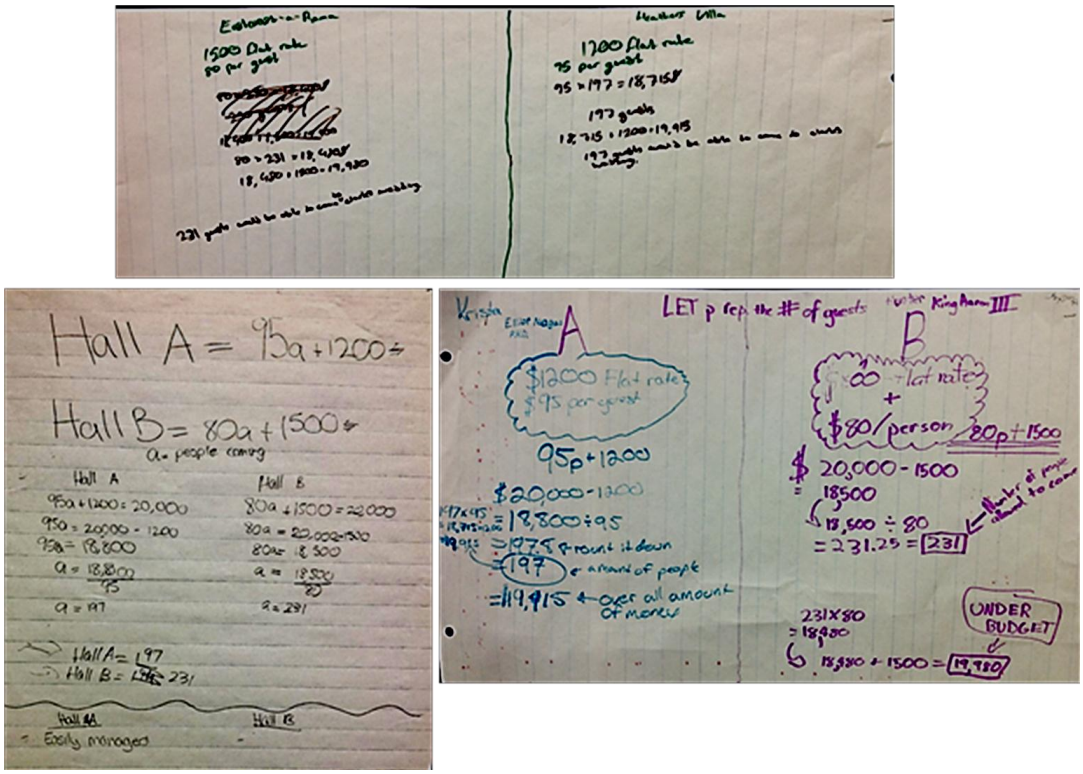


*Figure* 5. Student Work from CLiC 1.

The second day, in the secondary class, the action problem required students to find the cost for a number of karate lessons given two other students' information about cost and number of lessons. The learning goal was for students to find the equation of a line given two points. Again, every group was able to engage in the problem and find a solution. During the observation, teachers were able to capture some of the conversation (see examples below in Figure 6) students were having while solving the problem.

For some teachers this opportunity to observe in both CLIC days was the first time they were given time to just sit and listen to a group of students as they solved a problem. The notes show that they captured what students we saying and doing in each stage of the 3-part lesson (minds-on, action, and consolidation). They also recorded their observation for both stages of consolidation: sharing and highlighting. During the de-brief phase they referred to their observation notes as they discussed how students were responding to the lesson. This was the first time most of the teachers had recorded observation evidence in a math classroom and had used it to analyse students understanding. Teachers were surprised but please that all students had attempted the

questions and worked together. This helps to further explain the result of teacher feeling they maintain high levels of engagement in their class for Question 4 in Table 23.

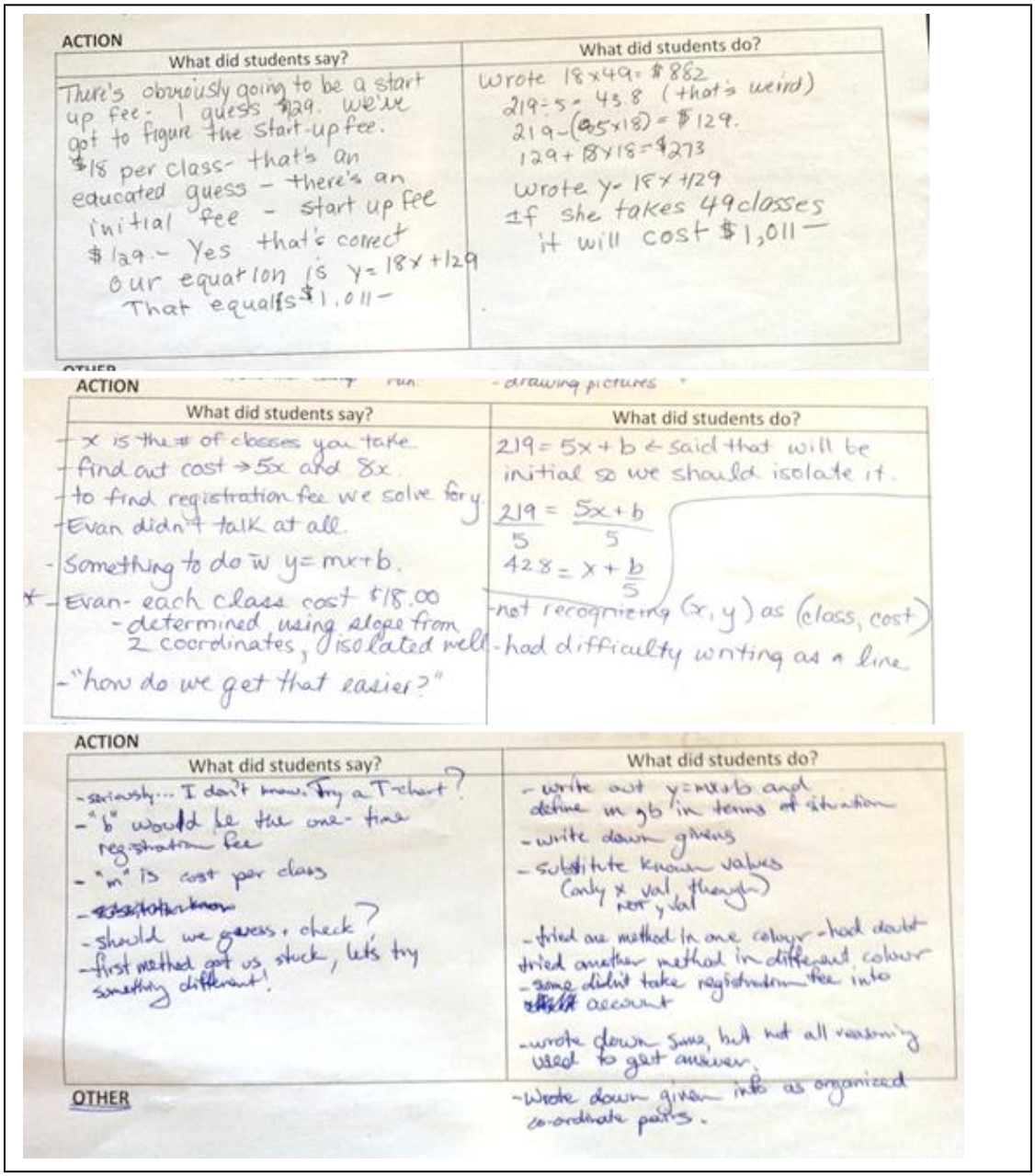


*Figure* 6. Samples of Teacher Observation Notes during the Action Phase from CLiC 2.

Teachers used two samples of student work (see samples in Figure 7) for highlighting to the class. Teachers were very pleased with the level of engagement, and, during the consolidation time, students were able to share and explain their procedures and together as a class develop an algorithm for solving similar kinds of problems.

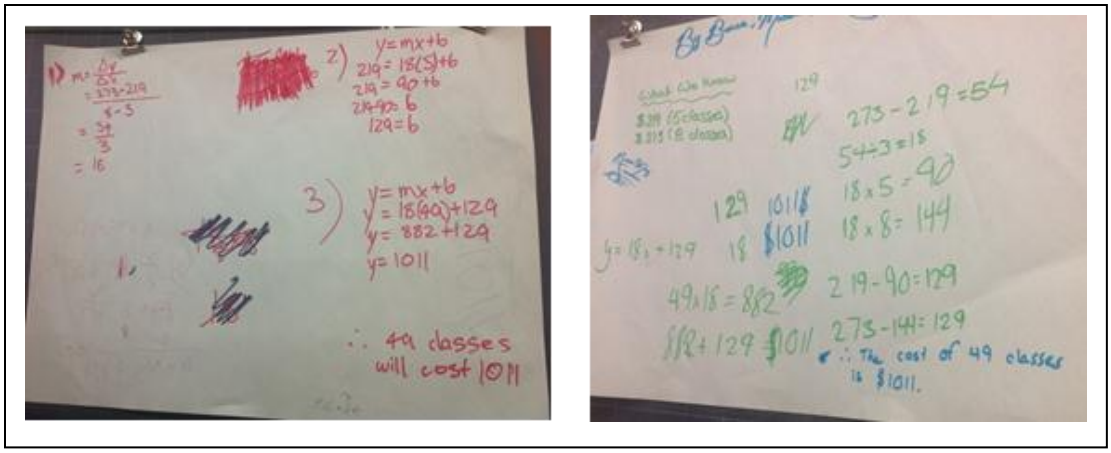


*Figure* 7. Samples of Student Work Used for Highlighting from CLiC 2.

On the third CLiC day, the selected team discussed their learning in the project and the impact it was having on their teaching and their students' learning. One of the elementary teachers commented on her success with three-part lessons and in particular, the highlighting strategy in consolidation. She felt more aware now of the need to show how different groups solved the problem, their different approaches or strategies, the formulas they chose, and the way they communicated their solution. She saw the value in using highlighting to gage student understanding and as a necessary component to show her when and where to incorporate direct teaching. With regards to TTPS, several of the teachers said that "it was working" and students were "retaining information" better with this teaching strategy. One the secondary teachers talked about using TTPS in his Grade 12 class and said that he was getting "better buy in" and that his students were "deconstructing their learning." These comments showed that teachers saw their involvement in the project with learning around three-part problem solving and TTPS was giving them different results with their students.

When it came to working with struggling students, one of the teachers, on the third CLiC day, commented on how the only strategy he previously offered was to "memorize and regurgitate." Another teacher said she now realized that students left behind were a reflection of their input. They all recognized that in their previous practice the teacher was the only source of feedback for students and that peer and self-feedback was critical for success. Strategies that got students talking about mathematics and sharing their learning, such as turn and talk, were becoming common practice in all their classes. How teachers' saw as their role in teaching and learning was changing. One of

the secondary teachers said, “We are discovering our role – what we do is help students learn to ask questions and work in groups.”

Responses to Question 13 in the self-efficacy survey, which asked teachers whether they felt they could improve student performance, are consistent with comments from the selected team in each CLiC about the increase and retention in student understanding. It should be noted that the selected team identified that students who struggled with concepts before still struggled with concepts in the TTPS lesson, but teachers felt they had a better understanding with where their students were struggling. Increased student engagement in the TTPS lesson allowed teachers more opportunity to see and hear student misunderstandings and to highlight more student work. More student engagement gave teachers confidence in their ability to impact student learning through their planning, instruction, and the environment TTPS created. Overall, teachers reported participation in the project increased their belief in their ability to impact and improve student learning.

# CHAPTER 5

## Discussion

> Educational research that is oriented by complexity science would, for instance, be interested in attending to the dynamic elements and conditions that enable the emergence of certain sorts of engagement and insight. (Davis & Sumara, 2005, p. 318)

Professional development for teachers should be about teacher learning, constructing knowledge about teaching, and about the process of learning (Loucks-Horsley et al., 2003). Davis, Sumara, and Luce-Kapler (2000) describe learning as a complex process in their claim that "knowledge is contingent, contextual, and evolving; never absolute, universal or fixed" (p. 78). To know *of* teaching is very different from knowing *about* teaching. Knowing of teaching is being able to give a definition and characteristics, whereas knowing about teaching is being able to use practical experience to explain how it changes for each unique student. How teachers gain this type of knowing, through a process like Lesson Study, is what this research project was about.

This chapter discusses the findings and implications from researching a Lesson Study project, a particular school board (system), individual teachers, and students involved in the project. Limitations from participant selection, data collection, and the role of the researcher are discussed. Finally, recommendations for success with future Lesson Study projects are outlined. Figure 8 is an organizer for the chapter.

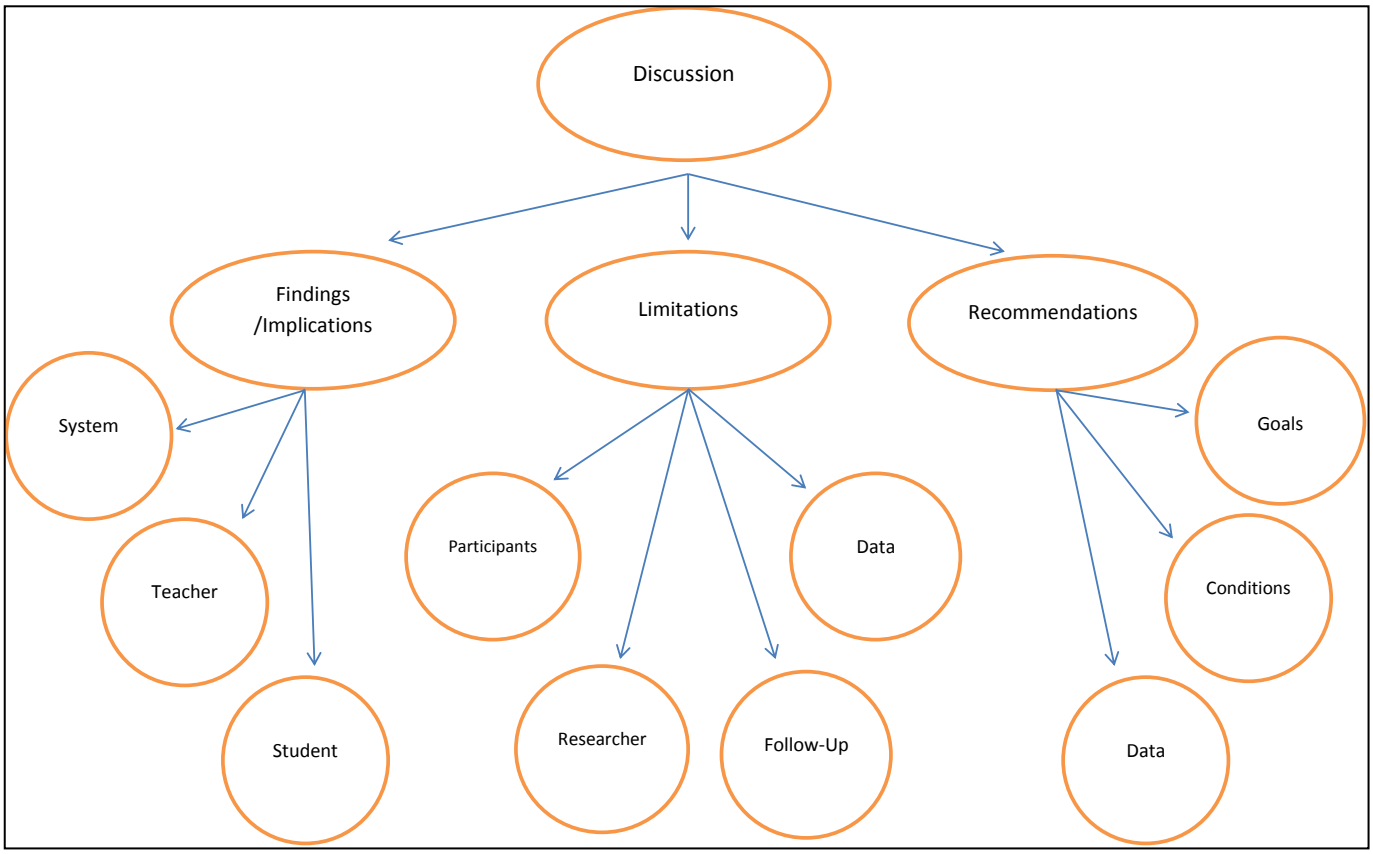


*Figure* 8. Organizer for the Discussion.

## Findings and Implications

In Japan, the reason for using Lesson Study for professional learning is to bring to life a particular goal or vision of education. In Ontario, the Ministry of Education (2011) stated their vision for Ontario is to remain a "great system" and to continue to be among the top 10 education systems in the world. In other words, to achieve their vision, the Ministry set a goal to focus on mathematics teaching, leading, and learning. In its report *Paying Attention to Mathematics* (2011), the Ministry outlines seven foundational principles for improving Mathematics in K–12 classrooms:

- Focus on mathematics.
- Coordinate and strengthen mathematics leadership.
- Build understanding of effective mathematics instruction.
- Support collaborative professional learning in mathematics.
- Design a responsive mathematics learning environment.
- Provide assessment and evaluation in mathematics that supports student learning.
- Facilitate access to mathematics learning resources.

The Ministry's goal around paying attention to mathematics served as one of the reasons behind the school board's decision to run the mathematics Lesson Study project that was the focus of this research.

### System

Teachers involved in this research followed a modified Lesson Study process created by the school board and adapted from the Ministry led initiative called CIL-M (Collaborative Inquiry Learning in Mathematics). The process involved teacher teams made up of both elementary and secondary mathematics teachers who created, delivered, observed, and debriefed a mathematics lesson for both an elementary and a secondary school classroom. Administrators and curriculum leaders were also part of the teams.

Some secondary schools in the project had never worked with their feeder schools prior to the project. Most of the teachers as well as administrators and curriculum leaders in both panels had never spent time reviewing curriculum from the other panel. As a result of the project, new working relationships formed between the elementary and secondary schools for the teachers and administrators. Teachers developed a better

understanding of the daily routines in the other panel and a deeper awareness of curriculum connections between grades. In both panels, teachers reported (through post-surveys and during the final debrief for the selected team) developing cross-panel relationships as a huge benefit from participation in the project. New relationships also formed between elementary curriculum leaders and secondary teachers and administrators. Secondary teachers commented on how valuable they found the new experience of working closely with an elementary curriculum leader on pedagogy.

Throughout the project, it was evident that elementary and secondary teachers had different approaches to teaching mathematics and had previously received different professional development about instructional strategies. This difference could be attributed to the fact that the Ontario Ministry of Education released several guides for effective instruction in elementary education which the elementary curriculum teachers had used to in-service elementary teachers. At the time of the project, there were no such guides available for secondary teaching so there had been no similar in-services on effective instruction for secondary teachers. In most groups, teachers from both panels benefitted from working together and increased their knowledge of instructional strategies. For example, "Turn and Talk" (a strategy where students turn to the person next to them and discuss a concept or question the teacher has posed) was widely used only in the elementary panel prior to the project and after the project became a popular strategy in secondary mathematics classrooms. Through the Lesson Study process, teachers in the project developed a common language and understanding of different teaching strategies. When teachers develop a common language about their practice they are able to talk about their students' achievement and develop a sense of collective responsibility for all students' success (Hargreaves, Morton, Braun, & Gurn, 2014). Through the sharing of strategies as well as experimenting with new ones, such as, TTPS (Teaching through Problem Solving), teachers increased their communication and consistency in practice across grades and schools.

### Teacher

Individual teachers, involved in the project, increased their knowledge and skills about teaching. A main goal of the school board's project was to expose teachers to a three-part lesson structure using TTPS. Unfortunately, most professional learning does

not involve time for teachers to work in classrooms where they are able to put theory into practice. Because the Lesson Study process involved creating lessons and testing them in a classroom the process was effective in giving all teachers, in the project, the opportunity to see and work with TTPS.

Through the use of the standards-based rubric of Mathematics Teaching (Ross & McDougall, 2003), the project focused on 4 key dimensions of teaching mathematics: Opportunity to Learn, Student Confidence, Student-Student Interaction, and Teachers Conception of Mathematics. Teachers increased their knowledge of the importance of each dimension, as well as, improved their use of strategies to have greater impact in each dimension.

For the dimension, Opportunity to Learn, teachers learned the importance of developing minds-on questions that activate students' prior knowledge and that engage all students at the start of the class. Teachers spent considerable time working on minds-on questions and making this a part of their daily practice. Teachers also learned how to create action questions that were open ended with multiple entry points so all students in the class could access the problem and contribute to a solution.

For the dimension, Student Confidence, teachers not only learned the importance of all students being able to access the content but also the need for students to struggle with the content. Prior to the project, most instruction was teacher led, where teachers shared solutions on the board, and teachers explained how to do the problems. As part of TTPS, students were given time to find their own solutions while teachers observed. Teachers at first found it very difficult to let their students struggle with a problem and try multiple strategies to discover a solution (as reported in surveys and discussed in lesson de-briefs). The selected team reported in their final de-brief, that it had been easier and less time consuming for teachers to tell students how to solve a problem than for students to discover the solution on their own. It was through the observation of students struggling that teachers learned how the struggle was connected to student confidence. Teachers saw how students took more responsibility for their learning, enjoyed their learning, and were proud of their learning. Teachers also noted that it was through the observation of the struggle, that teachers gained a better of understanding of when and why students were having difficulty. Teachers learned more about and became more

focused on how students were thinking and approaching problems versus just knowing which problems students got wrong.

For the dimension, Student-to-Student Interaction, in addition to giving students more time to work in groups, explore problems, and share ideas, teachers learned how to encourage more student "math talk" in their classroom. The action phase of the three-part lesson was all student-to-student interaction as groups of students worked together to discuss and solve the problem. Teachers only intervened to answer questions or to probe student thinking with guiding questions. Teachers observed the value of this discussion among students in building each student's own understanding of the concepts. During the consolidation phase in the three-part lesson, teachers had more students presenting and sharing their work with the whole class than in the past as reported in post-surveys. This sharing gave teachers more opportunity to hear students explain their ideas with mathematics terminology and conventions.

For the last dimension, Teachers Conception of Mathematics, teachers demonstrated a change in thinking through discussions. Teachers moved from talking about worksheets for missing mathematical skills, such as algebra skills or number sense, to teaching skills in context and highlighting skills throughout the course. Teachers used the highlighting time in the consolidation phase as an opportunity to address any misconceptions and reinforce necessary skills. Teachers learned to ask real-world questions to give more meaning and context to the mathematical skills they were teaching and shifted their focus from teaching only discrete skills to teaching learning skills, such as initiative and self-advocacy. They moved from seeing their job as mathematics teachers, as one of helping students master a specific set of rules, to one of helping students to embrace inquiry and use mathematical thinking to solve interesting problems.

Individual teachers, involved in the project, not only improved their knowledge and skills about teaching mathematics but also changed their attitudes and beliefs about teaching mathematics. In addition to the impact of Dimension 10 on teacher beliefs, the self-efficacy survey showed teachers' confidence in their ability to help students learn improved. Teachers reported an increase in their ability to engage their students and to improve student performance. Teachers reported using TTPS between CLiCs and in other

classes and feeling an increase in student "buy in" or participation in the lesson as well as seeing an increase in overall student learning.

The teaching profession is sometimes referred to as an isolated profession. Teachers are generally alone in their classrooms focused on managing their students and covering the content in the curriculum. Rarely are teachers observers of teaching, especially in their classroom or any classroom. The Lesson Study process opened the classroom door and gave teachers an opportunity to see each other's classroom and to observe teaching. Teachers, in the role of observer, were focused on student responses and reactions to co-created lessons. Teachers saw the lesson through student eyes. For some teachers in the project this was the first time they had observed teaching through the perspective of the student. This opportunity was both enlightening and rewarding for teachers and had a huge impact on their beliefs and attitudes about teaching mathematics. Teachers in the project commented on how their teaching practice was forever changed as a result of the project and that they could never go back to doing only the teacher-directed instruction they did before.

Teachers in the project also reported an increase in their ability to collaborate with their peers. The debrief discussions focused on the lesson they had just taught and centred on the students' responses they witnessed and collected, leading them to have meaningful and productive conversations. Teachers reported finding this type of collaboration more meaningful than what they experienced in the past. At the conclusion of the project, teachers reported wanting to continue with TTPS and working collaboratively with their colleagues in their school and the other panel. At several of the participating schools, teachers indicated they were using or were planning to use the lesson study process of creating a lesson, teaching, observing, and debriefing with their colleagues during their PLC time.

**Student**

The implications of the project on student learning and achievement were measured through teachers' perceptions. Student interactions and student work was observed, photographed, and collected for use in teacher debrief meetings. Comments in discussions and on surveys revealed that students were given more time to interact with their peers, more opportunity to voice their thinking, and to ask questions during the

project. Through teacher use of TTPS and the use of observation in the Lesson Study process, teachers focused more than previously in their practice on creating a student-centered classroom.

The process of Lesson Study was new to most participants in the project, and, hence, having observers in the classroom was also new for most students. This was a unique opportunity for students to see their teachers as learners. Teachers of the visiting classrooms explained to students what was happening and why extra teachers, curriculum leaders, and administrators were watching them in their classroom. Students saw a variety of teachers taking turns teaching, taking photographs of student work, listening to what students were saying, taking notes of what was being said as well as teachers leaving the room with students' work and coming back later with a new approach to help students improve their work and further their learning. Students saw their teachers involved in inquiry with the hope it would help students to follow a similar process they were being asked to do in the TTPS lesson. According to the teachers self-reports, students benefited from the modeling of learning that teachers were providing.

One question left unanswered was did the project improve student achievement? It was too early in the process of teachers creating and using three-part lessons with TTPS to accurately determine this with achievement data. It was possible that teachers in the project observed only one lesson, with TTPS, at the level they teach. There was a chance they did not teach the TTPS lesson, and, if they did, it may not have been in their own classroom. Teachers would need to teach a whole unit (several lessons) with TTPS and then test to see whether it made a difference in overall achievement. The belief is that if teachers used the three-part lesson with TTPS regularly, then they would pick up misunderstandings sooner and respond (i.e., have a follow up next day) so students would have less achievement issues. Some of the teachers in the selected team believed that this was happening in their classrooms, outside of the project. Teachers in the selected team noted that they were experimenting in their own classrooms with three-part lessons with TTPS on a regular basis. To be certain that this style of instruction impacted student achievement a further study would need to be conducted where some students would receive three-part lessons with TTPS every day compared with some students who would receive a different type of instruction. At the end of the instruction, a test could be

administered to each group to compare performance. This study could follow a similar format to Boaler and Staples's (2008) Railside study where they used content-aligned tests and open-ended project assessments to measure the effect of different mathematical approaches and equitable practices on student achievement.

## Limitations

When considering factors that may have limited the success of the research, three come to mind. First is how participants were selected for the school board project. Because participants for the research could only come from the group selected by the school board, how the school board selected participants could have influenced the results. The second factor is related to the type of students' data collected. Because the teachers in the project controlled the creation of lesson, they also controlled what type of student data was collected, if any. The last factor to consider is the relationship between the researcher and the participants and any influence the researcher may have had on the behaviour of the participants. The researcher was a principal in the school board being studied and a participant in one of the teams.

### Participants

Selection of schools to participate in the project was done by the superintendent and one secondary curriculum leader in consultation with secondary principals, guided by Grade 9 math EQAO results. Once secondary schools were selected, feeder schools were also approached to participate. Principals made the final choice to determine which teachers would participate in the school board's project. As a result, some teachers in the project were initially unclear about the purpose of the project. At the introductory session in February, many teachers were confused about the expectations around the project. Secondary and elementary teachers sat at separate tables and did not interact until the very end of the session when asked to select dates for meetings. Elementary and secondary curriculum leaders were not familiar with each other's schools, their administration, or their staff, even when the elementary school was a feeder school for the secondary school meaning they were in the same family of schools. Not all elementary and secondary administrators in the same family of schools had an opportunity to meet prior to the introduction of the project. Many participants only

learned of project and their role at the introductory session that led to some initial confusion of what they had been signed up to participate in. The research project was also explained at the introductory meeting in February. It was made very clear at that time that participation in the research was optional. A letter explaining the research part of the project, consent form and pre-survey was handed out to all the participants. Most of the teachers who chose to participate in the research, signed the consent form and completed the pre-survey at the introductory session. Given the confusion of many teachers about the purpose of the school board's project and why they were selected may have influenced the number of teachers who chose to participate in the research component.

The first team to be the selected team for the research was chosen by the one of the curriculum leaders after reaching agreement with both the secondary and elementary principals of the team. However, the teachers of the first selected team decided not to participate in the research once it was explained. Several of the teachers in that team also chose not to complete the school board's project. In the final school board debrief at the conclusion of the project, the curriculum leader for this team reported that teachers struggled to follow the CLiC process, with co-creating and co-teaching a lesson. The inability of the team to build trust or a lack of understanding of the project and its purpose may have caused the team to not follow through on their project.

A second team selected by the curriculum leaders all agreed to participate in the research and signed the team consent forms. However, at the first meeting with the selected team, when asked why they chose to participate in the school board's project, they responded that they were told they had to participate, indicating their belief that they had no choice about participating in the school board's project. They also expressed their belief that the purpose of the school board's project was to tell them what and how to teach. Although somewhat hostile at the start of the project, once the curriculum leaders explained that the purpose of the project was professional learning and that is was going to happen through collaboration, the selected team cautiously began to participate willingly with the curriculum leaders. Although the selected team expressed no concerns about the research component and signed consent, their confusion at the start of the project may have influenced their decision to participate in the research.

At the time of the project, teachers in the province were experiencing a labour dispute. During the dispute, many teachers chose not to continue with extracurricular activities. At the elementary level, the Federation publically asked teachers to not participate in extracurricular activities. While the project was completely funded by the Ministry of Education, teachers may have thought of the project as an extra thing they were doing. There were originally 5 secondary schools chosen to participate, but one of them declined because none of their feeder schools would participate. Each of the remaining participating secondary schools had varying levels of participation from their feeder schools. This may help to explain some of the confusion around the project and why some teachers may have interpreted participation as mandatory. The confusion around mandatory activities and extra activities may have also influenced the number of teachers who chose to participate in the research component. Although teachers may have felt they were required to participate in the school board's project, the research component was clearly explained as an optional activity.

**Data**

Pre-planned surveys and interview questions as well as the researcher's observation notes served as the main sources of data for this research. Originally, it was thought there would be many artifacts from the project, but, unless teachers were specifically asked to collect data, they did not engage in this process. Teachers were not instructed to collect pre- and post-assessment data, as part of the school board's project to determine the impact of their learning in the project on student achievement. This type of data collection was not a previous practice; thus, it did not occur to teachers or curriculum leaders, at the start of the project, to ask for this type of data. Some teachers only filled out an observation sheet during the teaching if reminded to do so immediately before entering the room. In the elementary classrooms, teachers collected student work from the action part of the observed lesson to help determine their focus for the consolidation part of the lesson. Most of the CLiC's teachers collected the independent practice that was usually in the form of an exit card that contained a similar problem to what was asked in the action. Samples of student work in the observed lessons were collected by teachers and photographed for the teachers, to use in discussion, but there was no previous work to compare it to. The only data collected that related to overall

student achievement were comments made by participants. Although these comments helped to answer the third research question about what impact teachers felt their participation in the Lesson Study had on their students' learning and achievement, it did not provide concrete evidence of the student learning or achievement. There were no specific data collected to show whether student achievement improved as a result of the project. Next time, setting clear goals for student improvement in precise areas of mathematics would give a focus for data collection on students learning.

**Researcher**

As a principal also involved in the project with my own teachers, it was hard not to influence others in the project. Survey participants were assured they would remain anonymous and were given a unique identifier to match their pre- and post-surveys. During CLiCs with the selected team, I did not offer any opinions or act as a participant in the conversations. I focused on taking notes and frequently reading back to the team what I had captured to ensure its accuracy and to build trust with the team. However, they were all aware I was a principal in the same school board where they worked. With my own school, I was an active participant, contributing to the conversations and the lesson creation. As principal, I participated in every session and was excited to be an observer in the classrooms and eager to debrief with my teachers after each lesson. My observations of the selected team occurred at the same time as I was participating with my school team. My additional experiences with the CLiC process, i.e., seeing what worked with the selected team and the challenges they were having, may have influenced my participation with my own school team.

Being a participant while researching the overall project helped me to better understand the process other participants were going through. However, because teachers, administrators, and curriculum leaders all knew I was also a participant, they all asked questions about the experience at my school. These questions were generally asked outside of the CLiC's at other meetings, different professional learning experiences, or when I encountered someone in the community. Some of the questions were what lesson topic we choose, how we structured the day at the secondary school, and how we choose to consolidate. My answers may have influenced other teams and the choices they made around their lesson creation or observation focus.

**Follow-Up**

From the first CLIC day to the second, there was evidence that teachers had become more familiar with creating three part lessons and using a TTPS approach. This result was similar to results reported by Robinson and Leikin (2012). In their Lesson Study research, Robinson and Leikin (2012) reported changes in teaching practice from the first lesson to the second, in the tasks teachers created, the questions they asked, and the structure of class discussions. The biggest change reported was in the teachers' sense of how students learn. They saw the changes as an indication of meaningful mathematics learning where students were encouraged to think and develop mathematical concepts and procedures.

However, did teachers, after the project, sustain the TTPS approach they claimed to have adopted? Because the study was designed for only 1 year, a limitation was this question could not be asked. To best measure teacher learning (i.e., a change in practice) requires revisiting the teachers in the project 1 or 2 years after the project to observe their classroom instruction and note any real changes (i.e., if were using TTPS and following a student-centered approach). A further study or follow-up interview could revisit the teachers in the project and determine if they had adopted the TTPS approach. Dudley (2013) looked at subsequent classroom practices months after the lesson studies in his research were completed and found teachers retained their learning about teaching in particular their knowledge about their students, how they learn, and how their learning could be improved. Would similar results be found with the teachers in this research?

Another unanswered question is about whether participation in Lesson Study influenced future professional learning formats for the teachers from the study. The selected team discussed using a Lesson Study model for their PLC time. They commented on how they enjoyed learning through collaborating on creating the lesson, co-teaching the lesson and de-briefing the lesson. The team commented on how the learning through Lesson Study was more authentic than usual professional development as it was "messy" and showed how "teaching is more complex than what can be presented in one hour." They felt Lesson Study gave them more control of their learning as they decided as a group the focus of the lesson. Owen's (2015) work on PLC's found teachers had the biggest "wow" moments when their PLC involved co-planning, co-

teaching/observing, co-assessment and co-reflection. In a follow-up interview it could be determined if the project impacted the type of professional learning teachers choose for their PLC time.

**Recommendations**

Lesson Study is a form of professional development that comes from Japan and is increasing in popularity in North America. Takahashi and Yoshida (2004) said:

> One of the reasons for its popularity might be that Lesson Study provides Japanese teachers with opportunities to: (1) make sense of educational ideas within their practice; (2) change their perspectives about teaching and learning; (3) learn to see their practice from the child's perspective; and (4) receive support from their colleagues. (p. 438)

For this research all four of those opportunities were supported. Teachers had the opportunity to make sense of what a TTPS approach entailed, to test their assumptions about teaching TTPS in the classroom, and to as a group observe students learning and collectively debrief the process. For those doing further research on the use of Lesson Study in North America, three recommendations come from this research (see Table 24 at the end of this section). The first is around ensuring participants, in addition to knowing the Lesson Study Process, have a clear goal for their Lesson Study. By identifying where their students are struggling and what in their practice teachers are hoping to change to address the student struggles, teacher will be able to more effectively use the Lesson Study process to achieve their goal. This leads to the second recommendation about student data. Since success in education is generally measured by student achievement, collecting student achievement data should be a part of the research. This type of data will help teachers to know whether their practice is affecting students' learning and improving student achievement. Collecting this type of data will also help to keep the focus on students and how they are performing as a result of the teacher learning.

The last recommendation is that the facilitator of the Lesson Study should be mindful of, plan for, and adjust, as needed, the necessary conditions for professional learning. By being aware of the elements of effective professional learning and the characteristics of a complex system like education, the facilitator can use the Lesson Study Process to help create the right conditions of learning to emerge. When the right

conditions are present for learning, teachers build trust with each other so they can work collaboratively to examine their practice, make sense of new educational ideas, and focus on challenging their views of teaching and learning.

**Goals**

Timperley and Alton-Lee (2008), through a synthesis of empirical studies on professional learning, identified three steps for developing teacher knowledge and effectiveness:

Step 1: Teachers identify student learning needs based on a variety of assessment and learning data.

Step 2: Teachers use the student needs to identify teacher learning needs.

Step 3: Teachers measure the effectiveness of their learning on addressing the identified student needs.

By using students' learning needs to identify teacher learning needs, teachers were better equipped to set their own learning goals and to give purpose to their professional learning. Once teachers were clear on their goals for learning, they could choose what actions to take (such as profession reading, workshops, Lesson Study) for their learning.

Without a clear understanding of the purpose for learning, teachers, like their students, lack motivation and enthusiasm. When teachers set their own learning goals, feel ownership over their learning, and see a need for their learning, they become highly engaged and eager to participate in the professional learning. An important characteristic of complex systems is the self-similar property. Teacher learning it is similar to student learning. Building a sense of ownership with clear goals increases the chance of full engagement. In the initial stages of the school board project, the selected team lacked an understanding of the purpose of the school board's project and why they were participating. Only after curriculum leaders explained to the selected team that the team members would be setting their own learning goals based on their students' needs did the selected team members begin to engage in their learning.

Lesson Study is an action teachers take or a process for teachers to follow for professional learning. By its design it can help to create the right environment for teachers to collaborate and to deeply examine their practice. Before a process can be adopted, the reason teachers need a process to examine their practice must be clearly

defined. Once teachers develop their own learning goal based on student need, then a process like Lesson Study can help teachers explore new teaching strategies or deepened their understanding of the process of teaching and learning.

**Data**

Research consensus appears to exist on the key elements necessary for effective professional development and professional learning, but which elements impact student achievement is not clear (Wayne, Yoon, Zhu, Cronen, & Garet, 2008). When choosing a professional development practice, looking for the effect teacher learning will have on student learning is now a necessary requirement given the ambitious targets governments set for student achievement. Timberley and Alton Lee's (2008) third step calls for measuring the effect of the teacher learning on addressing the identified student's needs. In the past, not all researchers had experimented with collecting empirical data to show the impact of professional development on student learning (Doppelt et al., 2009). More rigorous evidence on how professional development is impacting both teacher and student learning is required (Hill, Beisiegel, & Jacob, 2013). If Lesson Study is to be seen as an effective professional learning practice, then there must be a focus on collecting student data to show the impact teacher learning is having on student achievement.

This research was focused on a school board's application of Lesson Study and its effect on teacher learning. The data collected also measured teachers' impressions of the effect of their own experience on student learning. The next step in researching Lesson Study, as a process for professional learning, would be to measure more directly the effect teacher learning had on student learning and achievement. Teachers would need to clearly define their learning goals and their intended effect on their students' learning. It would be necessary to involve teachers in more data collection, possibly doing pre- and post-assessment with their students if content was the focus or pre- and post-surveys if the approach to learning was the focus. If teacher learning was about addressing a student need, then collecting data on student performance or student perceptions would be an appropriate measure on the effect of the teacher learning on the student need.

**Conditions**

The Lesson Study process followed in this research created the conditions for teachers to examine the way they learn and think about teaching. All four elements of effective professional help were present at different times, and maybe not equally, during the Lesson Study, as outlined in Chapter 2:

1. build on teachers previous knowledge and address their beliefs and attitudes about education
2. engage teachers in an active learning process situated in the curriculum ( i.e., learning driven responsive teaching)
3. use metacognition and reflection by where teachers set goals and monitor their progress
4. facilitate a collaborative community of teacher professionals for support and sharing of resources

Planning for all four elements and paying attention to, and using some of the characteristics of complex phenomena such as structure-determined, far-from-equilibrium, nested structures, ambiguously bounded, bottom–up emergent properties, organizationally closed, interacting agents and self-organization in each element, would help create the conditions for learning to emerge and practice to improve.

During the project, teachers had the opportunity to examine their preconceptions about teaching and learning mathematics, evidence of element one of effective professional learning. Having to work collaboratively to create the lesson gave teachers the opportunity to share their ideas about a variety of teaching strategies to best illustrate different concepts. Teacher teams discussed things like the use of manipulatives and technology to increase engagement and how to effectively use student groups to encourage more math talk among students. Paying attention to the idea of structure determined meant teachers needed to be specifically told not to start with a prescribed lesson and encouraged to create something new together that met the expectations in the curriculum and addressed students learning needs. There are certain structures or boundaries teachers have to work within, such as following the Ontario curriculum, but how they use and interpret the curriculum (i.e., how teachers combine expectations to create lessons and activities) should not be predictable and should change, based on how

students respond. Teachers should be told that Lesson Study is an opportunity to embrace change and experiment with different strategies so they can find new and creative ways to engage learners. The goal is not to maintain the status quo but to move from the everyday practice or create a far from equilibrium state.

Teacher teams built their lessons based on previous knowledge but were willing to work with new ideas and ways of teaching to engage their learners and build deeper understanding. The Lesson Study process gave them time to experiment and test these new ideas, such as three-part lessons and teaching through problem solving, evidence of element two of effective professional learning. Through the process, teachers spent time observing how students reacted to the new lesson structures, challenging some of the teachers' previous beliefs and attitudes about teaching and learning mathematics. Teachers in the study were repeatedly surprised by students' previous knowledge and the students' willingness to engage in problem solving. Results of this project showed that Lesson Study requires time for teachers to be active in the learning process similar to how students need to be active in the learning process, planning for this is using the characteristic of nested structure. Teachers, just like students, need to be given time to build on their previous knowledge by testing and re-testing their assumptions. When teachers are given this time to observe and re-teach modified versions of lessons, there is a greater chance they will see how they can learn from their students. While there was an initial purpose for each lesson making it bounded, learning for both student and teacher emerged intertwined as they together experienced the lesson and interacted with one another influencing the outcome. These interactions exemplify the characteristic of being ambiguously bounded. The quality of the interactions is integral to the recursive and enhanced development of the collective (Fazio & Gallagher, 2009). Student learning and teacher learning are intertwined and each influences the other, thus a Lesson Study should give teachers time to slow down and focus on student responses and the opportunity to examine and experience learning through their students' eyes.

The steps teachers went through in their Lesson Study required them, at times, to be metacognitive and to think about how to accomplish their learning goal of engaging more students, evidence of element three of effective professional learning. During constructive feedback about the lesson, teachers had the opportunity to be reflective

about their practice. It was through this reflection that new ideas grew. Change in teaching practice comes when teachers are ready and willing to make the change and this is more likely when they feel the change was their idea (Vescio et al., 2008). When teachers have the opportunity to reflect on the kind of observations they have in Lesson Study, observations of lessons they helped create, they begin to see many possibilities for learning in their classrooms. This bottom-up approach has more chance of being sustained than a top-down mandate. Research shows that professional learning has a great chance of improving the quality teaching when it is bottom up and teachers take responsibility for their learning (Kent, 2004). As a result, Lesson Study should be explained as a teacher-directed, job-embedded practice that allows teachers to direct their own learning.

Teachers reported one of the biggest benefits from the project was the opportunity to collaborate with teachers from the other school (either elementary or secondary) and teachers in their own department. The busyness of the school year leaves little time for teachers to truly share ideas and create new ones together. The process of Lesson Study brings people together and requires them to listen and contribute. Because the system is organizationally closed, being it is made up of all teachers and the group is predetermined by the school they work at, it means ensuring the environment is safe and inclusive is critical to the Lesson Study Process. It is important that all the participants not be too similar or new ideas will not emerge, but equally important is that the group not be too diverse or they will not have any common ground to start with. Because complex systems are rule-bound, it is critical to establish a balance between redundancy and diversity because those rules only determine the boundaries of the activity not the limit of possibilities (Davis & Simmt, 2003). Both diversity and redundancy need to be considered when planning a Lesson Study. The mixing of elementary and secondary teachers allowed for some diversity in thinking but focusing on just the subject of math gave everyone a single common characteristic.

Through the planning, teaching, observing, and debriefing teachers in the project supported one another and came together as a collective, evidence of element four of effective professional learning. The lessons they created had a part of each of them and teachers took turns teaching the different parts of the lesson in the different classrooms.

They were each other's eyes and ears during the observations, each observing a different group of students during the lessons and noting those students' responses. It was through the teacher-teacher, teacher-student and student-student interactions that learning emerged. Every interaction no matter how small, played a part. This shows the power of interacting agents. Planning a Lesson Study means purposefully encouraging all those interactions to occur.

Table 24. *Overall Recommendations for Future Lesson Study*

| Overall Recommendations for Future Lesson Study | | |
|---|---|---|
| **Goals** | | |
| Teachers should set clear learning goals for their own learning that are based on a student need. | | |
| **Data** | | |
| Teachers should collect student work/data to measure the effect of teacher learning. | | |
| **Conditions** | | |
| Element | Characteristic | Recommendation |
| 1 | Structure Determined | Teachers should not start with a pre-made lesson but create one together to address a student learning need in the curriculum and allow it to change based on student responses. |
| | Far From Equilibrium | Teachers should be told Lesson Study is an opportunity to embrace change and encouraged to try new and creative ways to engage students. |
| 2 | Nested Structure | Teachers should be given time in Lesson Study, similar to the time students are given in the classroom, to build on their knowledge and test and re-test assumptions and experiment with new strategies. |
| | Ambiguously Bounded | Teachers should be encouraged to see learning through their students' eyes and take advantage of the intertwined nature of student and teacher learning and allow themselves to learn from students. |
| 3 | Bottom Up | Teachers should be told that Lesson Study is a teacher-directed and job embedded learning opportunity. Teachers should be encouraged to direct their own learning. |
| | Organizationally Closed | When creating teams there should be thought around both redundancy (shared experience - such as all teachers teach same subject – so they start with common ground) and diversity (variety of backgrounds – such as elementary &secondary teachers - so new ideas will emerge). |
| 4 | Interacting Agents | Teachers should be encouraged to value all interactions (i.e., teacher-teacher, teacher- student, and student-student) as all influence learning. |
| | Self Organization | While it is important for consultants (experts) to share new ideas and ground them in research, teacher teams need explore the new ideas together and find their own ways to adapt/incorporate them into practice. |

Taking advantage of the self-organizing nature of a complex system requires giving up control of the direction of the Lesson Study to the teacher team. While the curriculum leaders played a significant role in teaching the teachers the process of Lesson Study, reminding them of three-part lessons, and exposing them to TTPS, it was the teacher teams who had to create the lessons and carry them out if learning was going to emerge. The teachers choose the content topics for the lessons and set the learning goal for the team. While most teams in the project chose a learning goal around increasing student engagement, how each team went about it varied. The teacher team needed to try their own ideas and learn from their own failures to find what worked. Teachers in a Lesson Study need to have a shared purpose and need to direct their own learning.

**Final Words**

The goal of effective professional learning is to challenge a teacher's thinking, to help them to imagine different possibilities, and to give them opportunity to experiment with something different in their practice so they can influence and improve student learning (Owen, 2015). This research examined teacher professional learning through the practice of Lesson Study. It followed a school boards' professional learning project, which used a modified Lesson Study, to see which features of the design helped learning emerge for teachers and students.

Teachers in the project were not necessarily looking to contribute to the theory on professional learning or on implementing Lesson Study. They were focused on learning how to create three part TTPS lessons in their classrooms to engage their students. However, it was the design of the learning that created the conditions for teachers to challenge their attitudes and beliefs and increase their knowledge and skills about teaching mathematics. They did not just learn new teaching strategies, but, according to their self-reports, they adopted them, developed confidence in using them, and made them part of their practice. They experienced learning in a new way that had a profound influence on their thinking and prompted them to consider a change in their practice.

The elements of effective professional learning and many characteristics of complex systems were present in the project. By helping to create and support collaborative teacher teams, encouraging teams to develop a shared purpose for learning, allowing them to direct their own learning, keeping the focus on student work, giving

time to experiment, observe, and test assumptions in their classrooms, and by facilitating metacognitive and reflective discussion, the conditions were present for learning to emerge.

This research adds to the body of the knowledge on effective teacher professional learning and specifically on how to implement a job-embedded practice of a variation on Lesson Study in Canada. Designing time for teachers to plan, teach, observe, and reflect on a lesson has proven to be a promising practice for teacher learning. However, more research is needed to collect evidence of the impact the Lesson Study process has on student learning and achievement.

# DENOUEMENT

> Denouement: 1. the final outcome of the main dramatic complication in a literary work; 2. the outcome of a complex sequence of events. (Merriam-Webster Online, n. d.)

The purpose of this denouement is to reflect on my academic experiences that have led me to the completion of this dissertation. Specifically, I wish to re-examine the different roles I played in the project, from committee member, principal, participant and researcher, and to describe the learning that emerged for me personally. Further, I wish to use this section to also describe how, in the end, similar patterns of learning occurred at all levels of participation in the project from students, teachers, curriculum leaders, and administration. To begin, however, I would like to go back to a time long before I began this degree to re-integrate the experience of my doctoral studies into my emerging sense of self.

## Declaration of Self

Mathematics has always been a passion for me. I earned both an undergraduate and graduate degree in applied mathematics and then choose a career teaching mathematics to secondary school students. As a mathematics teacher I enjoyed opportunities for my own professional learning and found it rewarding to help organize professional learning sessions for teachers in my own school board. After 13 year of teaching, I moved into the role of vice-principal. As an administrator, I had the opportunity to participate in board committees and, in particular, to co-chair the board numeracy committee with one of the board curriculum leaders. The committee was responsible for the professional leaning of grades 7 through 12 mathematics teachers and, over the years, offered a wide variety of sessions. I was introduced to the lesson study model by one of the board curriculum leaders. Our committee created a modified version of Lesson Study (with teaching just to the teachers) for grades 7 to 10 mathematics teachers using newly purchased Interactive white boards. This was my first experience with Lesson Study and I was amazed at the lessons teachers created using the interactive

white boards and their renewed energy and enthusiasm for teaching mathematics as a result of the project. After the project, I became very interested in the Lesson Study process as a professional development practice. I applied for the Joint PhD program with the hope of continuing to learn about professional learning practices and, in particular, about Lesson Study.

In 2010, the ministry of education provided special funding to assist teachers with differentiated instruction. My school board's student success committee, at the time, created an instructional strategies committee to support teachers in grades 7 through 12 with differentiated instruction. As a co-chair on this committee, I supported a project using modified Lesson Study as a process for professional learning in a variety of disciplines other than mathematics to create lessons that incorporated differentiated instruction. I was again impressed with the lesson teachers created and the energy and enthusiasm they brought to their teaching.

In 2012, when the ministry of education was looking for boards to submit projects for special funding under the title Building Innovative Practices (BIP), my board's student success committee made a proposal. The committee made up of the chairs from the numeracy, literacy and instructional strategies committees, secondary and elementary curriculum leaders, student success lead, and the principal and superintendent of the program department, put forth a proposal to use a modified Lesson Study model that the elementary panel had been using called CLiC to improve mathematics instruction, with grades 7 through 10 mathematics teachers. As a member of the committee, I was very excited to help create the project and as a researcher I was very excited to be given permission to study the project.

I went in to the project naively thinking everyone would be as eager to learn and explore the best strategies for mathematics teaching and was quickly reminded that this only happens if the right conditions are present. Through the PhD program, as I was reading the literature on professional learning, mathematics education, and complexity theory and interacting with professors and other PhD students, my views on teaching and learning were changing. My understandings of the conditions necessary for effective professional learning were being informed by complexity thinking. As a PhD student and researcher, I knew intellectually that successful professional learning occurred when

participants came with an open learning stance and I was struggling with how to help teachers move into this stance. This project helped me experience professional learning with a new lens and helped me see how to better plan for and set the conditions for teachers to be willingness to explore, inquire, experiment, and learn new practices.

As a committee member helping to plan the learning, I thought more about which schools should participate, how to communicate the goals of the project, whether there was enough time left in the school year to get multiple teaching opportunities in the make-up, organization, and timing of each CLiC, the structure teachers should follow, and what handouts would be needed. As a principal, I thought about which classes to visit and which teachers would work well together. As a participant on a team, developing a lesson and planning to teach it I felt panic and uncertainty and worried if we could accomplish all we had planned in a day. I also wondered if students would understand and see that we were learners too.

## Nested Learning

Through every survey I read, interview I did, and every CLiC day I attended, whether as a participant in my own school or as a researcher following the selected team, I witnessed teaching and learning. Three key themes emerged at every level of participation: building relationships, experiencing struggle, and finding voice. The themes were first evident in the students as teachers reflected on the lesson and reported what was happening in the classroom. As the researcher, listening to the conversations teachers were having, I realized that the same themes were emerging for the teachers. Later, after the project concluded, I was invited to participate in the school board's debrief of their project with the curriculum leaders. After reflecting on this experience, I now see that the same themes were emerging for both participating administrators and curriculum leaders. Figure 9 captures this nested learning that was happening.

### Building Relationships

Students working collaboratively to solve open ended problems had not been the regular practice in the intermediate mathematics classrooms observed. This new opportunity allowed students to interact in different ways with their peers. Students listened to their peers' ideas about the problems worked collaboratively in small groups

to solve the problems and watched peers from other groups share their solutions to the problems. These experiences helped students to develop new working relationships with their peers. Having multiple teachers in their classroom was also a new experience for students in the project. Elementary students were excited to meet their future high school teachers and high school students were excited to re-connect with their elementary teachers. Students had not previously witnessed their teachers interacting with colleagues in their classroom or exhibiting a learning stance. Experiencing their teachers as learners changed the relationship between students their teachers.

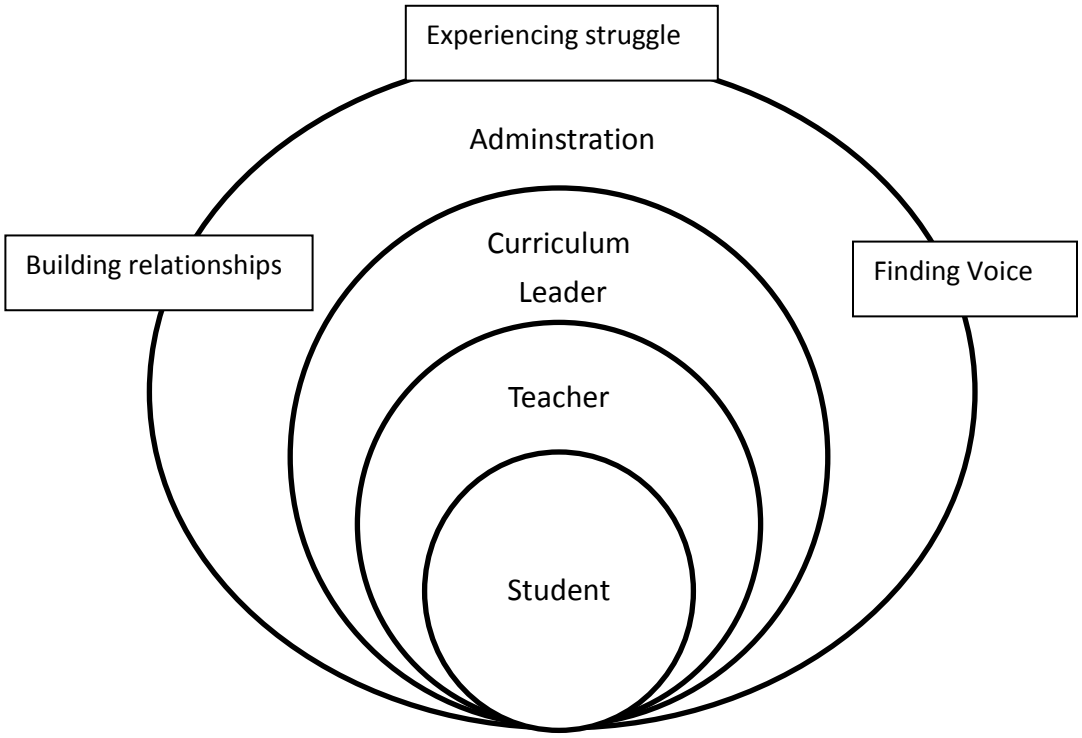


*Figure* 9: Nested Structure of Learning.

Prior to the project, the participating elementary and secondary teachers had not been in each other's classrooms, co-created or co-taught lessons, or had many discussions about their attitudes and beliefs around teaching mathematics. Through the process of developing lessons, co-teaching lessons, and being in each other's classroom, new working relationships were formed by the teachers in the project. The project continued after the initial year with more feeder schools joining in the second year and every high school in the board, with most of their feeder schools, participating in the third year.

Having an administrator sitting at the table co-participating and co-learning was also a new experience for many teachers. For some teachers the prior relationship with their principal had only been directive or evaluative so this was a very new experience for them. Although each school was familiar with the curriculum leader assigned to their school, they had not worked with the curriculum leaders assigned to other schools or the other panel. Secondary teachers in the selected team, specifically, commented on the relationship they developed with the elementary curriculum leaders and the knowledge they gained from working with them. Because the board had only one secondary curriculum leader assigned to mathematics, these secondary teachers, had never experienced having a curriculum leader in their classroom.

During the final project de-brief, elementary curriculum leaders commented on the new relationships they had built with both secondary teachers and administrators. Although many had worked closely with some elementary teachers, they had never worked with any of the participants from secondary before the project. They reported building a new understanding of the challenges and needs in the secondary panel.

As a principal in the project, it was the first time I had worked collaboratively with the principals at my feeder schools and with some of the elementary curriculum leaders. It was also the first time I had met some of the elementary administrators. Outside of our time with the teachers, we discussed school organization, programs, teaching strategies and engaging teachers in professional learning. As a group, we continue to meet and have conversations about our school organization, students, and teachers.

**Experiencing Struggle**

Students in the intermediate classroom had mostly experienced an algorithmic approach prior to the project when teachers provided a step-by-step algorithm and students individually followed it to solve similar problems. Being told to talk to their peers about a math problem, share ideas, and to test their ideas together was uncomfortable and stressful for many students. Students were unsure how to proceed and how to talk with their peers. Student repeatedly asked teachers for feedback on their progress at each stage. Several students made comments to their teachers like “can’t you

just tell us what to do" and "how do we know if we are doing it right." At first, students did not understand why their teachers had changed their approach, i.e., why their teachers were answering their questions with more questions, asking them to continue to think about the problem, and telling them to work together with their peers. However, as students discussed the problems with their peers, they came up with ideas and started to test them. Students became very engaged in trying to find a solution and helped each other to work through the struggle.

Teachers had a difficult time letting students struggle. They were tempted to run to the board and solve the problem for the students. Letting students struggle with the problems led to an inner struggle for the teachers. It was very difficult for teachers to not follow an algorithmic approach and to give students more control over the learning. This made the class unpredictable and caused uncertainty in the teachers mind leaving them with a sense of panic about where students might take the problem. TTPS was a new approach for them and one that was challenging and required a great deal of support from their peers. The teachers in the selected team shared stories from their classrooms about students struggling and the challenges they were having. Together they helped each other by listening and acknowledging their challenges. They brainstormed ways to help each other and their students through the struggle. Teachers were very surprised by the knowledge their students demonstrated. They quickly realized that students could handle the struggle and it was the struggle that motived students to take more ownership for their learning.

Most of the curriculum leaders were elementary and had no experience with secondary teachers or secondary administration. There was no working relationship between the elementary curriculum leaders and the one secondary curriculum leader. They were unaware of what pedagogical knowledge secondary teachers had and felt uncomfortable guiding the secondary teachers especially in mathematics, as most of the secondary teaches had degrees in mathematics. At the beginning of the project they felt uncertain of their role and felt a huge responsibility to "make things work". With very little administration participating in CLiC days they felt pressure to lead. Because the elementary curriculum leaders had relationships among themselves, they contacted each

other for support. They shared materials to help guide teachers through the three part lesson and ideas on how to engage the teachers.

Many of the administrators of the schools in the project chose to not to participate in the learning. While they were invited to participate, they struggled to fit it into their schedule and did not make it a priority. For many administrator it can be very difficult to find the time to participate even knowing that letting teachers see you as a co-learner helps to build positive relationships. Their lack of presence in the project left curriculum leaders feeling responsible for guiding teachers through the learning. In the subsequent years of the project, the board decided that schools were only allowed to participate if their administration was present. As a participating principal, I found the CLiC days rewarding and exhausting. It was difficult to focus on the project, ignore what was happening in the rest of the school, and to leave someone else in charge. I found it very hard in my role of guiding teachers to know when to apply pressure and when to provide support. Sometimes it was important to provide a push so the teachers would try something new and sometimes it was important to just listen and help the teachers carry out their plan. I relied on the curriculum leaders to help me decide what was needed and when other administrators were present we checked in with each other and shared our thoughts. I found the more opportunity I had to work alongside my teachers the more I came to know their interests, passions, and learning needs, and the better I understood what motivated them. This information has continued to helped me to build strong relationships with my math teachers.

**Finding Voice**

As students worked in groups during the lesson to find solutions to the problem, they shared their ideas with others in their group. With teachers watching and making notes of what was said, students had to talk and interact with each other. During the consolidation phase students were asked to share their solutions with the whole class and to explain the work their group had done. Students were doing the talking and explaining the math. Working together as a group on the problem gave them more confidence to share their solution with the whole class. This was a new experience for many students.

While having students speak to students about the math happening in the problem, teachers were speaking to teachers about the teaching and learning that was happening in

the classroom. Teachers were finding a common language to talk about the teaching strategies they were practicing. They were building a common knowledge across both panels about three part lessons and TTPS that they could talk about and apply in all their classrooms.

In the final sharing, after the project, curriculum leaders from every group shared their successes and their struggles. They talked about moving their our own learning forward about the math, the facilitation, teaching, and elementary/secondary differences, and about addressing their own preconceptions They made a clear plan for the following years project that involved more support and training for the curriculum leaders, participation of both secondary and elementary curriculum leaders at all CLiC's, and more participation from administration. This supported building the diversity in the leadership of the project which was missing in some teams. They focused their discussion on how to create a culture of professional learning and on how to bring the two panels closer on pedagogy.

The principals participating in the project saw the value of doing so and were encouraged to share that knowledge with other administrators who did not participate. At the secondary family of school meetings, principals including myself shared our learning in the project with our colleagues. We talked about student and teacher engagement, about TTPS and three part lessons, about professional learning, and about building relationships with teachers.

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# APPENDICES

## Appendix A: Standards-Based Mathematics Teaching Rubric

| Dimension | Level 1 | Level 2 | Level 3 | Level 4 |
|---|---|---|---|---|
| 1. Program Scope | The teacher addresses one strand. | The teacher addresses most of the strands. | The teacher addresses all strands, each taught separately. | The teacher addresses all strands, taught so the interconnections among them are explored. |
| 2. Opportunity to Learn | The teacher provides all students with activities to consolidate mathematical algorithms. | The teacher provides all students with activities to consolidate mathematical algorithms and procedural support. | The teacher provides all students with the opportunity to learn higher level mathematics and procedural support. | The teacher provides all students with the opportunity to learn higher level mathematics with appropriate support, such as cues. |
| 3. Student Confidence | The teacher builds student confidence by providing external awards for achievement. | The teacher builds student confidence by providing external awards for achievement and praising student effort. | The teacher builds student confidence by providing external awards for achievement, praising student effort, and modeling positive attitudes. | The teacher builds student confidence by providing external awards for achievement, praising student effort, modeling positive attitudes, developing strategies for student success to occur, and helping students recognize their mathematical ability. |
| 4. Student Tasks: *Solution Strategies* | The teacher assigns tasks that can be solved by using a specific algorithm that the teacher identifies. | The teacher assigns tasks that can be solved by using a specific algorithm that students must identify. | The teacher assigns tasks that have several possible solution strategies OR that have several possible answers using one strategy. | The teacher assigns tasks that have several possible solution strategies AND that have several possible answers. |
| 4. Student Tasks: *Multiple Representations* | The students are expected to use one form of representation as defined by the teacher | The students are required to use multiple representations for their ideas when the teacher prompts them to do so. | The students are encouraged to represent their ideas in various ways (i.e., numeric, algebraic, or graphic). | The students generate different representations and select the most appropriate one(s) to best represent their ideas or solutions. |
| 5. Construction of Knowledge | The teacher believes that students learn through transmission of facts and algorithms. | The teacher believes that students learn through transmission of concepts and algorithms. | The teacher believes that students learn through development of concepts and algorithms through application. | The teacher believes that students learn through construction and elaboration of concepts and algorithms through inquiry. |

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|---|---|---|---|---|
| 6. Teacher's Role | Teacher is the sole knowledge expert. Student roles focus on tasks which require minimal cognitive effort. | Although the teacher is the sole knowledge expert, some student expertise is acknowledged. Students are assigned roles with the teacher being central to the activities. | The teacher shares the knowledge expertise role with the students. More teacher-directed tasks are provided for students with lower abilities, and more student centred activities are provided for higher ability students. | The teacher is a co-learner with the students. The teacher and the entire student body are responsible for building a mathematics community. The teacher ensures that each student is an integral part of the learning process. |
| 7. Mathematical Tools: *Manipulative Use* | The teacher uses manipulatives to demonstrate concepts/ideas to the class. The students use the manipulatives only occasionally. | The teacher uses manipulatives to model concepts/ideas which the students imitate when directed. | The teacher uses manipulatives to model concept / ideas. The students use the manipulatives in both teacher-directed explorations and through free choice. | The teacher uses manipulatives to model concept/ ideas. The students use the manipulatives in teacher-directed explorations and through free choice. The students are also encouraged to create their own inventive uses for the manipulatives and test their own mathematical ideas. |
| 7. Mathematical Tools: *Technology Use* | The teacher uses technology for class demonstrations. There is little student use of technology. | The teacher uses technology for class demonstrations which the students imitate when directed. | The teacher uses technology to involve the students in teacher-directed explorations. The technology is available should the students choose to use it. | The teacher uses technology to involve the students in teacher-directed explorations. The technology is available should the students choose to use it. Students are encouraged to create inventive uses for the technology and test their own mathematical ideas. |
| 7. Mathematical Tools: *Purpose of Manipulatives and Technology Use* | The teacher uses manipulatives and technology to illustrate concepts. | The teacher uses manipulatives and technology to demonstrate for students connections between concrete and abstract mathematical ideas, | The teacher uses manipulatives and technology to encourage students to make their own connections between concrete and abstract mathematical ideas, | The teacher uses manipulatives and technology to encourage students to move, on their own, from concrete ideas to building generalizable abstractions which they can defend. |
| 8. Student—Student Interaction *Explicit Instruction* | The teacher provides instruction on expected classroom behaviours focusing on whole | The teacher provides instruction on expected classroom behaviours focusing on small group | The teacher provides instruction and models expected small group behaviours focusing on | The teacher provides instruction and models expected small group behaviours focusing on cooperative learning skills, shared |

| | | | | |
|---|---|---|---|---|
| | class management without reference to student interaction. | management. | general cooperative learning skills and shared group leadership. | leadership and effective mathematics communication. |
| 8. Student-Student Interaction: *Task* | The teacher assigns tasks that require students to work independently at their desks. | The teacher assigns tasks that require students to work independently within small groups. | The teacher assigns tasks that require students to work independently and share their solutions with their peers to check for accuracy. | The teacher assigns tasks that require students to work together within groups to develop joint solutions and strategies. |
| 8. Student-Student Interaction: *Communication* | The teacher controls question and answer discussions by providing opportunities for students to recite their answers to the whole class. | The teacher allows students to describe their answers to peers, either as a whole class or within small groups. | The teacher allows students to explain and defend their answers to peers, either as a whole class or within small groups. Students are encouraged to challenge the validity of their classmates' solutions. | The teacher allows students to explain and compare their solutions and solution strategies with their peers. They are encouraged to discuss the mathematical concepts within the problems and to be both supportive and challenging to their peers. |
| 9. Student Assessment: *Purpose* | The purpose of assessment is for the teacher to report to parents. | The purposes of assessment are for the teacher to report to parents and to sort students . into achievement or ability groups. | The purposes of assessment are for the teacher to report to parents and students in order to improve student learning. | The purposes of assessment are for the teacher to report to parents and students to improve student learning, teaching methods, and curriculum modification. |
| 9. Student Assessment: *Transparency* | The teacher's criteria for assessing student work are defined during marking. | The teacher defines the criteria for assessing student work before administering the assessment but does not disclose the criteria to the students beforehand. | The teacher defines the criteria for assessing student work and discloses the criteria and assessment procedures to students before administering the assessment. | The teacher negotiates with students the criteria for assessing student work and the assessment procedures before administering the assessment. |
| 9. Student Assessment: *Variety* | The teacher consistently uses one type of assessment that enables students to demonstrate their learning in one way. | The teacher consistently uses a dominant type of assessment that enables students to demonstrate their learning in one way, and supplement it with the occasional use of other types of assessments. | The teacher consistently uses an assortment of assessments that enable students to demonstrate their learning in several ways | The teacher consistently uses an assortment of assessments that enable students to demonstrate their learning in several ways, and consults with the students to decide on which assessment to use |

| | | | | |
|---|---|---|---|---|
| 10. Teacher's Conception Of Mathematics As A Discipline: *Dynamic Nature of Mathematics (stability/ flexibility)* | The teacher views mathematics as a fixed body of knowledge. | The teacher views mathematics as a fixed body of knowledge with some new concepts being added over time. | The teacher views mathematics as a stable body of knowledge that is occasionally modified as new concepts are added to the mathematics field. | The teacher views mathematics as a flexible and dynamic body of knowledge that is based on human activity including new research. |
| 10. Teacher's Conception Of Mathematics: *Connections* | The teacher describes mathematics as a single set of defined mathematical rules and algorithms. | The teacher describes mathematics as a set of topics that are distinct from one another and from other disciplines. | The teacher describes mathematics as a linked set of mathematics topics that are connected to each other. | The teacher describes mathematics as an integration of interdependent topics. |

From: Ross, J. A. & McDougall, D. (2003, September). The development of education quality standards in grade 9 & 10 mathematics teaching. Final Report of Ontario Ministry of Education & Training Transfer Grant. Peterborough, ON: OISE/UT Trent Valley.

## Appendix B: Pre-Survey

Background Information

(some questions adapted from the OECD Teaching and Learning International Survey (TALIS))

**Teaching experience and qualifications**

1. What is your employment status as a teacher? Please indicate the amount of contract and/or LTO for your position.
   Contract amount: _____ LTO amount: ____
2. How long have you been teaching? _____years
3. How long have you been at your current school? _____years
4. Do you hold a degree in mathematics? Circle: Yes/No
5. Do you hold a graduate degree in education? Circle Yes/No
6. Please indicate any additional qualification in mathematics you have :

   _____
7. How long have you been teaching mathematics? _____years
8. What Grade levels have you taught? _____

**Professional Development/Learning:**

1. Please indicate which types of formal professional development/learning you have been involved in and the level on impact ( 1 low to 5 high) it had our your teaching practice.

| | | |
|---|---|---|
| One day-Course/ Workshop on content or teaching strategy | Y N | 1 2 3 4 5 |
| Two days or more Conference where research on teaching shared | Y N | 1 2 3 4 5 |
| Additional Qualification Course | Y N | 1 2 3 4 5 |
| Participation in a Professional Learning community | Y N | 1 2 3 4 5 |
| Mentoring/Peer observation of your practice | Y N | 1 2 3 4 5 |
| Collaborative inquiry with other teachers | Y N | 1 2 3 4 5 |
| Classroom observation of other teachers | Y N | 1 2 3 4 5 |

2. Please indicate which types of informal professional development/learning you have been involved in and the level on impact ( 1 low to 5 high) it had our your teaching practice.

| | | |
|---|---|---|
| Reading educational literature (Ex: books, magazines, websites etc) | Y N | 1 2 3 4 5 |
| Conversations about teaching with other staff at lunch on breaks etc | Y N | 1 2 3 4 5 |

3. How often do you engage in these activities?
   (1 never, 2 yearly, 3 few times a year, 4 monthly, 5 weekly)

| | |
|---|---|
| Examine data on student achievement | 1 2 3 4 5 |
| Have conversations about the learning development of specific students | 1 2 3 4 5 |
| Use student work to guide meeting with colleagues | 1 2 3 4 5 |
| Follow a professional learning cycle (plan, act, observe, reflect) with colleagues | 1 2 3 4 5 |
| Team teach with colleagues in the same classroom | 1 2 3 4 5 |
| Observe other teachers teaching and provide feedback | 1 2 3 4 5 |
| Engage in a collaborative inquiry with other teachers | 1 2 3 4 5 |

4. What practices do you find most helpful for improving your practice? Why?

   _____
   _____
   _____

**Feedback and reflection on practice**

1. Please indicate the sources of feedback you receive on your practice and indicate how helpful the feedback generally is ( 1 being not helpful to 5 very helpful).

| | | |
|---|---|---|
| Principal/Vice Principal | Y N | 1 2 3 4 5 |
| Department head | Y N | 1 2 3 4 5 |
| Peers (fellow teachers) | Y N | 1 2 3 4 5 |
| Union | Y N | 1 2 3 4 5 |
| Students | Y N | 1 2 3 4 5 |
| Parents | Y N | 1 2 3 4 5 |

2. How strongly do you agree with the statement (1 strongly disagree to 5 strongly agree).

| | |
|---|---|
| I am a reflective practitioner. | 1 2 3 4 5 |
| I see Professional Development as an opportunity for personal learning | 1 2 3 4 5 |
| I journal/write about my practice | 1 2 3 4 5 |
| I revise lesson plans after teaching | 1 2 3 4 5 |
| I regularly collaborate about teaching and learning with my colleagues | 1 2 3 4 5 |
| I am not afraid to ask for help to improve my practice | 1 2 3 4 5 |
| My colleagues regularly challenge by thinking about teaching and learning | 1 2 3 4 5 |

**Mathematics Teaching Survey**

| | | |
|---|---|---|
| 1 | I like to use mathematics problems that can be solved in many different ways. | 1 2 3 4 5 |
| 2 | I regularly have my students work through real-life mathematics problems that are of interest to them. | 1 2 3 4 5 |
| 3 | When two students solve the same mathematics problem correctly using two different strategies I have them share the steps they went through with each other. | 1 2 3 4 5 |
| 4 | I tend to integrate multiple strands of mathematics within a single unit. | 1 2 3 4 5 |
| 5 | I often learn from my students during mathematics time because my students come up with ingenious ways of solving problems that I have never thought of. | 1 2 3 4 5 |
| 6 | It is not very productive for students to work together during mathematics time. | 1 2 3 4 5 |
| 7 | Every child in my room should feel that mathematics is something he/ she can do. | 1 2 3 4 5 |
| 8 | I integrate mathematics assessment into most mathematics activities. | 1 2 3 4 5 |
| 9 | In my classes, students learn mathematics best when they can work together to discover mathematical ideas. | 1 2 3 4 5 |
| 10 | I encourage students to use manipulatives to explain their mathematical ideas to other students. | 1 2 3 4 5 |
| 11 | When students are working on mathematics problems, I put more emphasis on getting the correct answer than on the process followed. | 1 2 3 4 5 |
| 12 | Creating rubrics for mathematics is a worthwhile assessment strategy. | 1 2 3 4 5 |
| 13 | I model all my mathematics lessons after the three-part lesson ( minds-on, action, consolidation). | 1 2 3 4 5 |
| 14 | I don't necessarily answer students' mathematics questions but rather let them puzzle things out for themselves. | 1 2 3 4 5 |
| 15 | A lot of things in mathematics must simply be accepted as true and remembered. | 1 2 3 4 5 |
| 16 | I like my students to master basic mathematical operations before they tackle complex problems. | 1 2 3 4 5 |
| 17 | I teach students how to explain their mathematical ideas. | 1 2 3 4 5 |
| 18 | Using technology to solve mathematics problems distracts students from learning basic mathematics skills. | 1 2 3 4 5 |
| 19 | I work with my student to develop success criteria for the learning goals. | 1 2 3 4 5 |
| 20 | You have to study mathematics for a long time before you see how useful it is. | 1 2 3 4 5 |

(1 strongly disagree to 5 strongly agree)

Adapted from: The Self-Report Survey: Elementary Teacher's Commitment to Mathematics Education Reform, J. R. Ross, D. McDougall, A. Hogaboam-Gray, & A. LeSage

Self – Efficacy Survey

(Modified TEBS-Selfa by A.B. Dellinger et al, 2008)

Response scale:

1. Weak beliefs in my capabilities
2. Moderate beliefs in my capabilities
3. Strong beliefs in my capabilities
4. Very strong beliefs in my capabilities

| | Right now in my present teaching situation, the strength of my personal beliefs in my capabilities to…… | |
|---|---|---|
| 1 | plan activities that accommodate the range of individual differences among my students | 1 2 3 4 |
| 2 | plan evaluation procedures that accommodate individual differences among my students | 1 2 3 4 |
| 3 | use allocated time for activities that maximize learning | 1 2 3 4 |
| 4 | maintain high levels of student engagement in learning tasks | 1 2 3 4 |
| 5 | communicate to students the specific learning outcomes ( success criteria) of the lesson | 1 2 3 4 |
| 6 | communicate to students the purpose and/or importance (goals) of learning tasks | 1 2 3 4 |
| 7 | utilize teaching aids and learning materials that accommodate individual differences among my students | 1 2 3 4 |
| 8 | provide students with specific feedback about their learning | 1 2 3 4 |
| 9 | provide students with suggestions for improving learning | 1 2 3 4 |
| 10 | solicit a variety of questions throughout the lesson that enable higher order thinking | 1 2 3 4 |
| 11 | adjust teaching and learning activities as needed | 1 2 3 4 |
| 12 | motivate students to perform to their fullest potential | 1 2 3 4 |
| 13 | improve the academic performance of students, including those with learning disabilities | 1 2 3 4 |
| 14 | work collaboratively with colleagues to develop effective tools for teaching | 1 2 3 4 |
| 15 | contribute to meaningful dialogue with colleagues about the teaching-learning process based on evidence collected from student work/observation | 1 2 3 4 |

Please return the questionnaire as soon as you complete it. Thank-you for your participation.

## Appendix C: Post-Survey

Post CLiC (Lesson Study)

1. Describe how each part of the CLiC (Lesson Study) process impacted your practice. (ie.: What you learned in this step and if that effects your ideas about teaching and learning)

a. Choosing a research question/ lesson focus

b. Collaboratively developing the lesson plan

c. The first teaching of the lesson (could have been just the Minds-on & Action)

d. The first lesson observation

e. The debrief discussion after the first observation

f. Collaboratively modifying of the lesson ( could have been creating the consolidation)

g. The second teaching (might have been the consolidation)

h. The second lesson observation

i. The debrief discussion after the second observation

2. Which part of the CLiC (Lesson Study) process was most important to your learning? Why?

3. Would you use CLiC (Lesson Study) as a process to engage in collaborative inquiry learning? Why?

4. How strongly do you agree with these statements? (1 strongly disagree to 5 strongly agree)

| | |
|---|---|
| I am a reflective practitioner. | 1 2 3 4 5 |
| I see Professional Development as an opportunity for personal learning. | 1 2 3 4 5 |
| I journal/write about my practice. | 1 2 3 4 5 |
| I revise lesson plans after teaching. | 1 2 3 4 5 |
| I regularly collaborate about teaching and learning with my colleagues. | 1 2 3 4 5 |
| I am not afraid to ask for help to improve my practice. | 1 2 3 4 5 |
| My colleagues regularly challenge by thinking about teaching and learning. | 1 2 3 4 5 |
| Planning a lesson around a research question helped me to take an inquiry stance. | 1 2 3 4 5 |
| Collaborating with my colleagues through CLiC (Lesson Study) helped to challenge by beliefs about mathematics education. | 1 2 3 4 5 |
| Observing in my colleagues classrooms and focusing on student responses to the instruction helped me to better identify success criteria in my class. | 1 2 3 4 5 |
| I have a better understanding of Standards-Based Mathematics teaching and how to incorporate the dimensions in my classroom. | 1 2 3 4 5 |
| CLiC (Lesson Study) helped me engage in professional learning (i.e., thinking about my practice and how to improve my students learning). | 1 2 3 4 5 |

Plus the same Mathematics Teaching Survey and the Self – Efficacy Survey from the pre-survey.

## Appendix D: Pre-Project Interview Questions

A **Board Curriculum Leader** (person organizing/running the PD)

1. Describe the goal for the PD you are offering and the sequence of events. How teachers are selected to participate? Are there any deliverables for the teachers participating?

2. Why did you choose a Lesson Study process?

3. How will you know if the PD was successful? What measures of success are you using?

B **Teacher Team**

1. Why/How did you decide to participate in this PD opportunity?

2. What do you hope to learn in this PD experience? What are your learning goals?

3. How will you know if you reached your learning goals? What are your measures of success?

C **Administrator**

1. What role do you play in Professional Learning in your school? In this Lesson Study?

2. What do you want to accomplish with this PD or Lesson Study? The learning goals?

3. How will you know if the PD was successful? What are your measures of success?

## Appendix E: Post-Project Interview Questions

A **Board Curriculum Leader** (person organizing/running the PD)

1. Was the project successful? Evidence?

2. What did you learn about the Lesson Study process?

3. Would you choose the Lesson Study process again? What would you do differently?

B **Teacher Team**

1. Was the project successful? Evidence?

2. What impact did Lesson Study have on your learning? Has your practice changed as a result? Has student learning changed as a result? In what ways?

3. Would you be involved in Lesson Study again? What would you do differently?

C **Administrator**

1. Was the project successful? Evidence?

2. Did you see any changes in teacher Knowledge/Skills/Attitudes/Beliefs as a result of the Lesson Study? Did you see changes in student learning?

3. Would you be involved in Lesson Study again? What would you do differently?

## Appendix F: Observation Form

CLiC Observation Form

MINDS-ON

| What did students say? | What did students do? |
|---|---|
| | |

ACTION

| What did students say? | What did students do? |
|---|---|
| | |

SHARING

| What did students say? | What did students do? |
|---|---|
| | |

HIGHLIGHT

| What did students say? | What did students do? |
|---|---|
| | |

OTHER

## VITA AUCTORIS

| | |
|---|---|
| NAME: | Deidre Wilson |
| PLACE OF BIRTH: | Windsor, ON |
| YEAR OF BIRTH: | 1965 |
| EDUCATION: | F.J. Brennan High School, Windsor, ON, 1984 |
| | University of Windsor, B.Sc., Windsor, ON, 1988 |
| | McMaster University, M.Sc., Hamilton, ON, 1990 |
| | University of Toronto, B.Ed., Toronto, ON, 1993 |